Budgeting, Costing and Estimating for the Injection Moulding Industry

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Peter Jones

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Preface

Peter Jones is a practising consulting engineer with over thirty-five years' experience within the plastics industry. He has wide experience of mould design, toolmaking, production management and general management and has worked for a number of well-known companies including ICI, United Gas Industries, Bettix and Smiths.

During his time as an employee, he has held positions of estimator, chief mould designer, technical manager, general manager, production director and managing director – all within the injection moulding industry.

In his capacity as a consulting engineer, he has advised several well-known national and international companies in the engineering, oil, medical, pharmaceutical, electronics and consumer industries and many others.

Peter has advised on costing and estimating procedures, mould design and construction, processing, production and management. In project management roles, he has been responsible for setting up complete injection moulding plants for both internal use and stand-alone units. Several of these have been turnkey projects where all the plant, machines, mould tools, ancillaries, systems and personnel have been provided.

Additionally, he has lectured on costing, estimating, mould design, injection moulding and related topics to many well-known companies both in the UK and overseas.

The intention of this book is to provide a clear understanding of the interrelated processes of budgeting, costing and estimating for the injection moulding industry. It is designed to give a clear account of all the stages involved that lead to a company costing and estimating procedure for the injection moulding industry. It includes examples of all procedures at every stage and as such, it should prove of interets to anyone concerned with these most important topics.

Budgeting, Costing and Estimating for the Injection Moulding Industry

Contents

Introduction

The objective of this book is to discuss and define the different methods of budgeting, costing and estimating that are normally used within the injection moulding industry.

In order to establish the costing system, the operating costs first have to be identified and quantified by means of a budget. Based on the budget, a costing system can then be developed that can be applied to determine the manufacturing cost of each product a company manufactures.

The estimating stage determines the selling price of the products that a company manufactures. In the injection moulding industry, a considerable amount of skill and experience is necessary to carry out this function successfully.

The underlying theme of this book is the maximisation of profits through the control of costs. Hence, emphasis is placed on ensuring the understanding of costing and estimating models through discussion and examples.

All companies have a hierarchical structure. This is necessary to define the duties and responsibilities of all the departments and employees. A typical example of the hierarchical structure of a company is shown in Figure 1. This illustrates the diverse job functions that are necessary in order for a company to operate properly. This example is typical of a medium-sized company, whereas in a smaller company several staff may have multifunctional roles combining two or more departments while other departments may not exist at all – like research and development for example. Conversely, larger companies may have much more complex structures with more departments and managers. Hence, the hierarchical structure of any company is a function of its size and the type of business it operates.

Whatever the structure of a company there are a few fundamental factors that are common to nearly all companies that determine whether the company will be successful:

- there must be a market for its goods or services;
- it must be able to sell them;

- it must be able to provide them;
- it must be able to deliver them on time; and
- it must make a satisfactory profit.

In this respect, the injection moulding industry is no exception and must satisfy all these criteria to survive.

In order to be able to make the parts, a plant must be capable of producing them competitively. For example, if polystyrene cups or disposable coffee spoons are being

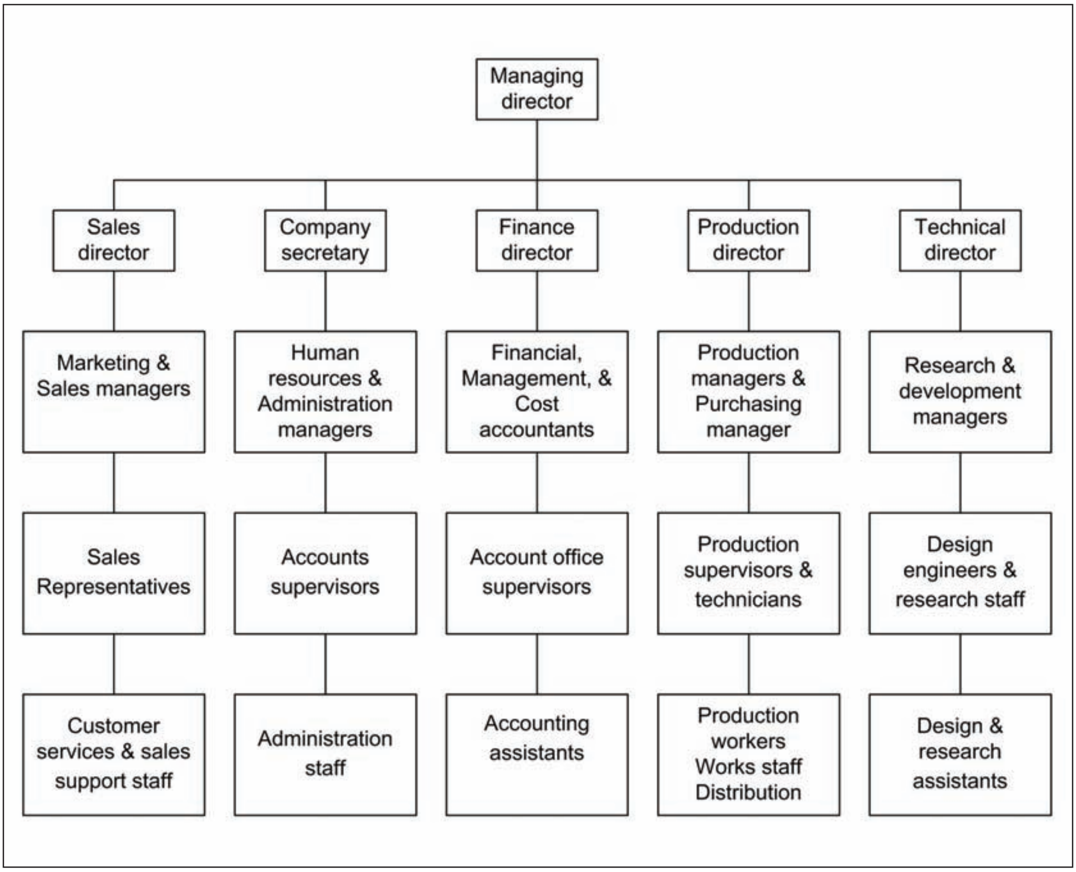


Figure 1 Typical hierarchical structure

produced the emphasis will be on speed of production. If highly technical, close-tolerance parts are being made the emphasis will be on maximum control and accuracy.

In all cases, a plant must be capable of producing parts:

- to the required quality;
- at the required rate; and
- within the estimated cost.

If the first condition is not met, the rejection rate will be too large and the cost of production will increase, usually accompanied by customer dissatisfaction and loss of profit. If the second condition is not met, the production costs will be greater than they should be, also leading to reduced profit. Thirdly, even if the parts are produced at the required rate and of good quality, they must be manufactured within the budgeted or estimated cost.

If the plant is old and unreliable, the less reliable production will be, the more frequently machine breakdowns will occur and therefore the greater the cost of production will be.

In all of these cases it is the *efficiency* of the operation that determines the competitiveness of the products and, consequently, the profitability.

Within the context of this book, efficiency means the production of parts competitively and profitably.

From this brief discussion, it can clearly be seen that that one of the most important factors in achieving satisfactory profitability is the production plant. If this is not capable of fast, reliable, competitive production, profits will decrease.

It is also significant that the terms ‘profit’ and ‘cost’ have already been mentioned several times. This is really no surprise, since they are the key factors in all companies.

We must be able to establish the cost of each product and add a profit margin to it so that:

- all costs are recovered; and
- a satisfactory overall profit is achieved.

In order to do this, we must prepare:

- a budget;

- a costing system; and
- an estimating procedure based on these.

A budget is a blueprint for defining the company's objectives in financial and non-financial terms, and clearly must be established before anything else. Once this has been done, a costing system can be designed that suits the company's type of business.

The four most common costing systems are:

- standard costing;
- absorption costing;
- marginal costing; and
- costing based on machine hourly rates.

All of these systems are discussed in detail in this book.

Finally, an estimating system based on one (or more) of these is selected and custom designed to suit the nature of the business.

In Chapter 1, we define some of the terms used in costing and some basic terms used in accountancy. Note, however, that different companies may attach other meanings to these. This is not uncommon and depends upon the accounting conventions preferred and the nature of the business.

The remainder of the book follows through the logical progression of preparing a budget, discussing costing models and the process of estimating accompanied by examples and illustrations.

The book also discusses unnecessary costs, control of costs, reduction of costs and, not least, an evolutionary mould cost estimating program.

In view of the technical nature of the injection moulding process, it is inevitable that there will be many references to technical processes and terms throughout the book. These are briefly explained in the text or in the glossary.

For an in-depth account of the injection moulding process and mould design, the reader is recommended to read the *Mould Design Guide* written by the same author and also published by Rapra. Visit *http://www.rapra.net/website/Bookstore/Bookstore.asp?* Alternatively, visit the author's website at *http://www.pmjconsultants.com* for further details.

1

Terms and Definitions

Throughout the plastics industry, as in many other industries, different terms are used for the same procedure, process, operation, and so on. In order to avoid confusion within the context of this book and for the sake of brevity we will define the following terms that are used throughout the book.

1.1 Injection Moulding

1.1.1 Customer

This is the company or individual who has placed the order for the moulded products and to whom the parts will be delivered and invoiced.

1.1.2 In House

This refers to a company whose main line of business is not injection moulding or toolmaking but which has on-site facilities for both activities. Such a company is referred to as having ***in house*** moulding/toolmaking facilities

1.1.3 Moulder

A moulder carries out the injection moulding operation. This could be an independent, separate company or an in house operation.

1.1.4 Toolmaker

This is either an individual with toolmaking skills or a company that employs toolmakers to manufacture mould tools.

1.1.5 Mould, Tool and Mould Tool

These three terms all refer to an injection mould. They all have the same meaning and are all frequently used in the industry.

1.2 Costing Terminology

1.2.1 Capital Costs

These are the purchase prices paid for plant and equipment (new or secondhand) required for production. They would typically include:

- moulding machines;
- water systems;
- sprue separators;
- re-processing equipment;
- chillers;
- temperature control equipment; and
- robots.

They may also include items not directly connected to production such as:

- office equipment;
- company vehicles; and
- building alterations.

1.2.2 Depreciation

Whenever capital items are purchased, these costs have to be recovered by putting funds aside on a regular basis. This is necessary so that further capital items may be purchased in the future when the current items need replacing. The usual way to do this is via ***revenue*** from sales.

Sometimes other sources of revenue are used such as sale of assets like machines, land, buildings, and so on.

Normally the financial director or the board will decide over what period of time the capital costs will be recovered. In most cases there are two choices:

1. Recover it all in one year.
2. Recover it over a number of years.

If the company is making large profits, it may choose to ***depreciate*** or ***write off*** the capital cost in one year to reduce taxation in that year.

More normally, a company will depreciate the costs over a period of years. This should reflect the period after which the current items will need replacing. Clearly the ***depreciation period*** should never exceed this and should be as short as is practicably possible.

For most normal moulding operations, the moulding machines are ***depreciated*** over an average of five years, although this will vary from company to company. Periods of between three and ten years are usual.

There are two methods of applying depreciation, straight-line basis and reducing-balance basis, as discussed below.

1.2.2.1 Straight-line Basis

A fixed percentage is written off the original cost of the asset each year based on the estimated useful life of the asset as follows:

$$\frac{\text{Original cost of asset} - \text{estimated final value of asset}}{\text{No. of years useful life of asset}}$$

Example. A machine has been purchased for £10,000 and has an estimated useful life of 5 years. At the end of this period, the machine will have a scrap or resale value of £1,000. Hence the depreciation will be:

$$\frac{£10,000 - £1,000}{5} = £1,800$$

(or 20% of the original value) per year

The results are shown in Table 1.1.

Table 1.1 Straight-line depreciation over five-year period			
Stage	**Depreciation (%)**	**Depreciation (£)**	**Balance (£)**
Start			10,000
End year 1	20	1,800 (20% × 10,000)	8,200
End year 2	20	1,800 (20% × 10,000)	6,400
End year 3	20	1,800 (20% × 10,000)	4,600
End year 4	20	1,800 (20% × 10,000)	2,800
End year 5	20	1,800 (20% × 10,000)	1,000

1.2.2.2 Reducing-balance Basis

With this method, a fixed percentage is written off the reduced (or outstanding) balance of the asset at the end of each year. The reduced balance is the cost of the asset less the provision for the depreciation at the fixed percentage. If we take the same figures as in the previous example:

Machine cost: £10,000

Final resale value: £1,000

Depreciation per year: 37%

Example. The depreciation is summarised in Table 1.2. It can be seen that the final written down value of this machine is shown as £993 instead of the £1,000 resale value required. This is because the depreciation rate has been rounded up to 37% instead of 36.9% that would lead to the correct result.

Table 1.2 Reducing balance depreciation over five-year period			
Stage	**Depreciation (%)**	**Depreciation (£)**	**Balance (£)**
Start			10,000
End year 1	37	3,700 (37% × 10,000)	6,300
End year 2	37	2,331 (37% × 6,300)	3,969
End year 3	37	1,468 (37% × 3,969)	2,501
End year 4	37	925 (37% × 2,501)	1,577
End year 5	37	584 (37% × 1,577)	993

Rounding up (and rounding down) the depreciation rate within reason is a common practice to keep the rate simple, although the exact rate can be applied quite easily if preferred by using a suitable program, spreadsheet or other means.

The actual depreciation rate for a given number of years can be determined mathematically as follows. Let:

A = the original asset value

p = the reducing balance percentage rate

B_r = the reducing balance at end of year n

n = the depreciation period in years.

Then,

at the end of year 1:

$$B_r = \left(A - A \times \frac{p}{100}\right) = A\left(1 - \frac{p}{100}\right)$$

at the end of year 2:

$$B_r = A\left(1 - \frac{p}{100}\right)\left(1 - \frac{p}{100}\right) = A\left(1 - \frac{p}{100}\right)^2$$

at the end of year 3:

$$B_r = A\left(1 - \frac{p}{100}\right)\left(1 - \frac{p}{100}\right)\left(1 - \frac{p}{100}\right) = A\left(1 - \frac{p}{100}\right)^3$$

and so on. Hence,

at the end of year n:

$$B_r = A\left(1 - \frac{p}{100}\right)^n \tag{1.1}$$

Therefore, if we know any three of the variables, we can determine the fourth.

Hence, to determine the depreciation percentage rate (*p*) we can transpose results of Equation (1.1) to give

$$p = 100\left(1 - \sqrt[n]{\frac{B_{\mathrm{r}}}{A}}\right) \tag{1.2}$$

Using the data from the example, we have

A = £10,000 (original asset value)

n = 5 (depreciation period in years)

Br = £1,000 (final resale or scrap value at end of 5-year depreciation period).

Substituting these values in Equation (1.2), we get

$$\begin{aligned} p &= 100\left(1 - \sqrt[5]{\frac{1,000}{10,000}}\right) \\ &= 100(1 - \sqrt[5]{0.1}) \\ &= 100(1 - 0.631) \\ &= 100 \times 0.369 \\ &= 36.9\% \end{aligned}$$

Sometimes, it is useful to determine the number of years of depreciation required to correspond with a given depreciation percentage rate. To determine this we can transpose Equation (1.1) or (1.2) to give

$$n = \frac{\log\left(\frac{B_{\mathrm{r}}}{A}\right)}{\log\left(1 - \frac{p}{100}\right)} \tag{1.3}$$

Substituting the appropriate values in Equation (1.3) gives

$$n = \frac{\log\left(\frac{1,000}{10,000}\right)}{\log\left(1 - \frac{37}{100}\right)}$$

$$
\begin{aligned}
&= \frac{\log(0.1)}{\log(0.63)} \\
&= \frac{-1}{-0.200} \\
&= 5 \text{ years}
\end{aligned}
$$

Whatever the method of depreciation, the depreciated sums are normally transferred into special holding accounts or transferred to general reserves and invested.

1.2.3 Book Value (or Present Value)

If a machine is purchased at a cost of £80,000 and depreciated over say five years on a straight-line basis, the depreciation will be £16,000 per year. At the end of the first year its value will then be £64,000, at the end of the second year £48,000, and so on.

These depreciated values are referred to as the ***book value*** or ***present value*** of the asset. Thus at the end of the first year the book value would be £64,000, at the end of the second year £48,000, and so on, until the end of the fifth year when the book value will be zero (or reaches its resale or scrap value). At this point it is said to be ***written off***.

The company accountant keeps a register of all capital purchases, the depreciation periods and the book values.

1.2.4 Utilisation

There is wide disagreement about what this term means. In practice, however, it does not matter what meaning different terms have, as long as those using them understand them. For the purposes of this book it will have the following definition:

The number of hours per week the company works.

A company working a six-day week for 10 hours per day has a utilisation of 60 hours per week. This can then be compared to the maximum possible number of hours the plant could be utilised of 168 (7 days × 24 hours per day).

1.2.5 Utilisation Factor (UF)

There is similar disagreement about what this means as well. We will define it as follows:

$$\frac{\text{No. of hours worked per week}}{168} \times 100\%$$

or

$$\frac{\text{Utilisation}}{168} \times 100\% \qquad (1.4)$$

If a company operates a continuous shift system from 8:00 am Monday to 5:00 pm Friday, this represents 105 hours per week. The plant *could*, however, be operated continuously without any break at all – 168 hours per week (the maximum possible). In this case, the utilisation of the plant is 105/168 = 0.625 or 62.5%.

It is simply a measure of how much use is being made of the plant expressed as a proportion, or more usually a percentage, of the maximum possible utilisation.

The utilisation will vary according to the nature of the business and how much business a company has.

1.2.6 Efficiency Factor (EF)

Clearly, a plant will not be producing saleable parts for the whole of the utilisation period. There will occasions when there are tool changes, breakdowns, material and colour changes and so on. The efficiency factor (EF) is defined as follows:

$$\frac{\text{No. of production hours}}{\text{Utilisation}} \times 100\% \qquad (1.5)$$

where ‘production hours’ means the amount of time the plant has produced saleable parts.

Thus if the utilisation is 100 hours per week and 20 hours per week are lost in tool changes, breakdowns, etc., the EF would be:

$$\frac{80}{100} = 0.8 \text{ or } 80\%$$

In practice, the EF will vary according to the field of work in which a company is engaged. Usually, the higher the volume of production and the more straightforward the products, the higher is the EF. Lower volume, highly technical products will involve more tool changes and stoppages for adjustments giving a lower EF.

In practice, the industry standard EF for general trade moulding is approximately 70%. Producers of highly technical parts of medium run length have an EF of around 55% and companies making very simple, very high volume products may have an EF of about 90%.

1.3 Accountancy Terminology

1.3.1 Assets

These represent the net investment by the company.

1.3.1.1 Fixed Assets

These represent the means by which the company earns its profits. These include premises, plant, equipment, office equipment, buildings and vehicles. The term ***fixed*** is used to convey the fact that these assets would not usually be for sale in the normal course of business.

1.3.1.2 Current Assets

This means the use of company finance to provide funds for the everyday operation of the company. For example:

- raw materials, components and packaging to support the production process;
- goods and services purchased to maintain the fixed assets to allow the production process to run; and
- labour to operate the production process.

1.3.2 Capital Employed

This is the total investment in the company as shown by the balance sheet.

1.3.3 Direct Costs

These are costs that are directly attributable to the production process. For example:

- Materials
- Energy
- Labour.

1.3.4 Fixed Costs

Fixed costs are those that are incurred irrespective of how many parts are made or the number of hours worked. For example:

- Rates
- Rent
- Salaries of permanent staff
- Some vehicle costs.

1.3.5 Indirect Costs

These are costs that are not directly related to production. For example:

- Rent
- Rates
- Certain salaries
- Insurance
- Depreciation.

1.3.6 Variable Costs

These are costs that vary according to the number of parts produced. For example as more parts are made, the material costs will increase. There may also be other costs as shown below. Variable costs include:

- Direct labour costs (wages, which vary according to hours worked, bonuses, etc.)
- Materials
- Packaging
- Energy
- Distribution
- Water charges
- Insurance
- Depreciation (will vary if additional machines are purchased)
- Pensions (may vary when people retire).

1.3.7 Turnover

This is simply the amount of ***invoiced sales*** during a given period of time. These two terms usually have the same meaning. However, the term 'turnover' is also used in a wider sense to represent the total amount of ***revenue*** received in a particular time period.

1.3.8 Profit

Basically, this is the difference between the invoiced sales and the total costs over a given period of time:

$$\text{Profit (trading)} = \text{Invoiced sales} - \text{total costs}$$

The invoiced sales must be greater than the total operating costs if a company is to make a trading profit.

1.3.9 Loss

If the total costs incurred in running a company exceed the invoiced sales the company will suffer a ***loss***.

Note that in this book we are mainly concerned with ***trading profit***. This is explained fully later in the book.

1.3.10 Return on Investment (ROI)

This is an important measure of the financial performance of a company. It is the same concept as any other form of investment (like the interest accrued from investing money in a bank or building society). It is normally defined as follows:

$$\frac{\text{Monies received} - \text{capital invested}}{\text{Capital invested}} \times 100\% \qquad (1.6)$$

Another term often used for ROI is ***return on capital employed*** (RCE).

In either case, we can rewrite Equation (1.6) as

$$\text{ROI/RCE} = \frac{\text{Profit}}{\text{Capital employed}} \times 100\% \qquad (1.7)$$

Note that RCE and ROI have the same meaning in this book. ***Capital invested*** and ***capital employed*** also have the same meaning.

Under normal circumstances, the ROI or RCE would be expected to exceed other forms of investment carrying the same level of risk.

2 Planning and Budgeting

One of the most important functions of management is planning and taking decisions in advance that will preserve or improve the profitability of a company in the future.

Knowledge of past and present events is vital in establishing future policy. This enables management to act proactively and lead development rather than be reactiv, simply following current events as they occur.

There is, however, a distinct difference between planning, forecasting and budgeting that needs to be clarified.

2.1 Planning

The function of planning is to create agreed future policies over a specified period to enable a company to achieve its objectives. These objectives do not necessarily have to be specified in financial terms. They may, for example, represent a statement of intent like the penetration of a different market or increasing automation of plant and equipment.

There are several ways a company can plan for the future, but a common method is the length of time over which these objectives are to be achieved which is normally divided into three groups:

- long term;
- medium term; and
- short term.

There is no universally adopted time span for these categories, as they will necessarily vary according to the type of business, market forces, future product development and economic factors, but the following common elements normally apply.

2.1.1 Long-term Planning

This is a strategy to assess future business and socio-economic trends for future periods of up to 20 years. Although such predictions may not be realised, it is important to be aware of possible market trends, new technologies, future competition from developing nations and so on. A company could also, for example, plan on moving to new premises.

Long-term planning is especially important in industries like shipbuilding, the motor industry and aerospace where new product development times may extend many years into the future. Such planning is vitally important to try to predict, for example, whether a market will still exist at all by the time a product reaches completion.

Conversely, there are some industries where such long-term planning is almost impossible, like the computer industry where changes in technology are so frequent that future prediction is extremely difficult.

Nevertheless, it is still important for companies in less volatile markets to develop a long-term strategy so that they have defined long-term objectives based on the best research available.

2.1.2 Medium-term Planning

This category usually covers a time span of two to five years. This strategy can be better defined than the long-term plan since it is nearer the present time, and therefore fewer assumptions have to be made. This in turn means that the probability of predictions being accurately realised during this period is much greater.

Medium-term planning normally includes some of the objectives in the long-term plan but concentrates more on the decisions needed to be taken during this period. This may include product replacement, plant replacement, new markets, labour, utilisation and so on.

2.1.3 Short-term Planning

This usually covers a period of a year and may be subject to several revisions within this period. Since short-term planning applies to the immediate future, it is prepared in greater detail than the other categories and provides a detailed statement of intent.

Short-term planning also includes the preparation of detailed budgets that lead to a master budget for the following year.

2.1.4 Discussion

There is no consensus of the time periods governing each of these categories, as there are many factors that will influence these including:

- type of business;
- the markets; and
- the importance that management attaches to future planning.

However, most companies will adopt some type of planning procedure even if it is much less formalised than that the model summarised in Figure 2.1. It can be seen

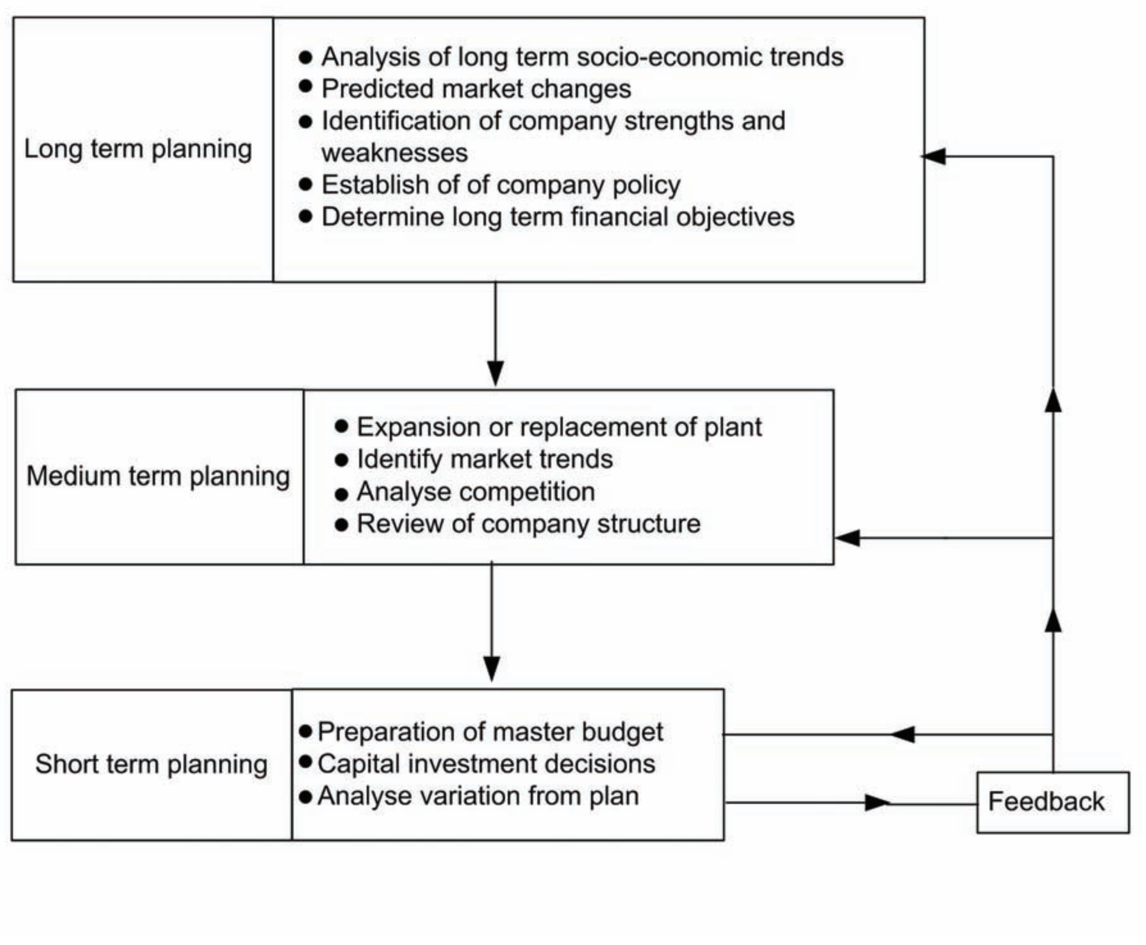


Figure 2.1 Planning Relationships

from this model that the entire planning process is a fluid one as long-term planning will affect each of the other planning stages as companies' long-term objectives change in response to market changes and socio-economic factors.

This is exemplified by the ever-increasing emphasis on green issues, where companies may have to take action to alter their products so that they can be recyclable. This could lead companies to continually revising their medium- and long-term plans to comply with predicted strict enforcement in the future.

Short-term developments may also affect longer term plans as advances in technology generate new materials and manufacturing processes. These in turn will demand that longer term plans are revised to take account of these advances.

2.1.5 Planning for the Injection Moulding Industry

Whilst the foregoing is a general analysis, the same principles apply to the injection moulding industry. To retain its share of the market and secure its future, this industry also has to plan ahead in the same way.

As a high-technology industry, it has to plan for the introduction of new technology, legislation, manufacturing processes and, of course, competition from other manufacturers, especially those from Asia.

Rapidly changing domestic and international factors will also influence medium- and long-term planning, and often short-term planning as well. Such factors may lead to drastic changes in overall company policy where markets and competition change.

Failure to respond to these and other factors can lead to serious consequences exemplified by the decline in the number of injection moulding businesses in Europe and the USA which have been 'priced' out of the market by competition from Asia with its much lower labour rates.

In an increasing number of cases, European and American original equipment manufactures are switching their complete manufacturing operations to India and other parts of Asia for the same reason.

This trend illustrates the need for injection moulding companies with higher labour rates to plan for the future to try to change direction and invest in higher technology processing equipment to achieve more efficient production, thus lowering costs and therefore prices.

Planning in this industry is therefore essential for medium- and long-term survival.

There are many different types of injection moulding operations, each with its own specialisation serving its own niche market needs. Examples of these are:

- general trade moulding for a wide range of custom parts;
- custom moulding for specific markets like the medical industry;
- high-precision custom moulding for products that will be used in demanding applications;
- own-brand products like fasteners, disposable cutlery, etc.; and
- in house moulding operations.

Each of these may have its own dedicated plant and equipment to support its own niche products and therefore each should have its own set of objectives to ensure future growth and profit.

2.2 Forecasting

Forecasting is simply predicting what will happen in a particular situation by any competent group or individual.

It could be a prediction of future market trends in terms of a company's market share, financial performance and so on.

Forecasting is only mentioned here to distinguish it from planning and budgeting. Whereas the former is a statement of intent for future policies, the latter is a goal that a company is aiming to achieve.

2.3 Budgeting

A budget usually takes the form of a financial statement that is prepared in advance of the period it will be put in to operation. In normal circumstances a budget will be based on it being implemented in the next financial year. Thus, a budget is normally prepared the year before it will be put into operation.

On a domestic level, few people would embark on a major purchase like, say, a new car without looking at all the costs associated with it. This would not normally be a detailed written analysis but some time would be spent in estimating the total costs involved. This is simple common sense to make sure the costs are within achievable bounds and that sufficient funds will be available.

A major purchase such as this would also have to take into account all other costs like mortgage payments, food, clothing, rates, projected holidays, water charges and so on.

If we are using a bank loan and will be paying it back over a period of time, this amount would have to be affordable in the event of other current costs increasing during the period of the loan.

If it became difficult to continue to make the repayments for the car, we may have to revise other spending plans like deferring holidays or other non-essential spending.

Business budgeting follows a very similar procedure but in a more formalised and detailed form. The key elements are the following.

- *Defining company objectives*. What the company aims to achieve in overall terms. Where the company expects to be at the end of the period.
- *Allocation of responsibilities*. Defining the individuals or departments responsible for achieving the company objectives.
- *Defining policies*. A statement of policies necessary to achieve the objectives so that those responsible for achieving them have a clear understanding of what they mean and what they are expected to achieve.
- *Budgeting*. Preparation of a financial budget to predict results.
- *Budget approval*. Adoption of the budget by those expected to achieve it.
- *Policy implementation*. Putting all the company policies and strategies into practice.
- *Budgetary control*. Assessing actual performance against the budgeted performance.
- *Budgetary revision*. Altering the budget to take account of changing (often unforeseen) circumstances like acquisition of additional plant for a new, unplanned project.

Such budgets are usually prepared by accountants in consultation with the managers that will be responsible for implementing them. In many types of business, this is essential, as there may be a large number of technical and other considerations that have to be taken into account if the budget is to be meaningful and practical to operate.

It is also important that budgets are realistic with achievable goals and approved by all senior managers so that they can use the budget as means of monitoring budgeted performance against actual performance.

The most successful budgets consist of a number of smaller budgets prepared by each department in the company. These smaller budgets are then integrated into the overall draft budget and finally consolidated into the master budget.

It is also important that the entire budgeting procedure is planned so that all the essential elements are included starting with future policy for the period.

Figure 2.2 shows a typical business budget model.

2.3.1 Budget Revisions

Revisions to the budget often have to be made to take account of unforeseen circumstances and are exemplified by the following:

- changes to production capacity due to serious machine breakdowns or the introduction of unplanned new plant and equipment;
- inability to meet the required quality standards;
- inability to meet production targets;
- inability to meet estimated product prices;
- insufficient funds to support expansion;
- inability to acquire suitable materials;
- unexpectedly high bad debts;
- unforeseen market trends;
- lack of suitably qualified personnel; and
- a competitor launching a new highly competitive product.

Essentially these are all unforeseen events that could not have been included in the original budget and those listed here are by no means exclusive.

It is for these reasons that budgets have to be constantly revised to take account of such circumstances to make sure the overall objectives of the company are still achievable.

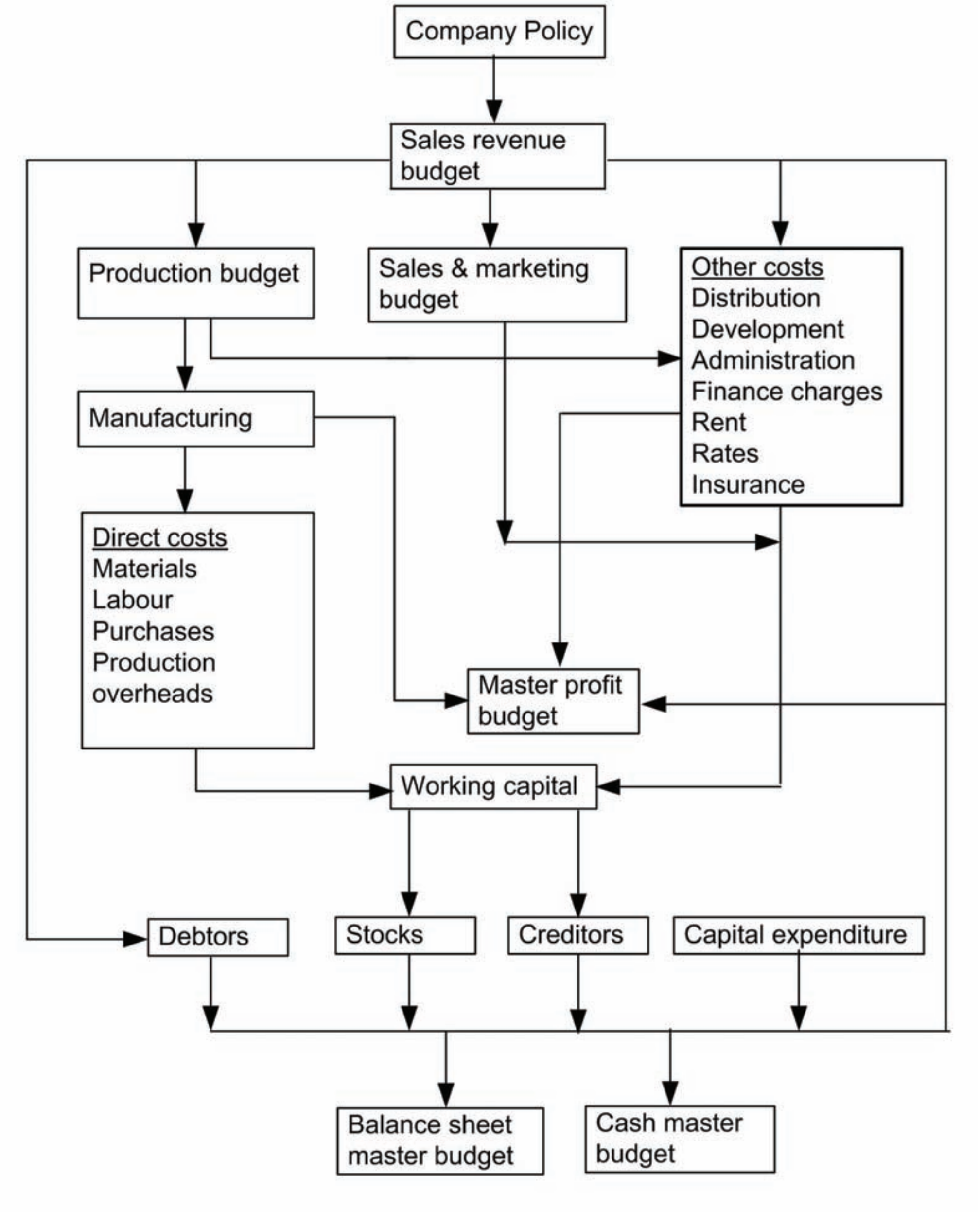


Figure 2.2 Typical budget model

In this sense, the budget is a control document that acts as a guide or blueprint for achieving the company's objectives. It has to be continually revised to take account of actual events as they occur.

With modern computer technology and software, the effect of any unforeseen events can be determined quite quickly allowing rapid action to be taken. The budget is, therefore, an essential instrument in the running and control of the company.

In some cases, however, the budget may be severely damaged by some of these events and an immediate major reassessment of the company's policy and budgeted performance has to be made, for example legislation introduced to ban certain materials for use in certain products due to green issues or perhaps a health hazard having been discovered.

2.4 Budgets for Injection Moulding

So far we have looked at the general model for budgeting, but many of the points discussed are valid for the vast majority of businesses including injection moulding. There are, however, certain aspects of the injection moulding process that call for a more detailed discussion.

The main difference between injection moulding and other methods of manufacture is that polymers have different characteristics from other materials that make them more difficult to process.

A fuller discourse of polymer behaviour is outside the scope of this book, but there are two properties of polymers that can make the injection moulding process particularly difficult:

- material shrinkage; and
- flow behaviour.

2.4.1 Material Shrinkage

A thermoplastic polymer is a material that may be heated to a molten state and allowed to cool and solidify. After solidification, the material may be re-used by granulating it.

After the material has been injected into the mould tool it undergoes volumetric shrinkage so that after it has solidified, its finished size is smaller than the mould cavity that produced it.

In many cases, the amount that the part will shrink is difficult to predict with the possibility that some parts may not be the correct size after they have been made. When this occurs, the mould tool has to be adjusted slightly so that parts may be subsequently moulded to the correct final size.

This problem and other aspects of injection moulding make it a process that requires considerable experience to ensure satisfactory production and, ultimately, profit.

2.4.2 Flow Behaviour

When molten moulding materials are forced to flow under pressure in a mould their flow behaviour is unlike that of other fluid substances like water for example. When pressurised, water will flow uniformly into an enclosed space and will exert the same pressure everywhere throughout the space, and is termed a *Newtonian fluid*.

By contrast, a moulding material when injected into an enclosed space exerts a decreasing pressure the further it travels. This means that in mould tools producing more than one part at a time, the parts may be moulded at different conditions from each other. This type of flow is termed *non-Newtonian*.

2.4.3 Observation

These and other factors illustrate the problems that the injection moulding process can present for the unwary or the inexperienced. The amount of technical expertise required will depend upon the nature of the business and the quality of the products it has to produce.

High-quality, demanding parts with close tolerances require considerable expertise as do those that need maximum preservation of physical properties like those used in the medical, aerospace or computer industries.

In such circumstances, it is essential that there is a substantial input from all the technical departments in the preparation of a budget.

There is still considerable skill and experience required in the moulding of more mundane products like those produced for the consumer market such as buckets, bowls and disposable cutlery.

In this case, the emphasis changes from preservation of critical properties and dimensions to a high level of efficiency in production to achieve fast cycles and thereby competitive prices.

The trade moulding industry requires a broader range of skills as this industry often has to manufacture parts in a large variety of materials and finishes for a widely differing range of end users.

Each company will have to take account of the degree and type of technical expertise required depending on the type of market they are serving. This will influence the following:

- capital expenditure;
- profit margins; and
- level of expertise and skills of management and workforce.

2.5 Preparing a Budget for an Injection Moulding Operation

This follows the same general procedure as that previously discussed and summarised in Figure 2.2. The only difference is that it has to be customised to suit the type of business and the markets it is intended to serve.

Just as in the general case, long-, medium- and short-term planning is required to set out a company's future objectives. This will be best explained with the use of an example, which will follow through the complete procedure for a custom moulding operation. This will be based on a fictitious smaller company, ABC Products, which has been in business for five years.

ABC believes it has sufficient expertise in the production of custom technical products to extend this to a niche market that should provide a greater return and more stability in the future.

The intention is to serve a market that does not suffer from as much variation in demand as ABC is experiencing with its current markets. It believes that the current market is mainly consumer driven and therefore sensitive to the state of the economy, whereas the medical and pharmaceutical markets are considerably more stable.

However, it realises that a substantial change of direction will be required and a considerable amount of capital investment will be necessary to achieve a successful penetration of these markets. The company, therefore, needs to prepare its long-, medium- and short-terms plans to effect these changes.

An abridged version of the plans is shown in the following sections.

2.5.1 Long-term Planning (Years 5 to 10)

- Penetration of medical and pharmaceutical markets.
- Acquisition of management and personnel to support this field of manufacture.
- Investment in dedicated plant and equipment for this market.
- Appointment of specialist sales and marketing personnel.
- A building extension to provide clean room conditions.

2.5.2 Medium-term Planning (Years 2 to 5)

- Market research into viability of long-term market objectives.
- Re-assessment of market viability.
- Costing research to establish expenditure necessary for medium- and long-term objectives.
- Introduction of machine production using temporary clean room conditions.
- Preparation of new quality control procedures.
- Raising necessary capital for long-term objectives.

2.5.3 Short-term Planning (Forthcoming Year)

- Preparation of working budget for forthcoming year.
- Initial market research into medium- and long-term market objectives.
- Costing analysis of medium- and long-term planning.
- Investigation of sources of finance for expansion plans.
- Introduction of suitable medical work that does not require clean room conditions.

2.5.4 Working Budget

Now that the longer term objective planning has been carried out, a working budget for the next financial year has to be prepared with these plans in mind.

The sales department has been instructed to start to focus on the medical market without losing sight of the existing customer base. The budget detailed in Table 2.1 been determined in consultation with all departments.

Table 2.1 Working budget: all costings are in pounds (£)

Moulding sales	8,580,000
Mould tool sales	1,100,000
Total sales	**9,680,000**
Less:	
Material purchased	2,000,000
Mould tools purchased	1,000,000
Direct labour costs	725,000
Works salaries	350,000
Subcontract work	325,000
Works expenses	150,000
Electricity	160,000
Water charges	55,000
Repairs to mould tools	155,000
Repairs to plant	170,000
Packaging and distribution	425,000
Maintenance to services	70,000
	5,585,000
Gross profit	**4,095,000**
Less:	
Salaries	825,000
Pensions	125,000
Office costs	26,000
Rates	50,000
Rent	250,000
Insurance	125,000
Repairs to premises	55,000
Sales costs	145,000
Depreciation	1,250,000
	2,851,000
Trading profit	**1,244,000**

Clearly, this budget is specific to this company and other companies may prepare budgets that are more detailed and allocate costs in different ways to that shown in Table 2.1. However, it represents a sufficiently general model for the basis of other injection moulding operations as most of the sales and cost elements will be common to a wide range of other moulding activities.

Notes.

1. The budget has been presented in a profit and loss form, which may then be compared with a monthly or quarterly actual profit and loss statement to monitor current performance against actual performance.
2. Mould tool sales and costs have been included as it is important to ensure these are monitored. Note that the budget is assuming that a nominal 10% profit will be made overall on mould tool sales.
3. The sales budget and all the major costs have been determined by analysis of the previous year's results. These serve as a basis for more accurately predicting results in the forthcoming year.
4. Some revenue and costs have been included that represent an expected involvement in the medical field.
5. A provision for bad debts, where customers will not or cannot pay for goods or services rendered, has not been included but some companies may include this potential cost if they have had bad experiences before.

As previously discussed, the budget is used as a control document that acts as a guide or blueprint for achieving the company's objectives. It is important, therefore, that all sales and costs are compared with the budget to ensure there are no major departures from it.

This does not mean that the budget is cast in stone and that any deviation from it will not be tolerated. Indeed, there will always be variations as actual events unfold. This is demonstrated in Table 2.2, which shows what has happened after the budget has been implemented.

Note that in this case the opening and closing stocks have been added so that a false picture is not presented. The stocks include all materials, work in progress, products awaiting despatch, etc.

This clearly demonstrates that significant variations from the budget can occur. In this case, it can be seen that the profit for the month of April is alarmingly down – almost 40%. This would trigger an immediate investigation into the reasons why this has occurred.

Table 2.2 The working budget in operation : all costings are in pounds (£)

	Budget April	Budget cumulative	Actual April	Actual cumulative
Invoiced sales:				
Mouldings sales	715,000	2,860,000	710,000	2,830,000
Mould tool sales	91,667	366,667	93,000	72,000
Total	**806,667**	**3,226,667**	**803,000**	**3,202,000**
Less:				
Opening stocks	104,166	416,667	126,000	380,000
Materials	166,667	666,667	175,000	710,000
Mould tools purchased	83,333	333,333	95,000	345,000
Direct labour costs	60,417	241,667	60,700	259,000
Works salaries	29,167	116,667	29,000	115,000
Subcontract work	27,083	108,333	29,000	116,000
Works expenses	12,500	50,000	12,100	48,300
Electricity	13,333	53,333	12,500	52,350
Water charges	4,583	18,333	4,500	18,100
Repairs to mould tools	12,917	51,666	13,000	49,850
Repairs to plant	14,167	56,667	13,950	55,500
Packaging and distribution	35,417	141,667	34,250	139,000
Maintenance to services	5,833	23,333	6,200	23,750
Total	**569,583**	**2,278,333**	**611,200**	**2,311,850**
Add:				
Closing stocks	104,167	416,667	110,250	430,750
Gross profit	**341,251**	**1,365,001**	**302,050**	**1,320,900**
Less:				
Salaries	68,750	275,000	67,500	270,000
Pensions	10,417	41,668	10,417	41,668
Office costs	2,167	8,667	2,100	8,450
Rates	4,167	16,667	4,167	16,667
Rent	20,883	83,333	20,833	83,333

Insurance	10,417	41,667	10,417	41,667
Repairs to premises	4,583	18,333	5,417	23,000
Sales costs	12,083	48,333	12,500	49,000
Depreciation	104,167	416,667	104,667	416,667
Total	**237,584**	**950,335**	**238,018**	**950,452**
Profit	**103,667**	**414,666**	**64,032**	**370,448**

A full analysis of the results from this example is discussed in Chapter 15 where we will examine the factors that led to this situation.

However, the value of the budget has been clearly demonstrated in this example where a significant deviation from the expected results has been highlighted, triggering further action. It may lead to, for example, a revision of the budget for the remainder of the year.

3

Methods of Costing

Having defined and discussed some of the more commonly used costing and accountancy terms, we are now in a position to investigate the major types of costing systems used in manufacturing industry.

When a company is deciding the prices it is going to charge for its products, it has to have a basis on which to compute these. There are three essential requirements for such a system:

- it must ensure that all costs are recovered;
- it must include the required element of profit; and
- it must be competitive.

Whatever system is used it should reflect how easy or difficult the product is to make and take account of any extra requirements like secondary operations (e.g., hot foil stamping/annealing) or special packaging and so on.

There are several different methods of costing and each company will have its own preferences. The actual method used is not as important as whether the chosen system works. The simpler the system is, the easier it will be to understand and implement.

However, there are four main costing systems that we will now examine in detail:

- Standard costing
- Absorption costing
- Marginal costing
- Machine hourly costing.

3.1 Standard Costing

This is arguably the most used costing method for the manufacturing industry. It is based on setting specific standards for each manufacturing activity or process. These standards are agreed between all the interested parties within the company and represent normal, reasonably efficient manufacturing performance.

It is most important to note that this system is *not* based on targets or goals based on optimum manufacturing performance that may or may not be achieved.

There are several advantages to using a standard costing system which are summarised below:

- It measures the expected performance at all levels in the company.
- It provides a standardised product costing system that can be used for direct product pricing comparison.
- It provides a system that may be used for non-financial assessment. For example:
    - labour and management performance; and
    - machine and equipment performance.
- It gives a stable platform for taking major management decisions like:
    - product pricing for new or existing lines; and
    - production capacity assessment.
- It provides a standardised system for developing future growth plans.

For new products, the initial standard cost will have to be based on previous experience with other similar products and subsequently developed and refined as more accurate costs become known.

It is essential that each company has a clearly defined meaning for its standard costing system and ensures that it is completely understood and implemented properly.

The following guidelines would be typical of a manufacturing business based on allowable expenditure for:

- direct material costs;
- direct labour costs; and

- production overhead costs (including depreciation allowances).

Additionally it must be based on manufacturing at a standard level of production and achieve the following:

- the required quality level;
- the required rate of production;
- the necessary functional performance; and
- the designated level of efficiency (not an optimum goal).

Example. This example illustrates a standard costing analysis for a typical product. Table 3.1 gives the ABC standard costing for an industrial pump per unit. From this table, the standard costing for this item is 1016p.

If these products were produced in high quantities, small variations in any of the individual costs can affect the profitability of the project quite significantly.

This is why it is so important to ensure that all individual cost components accurately reflect realistic performance levels and not targets. Standard costings based on overoptimistic targets frequently lead to reduced profitability. This effect will be amplified in high-quantity production.

3.2 Absorption Costing

Absorption costing is a method that ensures that all the manufacturing costs are absorbed (or recovered) by the products produced. In other words, the cost of a product will include direct and indirect labour and both the variable and fixed overheads.

This method is often referred to as a full costing or complete absorption method. It ensures that all costs are recovered.

3.2.1 Steps in Introducing an Absorption Costing System

1. Identify and make an accurate assessment of all costs in the business.
2. Classify these costs into cost categories.
3. All direct costs are allocated to the manufacturing output.

Table 3.1 Standard costing example

Part	Source	Standard unit time (s)	Quantity per unit	Material cost per unit (p)	Labour cost per unit (p)	O/head cost per unit (p)	Total cost per unit (p)
Pump body	ABC	20	1	20	12	80	112
Pump lid	ABC	15.5	1	16	9	62	87
Seal	Ext	Nil	2	35	Nil	15	50
Lever arm	ABC	18	1	12	5	45	62
Float	ABC	35	1	18	15	20	53
Counter weight	Ext	Nil	1	55	Nil	25	80
Switch housing	ABC	17	1	12	8	18	38
Switch	Ext	Nil	2	85	Nil	12	97
Assembly	ABC	185	1	Nil	55	215	270
Packaging	ABC	11	1	27	35	105	167
Totals		**301.5**	**12**	**280**	**139**	**597**	**1,016**

Notes: 1. Entries listed ‘ext’ are bought out items from external suppliers and hence have no labour content. However, they attract an overhead charge to cover purchasing and processing costs, etc. 2. The following activities have been included in the costing: design drawings; inspection and quality control; an allowance for wastage and rejects; amortised tool costs where applicable; plant and equipment used; purchasing costs; storage costs. 3. Labour costs are based on standard times established through work study analysis. 4. Overheads used are those allocated per cost centre. (Note that these could also be based on a standard overall (global) cost allocation.)

4. Allocate all the indirect costs to individual service departments.
5. Re-allocate the costs from production support services to production departments.
6. Establish an accurate overhead rate.
7. Absorb all direct and indirect overhead costs into each product.

3.2.2 Absorption Rate

The absorption rate (also known as the recovery rate) is the method of assigning overheads to a product or service and may be based on:

1. Direct labour hours.
2. Direct material costs.
3. Machine production hours.
4. Units of output.
5. Percentage of the product sales prices.

If a company is producing several different products then each of these may attract a different absorption rate because each product may make a greater or lesser demand on support services like purchasing or human resources.

For each product, all production costs directly associated with it and all related overheads are allocated to this product cost centre.

However, sometimes it is possible to establish an overall relationship between certain costs for the manufacture of a wide range of different products.

Example. A company manufactures a large range of different products with the overall production costs given in Table 3.2.

It has been established that there is a close relationship between the material costs for each product and the overhead cost. In this case the absorption rate would be

$$\frac{\text{Direct material cost}}{\text{Total overhead}} = \frac{585}{730} = 0.8 = 80\%$$

Table 3.2 Production costs	
	Cost (£000)
Direct materials	585
Direct labour	550
Direct works expenses	175
Total cost	1,310
Total overhead	730
Total works cost	**2,040**

This relationship can now be used to determine individual product costings (Table 3.3). In this case, there is a relationship between direct material costs and the manufacturing overhead cost. However, any other cost may be used as a base for a similar relationship – like the labour or total costs.

If a global relationship like this can be established, it clearly makes for a simpler method. If such a relationship cannot be established then each product would include its own individual overhead allocation as previously explained.

Table 3.3 shows the basic absorption of manufacturing overhead costs. This shows the product costing for manufacturing overheads but there are other overheads that have to be added to these. Examples are selling and distribution costs which may be a mixture of direct and indirect costs and advertising campaigns for specific products or global advertising. These non-specific costs are usually absorbed in one of the following ways:

- as a percentage of the selling price;
- as a rate per unit; and
- as a percentage of the manufacturing costs.

Table 3.3 Basic absorption costing for three typical products

Category	**Product A (£)**	**Product B (£)**	**Product C (£)**
Materials	25	35	15
Labour	20	38	12
Expenses	15	12	5
Total cost	60	85	32
Works overhead	20 (25 × 80%)	28 (35 × 80%)	12 (15 × 80%)
Total works cost	**80**	**113**	**44**

3.2.2.1 Percentage of the Selling Price

This method is usually used where sales are made through a variety of different sales outlets. For example:

- a direct sales force;
- through national distributors;
- through local dealers;
- retail chain stores;
- online sales via a web site; or
- through agents.

Each one of these categories will require a different discount from the nominal sales or list price. **Table 3.4** shows the absorption of selling and distribution costs for four categories.

The published list price is rarely charged out in full but serves as a base figure against which discounted prices are established. This example shows that the company will have to manufacture this product at 48% of the list price to absorb or achieve the manufacturing costs + profit margin.

This method is also useful for establishing the optimum ex works or production cost of a product by using the list price of a competitor's product and working backwards.

Table 3.4 Absorption of selling and distribution costs

	Sales force (%)	**Local dealer (%)**	**National distributor (%)**	**Online sales (%)**
List price	100	100	100	100
Discount	12	40	45	30
Total sales revenue	88	60	55	75
Sales and distribution costs	40	12	7	27
Production cost + profit	48	48	48	48

3.2.2.2 Rate Per Unit

This method allocates a separate proportion of the total overhead costs to each product item so that all the overhead costs are absorbed by the total of all of the products manufactured.

Fixed costs like rent, insurance, showrooms, etc., can be allocated by the turnover of the product or by product volume. The variable costs can then be allocated on a rate per item basis. This method is shown in Table 3.5. These results are added to the manufacturing costs per unit plus a profit element if one has not already been included.

Table 3.5 Absorption of selling and distribution costs on rate per unit basis

Category	Product A	Product B	Product C
Fixed costs	£10,000	£20,000	£50,000
Sales volume	15,000	40,000	100,000
Fixed cost per unit	£0.67	£0.50	£0.50
Variable costs per unit	Nil		
Packing costs	£0.35	£0.30	£0.40
Delivery costs	£0.25	£0.30	£0.20
Commissions	£0.30	£0.30	£0.35
Sales and distribution cost per unit	£1.57	£1.40	£1.45

3.2.2.3 Percentage of the Manufacturing Cost

This system is used where the products are of a similar nature or a similar price. In this case it should be relatively straightforward to establish a fixed percentage to add on for administration and selling costs. In Table 3.1, the production cost was established as £101.60. Using this figure, the final product cost can be arrived at as shown in Table 3.6. In this case the percentage added is the standard company figure for this product.

Table 3.6 Absorption by adding percentage of the manufacturing cost

Standard cost from Table 3.1	£10.16
Distribution costs	£3.50
Administration and selling costs at 12%	£12.19
Total	**£12.54**

3.3 Marginal Costing

With both standard costing and absorption costing, the allocation of fixed and overhead cost can be complex (but necessary) to analyse and apply to establish complete costings.

Costs behave in different ways as the production or sales volumes change. In marginal costing it is the behaviour of the associated costs that is measured rather than the origin of the cost. It measures relative effects rather than total costing. It determines the change in cost that occurs when the output volume changes by one unit. This is quantified by the total variable cost for a single unit.

To carry out a marginal costing analysis it is first necessary to identify the fixed and variable cost elements. The following example demonstrates the procedure for establishing a marginal costing for a small company producing a single product.

Example. Table 3.7 summarises the procedure for establishing a marginal costing. To look at these results on a marginal costing basis, it is necessary to rearrange the figures as shown in Table 3.8.

With each product the company sells, it will receive £1.25, and, as this is greater than the £0.42 variable cost, there will be a ***contribution*** to cover the fixed costs. Hence, contribution = sales value minus variable costs – in this case £0.83 per unit. It directly follows therefore that profit = contribution minus fixed costs – in this example £0.17.

Table 3.7 Cost analysis for 160,000 units

Category	**Total (£)**	**Fixed costs (£)**	**Variable costs (£)**
Sales (160,000 units)	200,000		
Costs			
Direct materials	40,000	Nil	40,000
Direct labour	35,000	19,000	16,000
Production overheads	20,000	20,000	Nil
Sales and marketing	30,500	22,000	8,500
Development	20,000	20,000	Nil
Administration	15,500	15,500	Nil
Distribution	12,000	9,000	3,000
Total costs	**173,000**	**105,500**	**67,500**
Net profit	**27,000**		

Table 3.8 Marginal costing for 160,000 units

	£	£ per unit
Sales	200,000	1.25
Less variable costs	67,500	0.42
Contribution	132,500	0.83
Less fixed costs	105,500	0.66
Net profit	27,000	0.17

The results from this analysis reveal an important point. That is, if more than 160,000 products are sold, the profit will increase as the fixed costs cannot change. Hence for each additional product sold, the profit on a marginal basis is equal to the contribution – in this case £0.83.

These results can also be demonstrated on a graph that gives a convenient method for viewing the effect of varying different parameters (**Figure 3.1**). This clearly demonstrates how increasing output, and hence sales, increases the profit. It also shows the break-even point, which is simply the point at which the number of items sold is sufficient to make the sales revenue equal to the total costs.

In this case this figure is around 127,000 items sold which corresponds to £159,000 of sales. If more items than this are sold, a profit will result. If less than this number is sold, a loss will result where the costs exceed the sales revenue.

Figure 3.2 shows how the basic graph is constructed.

1. Establish a table similar to **Table 3.8** based on *your* figures.
2. Draw the axes for the sales/costs and number of item sold.
3. Draw a line from point A horizontally across the graph representing the budgeted sales – in this case £200,000.
4. Draw a line vertically upwards to represent the number of items sold – in this case 160,000.
5. These two lines will intersect at point C.
6. Draw a line from the origin through point C and continue it a little further.

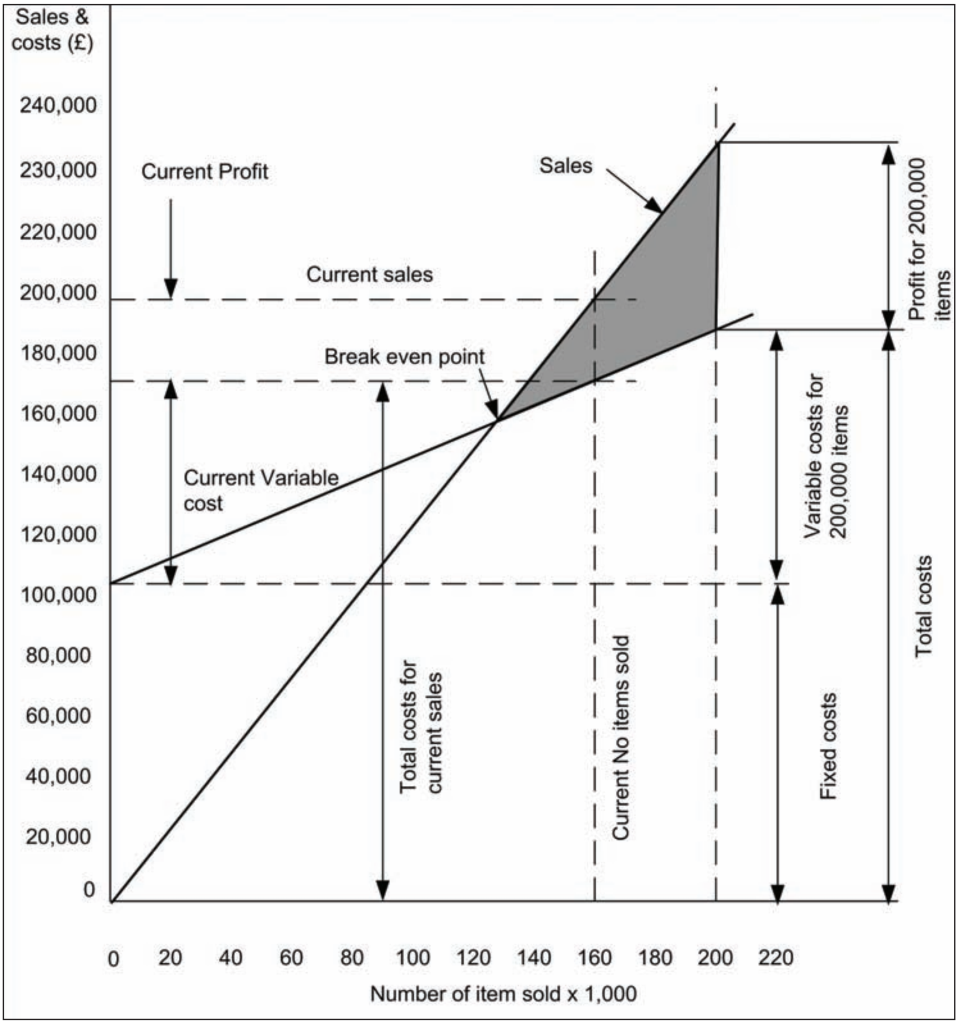


Figure 3.1 Break even graph for data in Table 3.8

7. Draw another line horizontally from point B at a distance up the sales/costs axis representing the total costs (variable + fixed costs) – in this case £173,000. Where this line intersects the vertical line already drawn we obtain point D.
8. Now draw a line from point F through point D and extend it a little further.
9. The break-even point is the intersection of these two lines at E.

The figures obtained from the graph give a reasonable estimate but, of course, will depend upon the accuracy with which the graph has been drawn and interpreted. For

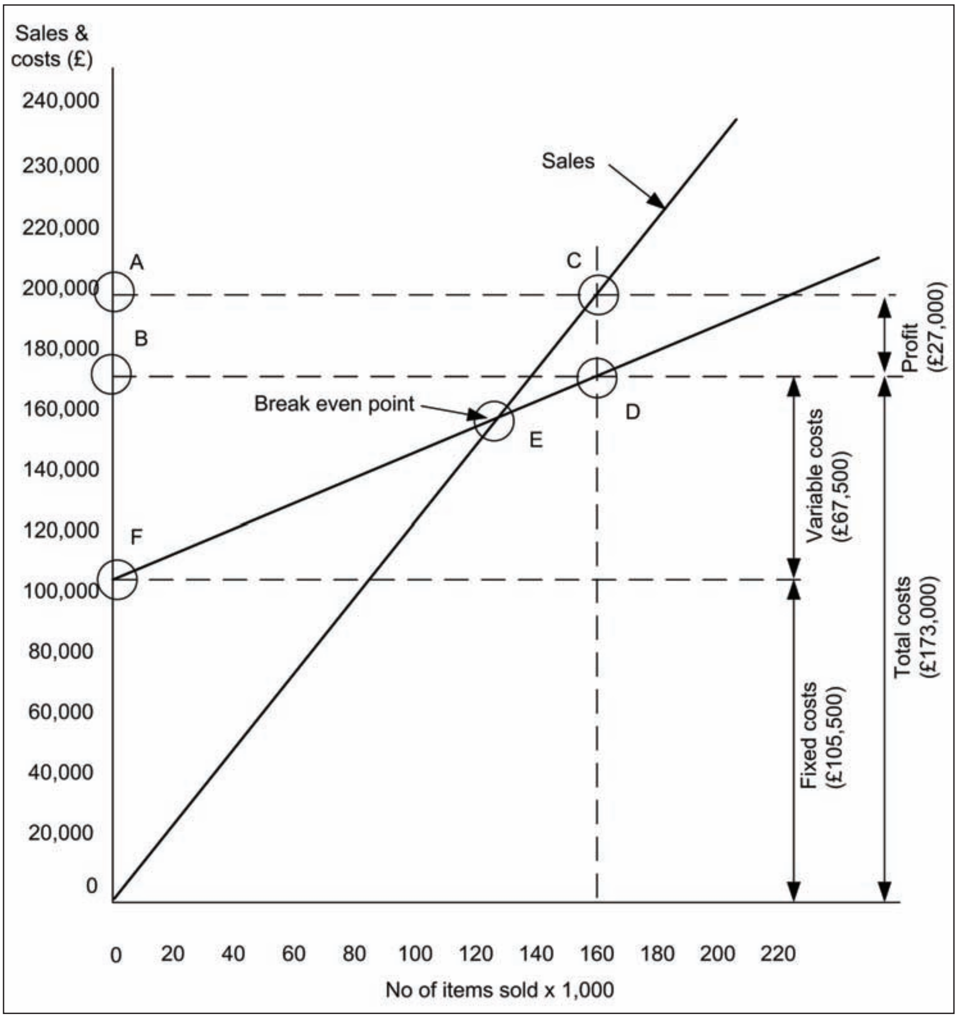


Figure 3.2 Basic construction of break even graph for data in Table 38

those who prefer a more accurate graphical method, a Microsoft Excel spreadsheet may be used (**Figure 3.3**). A better visual result is obtained by altering the row and column sizes to suit the figure involved.

An alternative algebraic approach gives an accurate result and can be put into program form in a computer for added convenience.

Using basic algebra, the break-even point can be established by the following equation where all figures have been taken from **Table 3.8**:

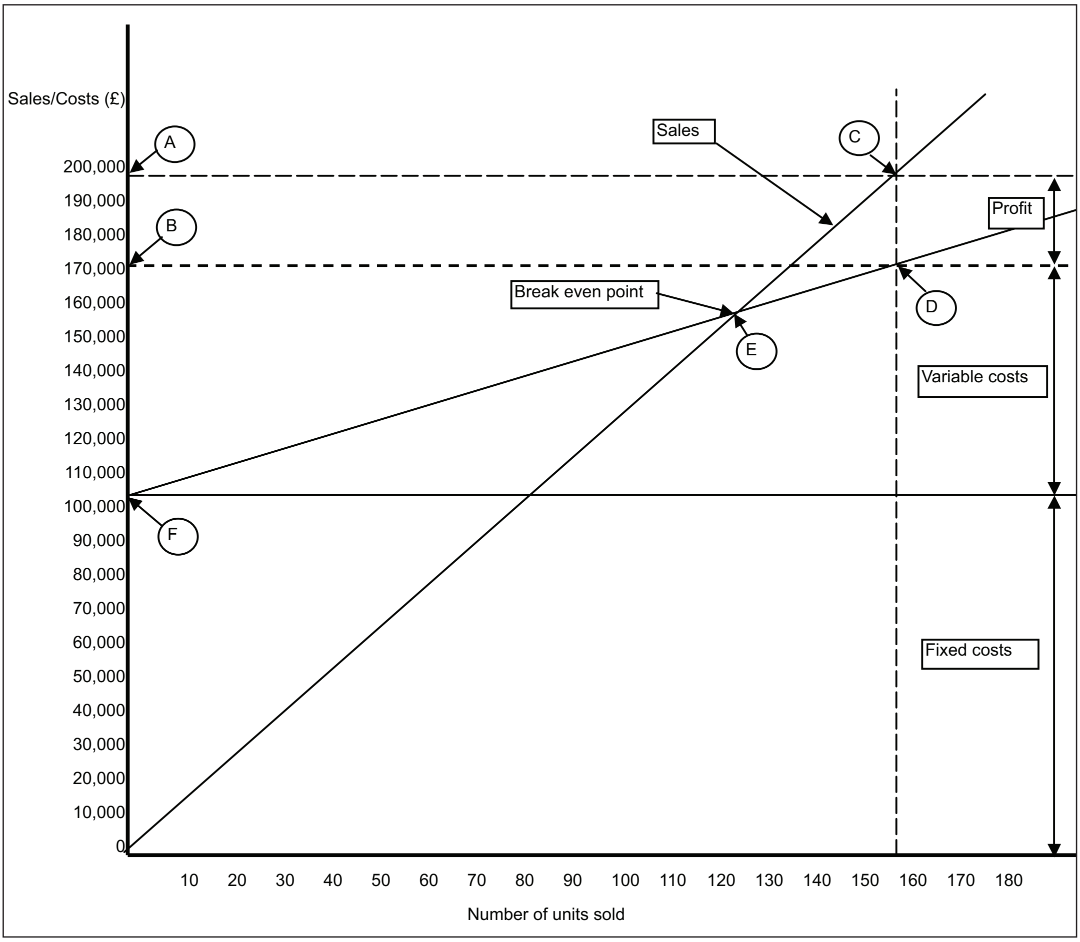


Figure 3.3 Microsft Excel graph

$$\frac{S \times B}{N} = \frac{V \times B}{N} + F \tag{3.1}$$

where S = sales value, V = variable costs, F = fixed costs, N = number of items sold and B = number of items required to be sold to break even. We can simplify and transpose **Equation** (**3.1**) to give

$$B = \frac{N \times F}{S - V} \tag{3.2}$$

If we now substitute the values from **Table 3.8** in **Equation** (**3.2**), we get

$$\begin{aligned} B &= \frac{160,000 \times 105,500}{200,000 - 67,500} \\ &= 127,396 \end{aligned}$$

which corresponds to 127,396 × £1.25 = £159,245 of sales.

Looking again at the graph in **Figure 3.1** we can also see that we can determine the profit as the sales or the number of items sold increases. For example, if 200,000 parts were sold we could expect the profit to increase to approximately £60,000.

We can similarly arrive at an equation to determine this algebraically:

$$P = \frac{S \times N_v}{N} - \left(\frac{V \times N_v}{N} - F \right) \tag{3.3}$$

where P = profit and N_v = different number of items sold, chosen for the analysis. On simplification this gives:

$$P = \frac{(S - V)N_v}{N} - F \tag{3.4}$$

Substituting the values from **Table 3.8** gives:

$$\begin{aligned} P &= \left(\frac{200,000 - 67,500}{160,000} \right) \times 200,000 - 105,500 \\ &= 0.828 \times 200,000 - 105,500 \\ &= £60,100 \end{aligned}$$

Note that **Equations** (**3.2**) and (**3.4**) are powerful results allowing other variables to be established once the break-even condition is known, for example establishing what the variable cost will be for a given level of profit. Another useful result is writing:

$$C = S - V$$

where C is the contribution since C = sales minus variable costs. Hence, **Equation** (**3.4**) may be written as:

$$P = \frac{C \times N_\text{v}}{N} - F \tag{3.5}$$

3.4 Machine Hourly Rates

This method of costing is frequently used where the majority of production is machine based. For example:

- injection moulding;
- blow moulding; or
- extrusion.

Clearly it would cost more to run a larger machine than a smaller one since:

- the capital cost is greater;
- the energy required to operate it is greater; and
- the maintenance and servicing costs are greater.

These facts must be reflected in the prices charged for manufacturing parts.

The difficulty is in establishing the amounts to charge for different size machines and for machines of differing ages. A number of methods have been developed for taking this into account, including those previously discussed, but by far the most frequently used is based on the ***machine rate per hour*** (or machine hourly rate, MHR).

First of all we will examine what would happen if we only had *one machine*. This is, of course, very unlikely in practice but it illustrates the principle more clearly. We will then extend this principle to any number of machines. The following analysis is based on injection moulding but a similar procedure can be adopted for any primarily machine-based production activity.

3.4.1 Computation of the MHR

The following analysis applies to an injection moulding operation only, based on custom moulding or general trade moulding.

There is no way of knowing in advance exactly what the mix of new work will be: whether the parts will be large or small, how many impressions the mould tools will be, what materials will be required and so on.

This is where analysis of past performance is extremely valuable. From such information we should know:

- the invoiced sales;
- the total cost of all moulding materials used;
- the energy costs;
- all other direct and indirect costs.

In fact by analysing the figures from several previous years, a trend can be established without too much difficulty. For example, previous labour costs can be projected forward, as can energy and several other costs. There may well be a variation from year to year but these can be averaged out.

Example. To illustrate this we will re-introduce our fictitious injection moulding company, ABC Products Ltd (ABC). The board of ABC has decided the performance for the forthcoming year:

- Invoiced sales: £10,000,000.
- Profit required: 15%.

This is based on previous years' figures given in Table 3.9, in which the ***material usage factor*** is defined as

$$\frac{\text{Cost of materials used}}{\text{Invoiced sales}} \times 100\%$$

From this analysis we can establish the average of the last three years' material usage factors: (29 + 31 + 28.5)/3 = 29.5%.

The decision is taken in this case to adopt 30% for the forthcoming year. In view of this we can establish the following:

Table 3.9 Analysis of previous years' figures

	Year 1	Year 2	Year 3
Invoiced sales	£6,000,000	£7,000,000	£8,500,000
Materials used	£1,740,000	£2,170,000	£2,422,500
Material usage factor	29%	31%	28.5%

invoiced sales: £10,000,000

less profit (15%): £1,500,000 = £8,500,000

less materials used (30%): £3,000,000 = £5,500,000.

This means that all remaining costs will have to fall within £5,500,000

The accountant and production manager have established to support this level of sales that all remaining costs (except material costs) amount to £5,000,000. This is less than the projected 'surplus' of £5,500,000 and leaves a factor of safety of £500,000 – a 10% margin on costs in case the actual costs are higher than expected.

ABC works a 125-hour week, 50-week year, giving a utilisation of 6,250 hours per year – a UF of 74.5%. From similar analyses of previous years' performance it is known the efficiency factor is 80%. With this information, we can now establish the average MHR for one (virtual) machine.

If we can imagine for a moment that ABC does have only one machine, all the costs of all work processed on it would be charged out in two basic parts:

1. The cost for the material.
2. A charge to cover all other costs.

The material cost would depend on the size of the parts, the runner system and the price of the material – the costs varying from job to job. Hence, these costs would have to be charged separately.

The machine charge would have to cover all the remaining costs. In order to do this we have to predict how many hours per year the machine is going to be actually producing parts and divide this figure into these costs. This gives us a machine rate per hour. Dividing this by 3,600 would give the machine cost per second.

If we then estimate the cycle of a job, we can determine how much we should charge per shot by multiplying the cycle by the machine cost per second. This gives a machine cost for the shot. Adding this cost to the material cost for the shot gives us the total cost for producing one shot. Dividing this figure by the number of impressions in the shot will give the cost per part.

To illustrate this procedure we will establish the MHR for one machine for the company ABC as follows:

Total number of hours worked = 6,250

Productive hours worked = 5,000 (6,250 × 80%) per year

Total costs to be recovered = £5,500,000

Therefore average MHR = £5,500,000/5,000 = £1,100.

Clearly it would be an understatement to say achieving a turnover of £10,000,000 with one machine with an MHR of £1,100 would be difficult!

We will now assume that ABC has 14 machines ranging from 25 tonne lock to 350 tonne lock and that its policy is to depreciate all machines over five years on a straight-line basis. The details of these machines are given in Table 3.10.

All that remains now is to apportion the MHR of £1,100 for this single machine over all the machines the company has. There are several methods used to achieve this but we will concentrate on four:

- capital cost method;
- machine lock method;
- book value method; and
- kVA (kilovolt ampere – see appendix) rating method.

Table 3.10 ABC machine details

M/C lock	No.	Age (years)	Original cost each (£)	Total cost (£)	Depreciation each/year (£)	Book value (£)	Total book value (£)
25	2	2	25,000	50,000	5,000	15,000	30,000
50	1	1	35,000	35,000	7,000	28,000	28,000
50	2	1	40,000	80,000	8,000	32,000	64,000
100	3	3	70,000	210,000	14,000	28,000	84,000
250	1	4	150,000	150,000	30,000	30,000	30,000
250	2	1	210,000	420,000	42,000	168,000	336,000
350	2	2	375,000	750,000	75,000	225,000	450,000
350	1	4	150,000	150,000	30,000	30,000	30,000
Totals	**14**			**1,845,000**			**1,052,000**

3.4.1.1 Capital Cost Method

This consists of expressing each machine cost as a percentage of the total original capital cost for all machines:

$$\text{Capital cost MHR} = \frac{\text{Original capital cost of machine}}{\text{Total capital cost of all machines}} \times £1{,}100$$

If we take the first machine listed in **Table 3.10** (25 tonnes):

$$\begin{aligned}\text{MHR} &= \frac{25{,}000}{1{,}845{,}000} \times 1{,}100 \\ &= £15\end{aligned}$$

3.4.1.2 Machine Lock Method

With this method the machine MHRs are grouped by their locking forces. To use this method we first need to work out the total locking force of all the machines. In this case we have:

$$(2\times 25)+(3\times 50)+(3\times 100)+(3\times 250)+(3\times 350)=2{,}300 \text{ tonnes}$$

Then each locking group is expressed as a fraction of the total locking force of all the machines added together:

$$\text{Machine lock MHR} = \frac{\text{Locking group}}{\text{Total locking of all machines}} \times £1{,}100$$

Taking the 25 tonne machine this gives:

$$\begin{aligned}\text{MHR} &= \frac{25}{2{,}300} \times 1{,}100 \\ &= £12\end{aligned}$$

3.4.1.3 Book Value Method (or Depreciation Method)

As the term implies, the book value or written down value of the machines is taken as the basis for computation for this method:

$$\text{Book value MHR} = \frac{\text{Book value of each machine}}{\text{Total book value of all machines}} \times £1{,}100$$

The book value of the first machine is £15,000. Hence:

$$\begin{aligned}\text{MHR} &= \frac{15{,}000}{1{,}052{,}000} \times 1{,}100 \\ &= £16\end{aligned}$$

Table 3.11 gives the capital cost, machine lock and book value MHRs for all machines.

3.4.1.4 kVA Rating Method

As we have already discussed, the electrical power requirements for moulding machines generally increase as the sizes of the machines increase in terms of their locking capacity. This is the basis of the machine lock method of determining the MHR. However, it is not the most accurate method.

Whilst there is a loose relationship between locking force and power consumed, it does not represent the *actual* power requirement of each machine. In this respect, the locking force MHR method can best be described as a reasonable estimate, although it will still recover all the costs of running all the machines.

A more accurate method is to use the total installed power of each machine as a basis for determining the MHR. The total installed power is the maximum amount of power each machine will consume and is measured in kilowatts (kW).

It is unlikely that every job being processed will need this maximum amount of power. Clearly, in practice there will be many jobs that may only require half or less of the available power on every machine on which they run. However, the same reasoning applies to the machine lock method in the sense that many jobs will not require the maximum available locking force of the machine on which they run, and hence use less power.

The reason why the kVA method is more accurate is that it uses power directly as a basis for costing rather than the locking force method that uses the machine lock capacity to estimate the power consumption. Since the power used represents a major cost component in running a machine, this is an important factor.

Table 3.11 MHRs according to machine lock, capital cost and book value methods

No. of M/C	Lock	Total lock	Original cost per M/C	Total original cost per M/C	Book value per M/C	Total book value per M/C	Depre-ciation per M/C	Total depre-ciation per M/C	Capital cost MHR	Machine lock MHR	Book value MHR
2	25	50	25,000	50,000	15,000	30,000	5,000	10,000	15	12	16
1	50	50	35,000	35,000	28,000	28,000	7,000	7,000	21	24	29
2	50	100	40,000	80,000	32,000	64,000	8,000	16,000	24	24	33
3	100	300	70,000	210,000	28,000	84,000	14,000	42,000	42	48	29
1	250	250	150,000	150,000	30,000	30,000	30,000	30,000	89	120	31
2	250	500	210,000	420,000	168,000	336,000	42,000	84,000	125	120	176
2	350	700	375,000	750,000	225,000	450,000	75,000	150,000	224	167	235
1	350	350	150,000	150,000	30,000	30,000	30,000	30,000	89	167	31
14	**1425**	**2300**		**1,845,000**		**1,052,000**		**369,000**			

Another compelling factor is that electricity suppliers normally base their charges on the maximum kVA requirement for each factory. This is because they have to ensure they can supply the maximum amount of power at all times in case it is needed.

A further case for the kVA method is that moulding machine manufacturers are now marketing machines with all-electric drives, thus eliminating the traditional hydraulic motor driven by a pump. This is designed to increase the operating efficiency and therefore reduce the power requirements substantially. However, the cost of these machines is up to 50% more than the cost of the equivalent hydraulic machines. Hence it may take several years before the savings in power costs offset the extra capital expenditure.

We re-list in **Table 3.12** all the ABC machines with their kW ratings to establish the kVA MHR. The difference between kVA and kW depends on the power factor of the installed electrical supply and is discussed in the appendix in further detail.

Table 3.12 kVA MHR method

Locking force (tonnes)	Rating (kW)	MHR (£)
25	8	18.57
25	10	23.21
50	15	34.81
50	15	34.81
50	16	37.13
100	18	41.77
100	19	44.09
100	19	44.09
250	50	116.03
250	53	123.00
250	56	130.00
350	63	146.20
350	65	150.84
350	67	155.48
Total	**474**	

The same procedure is used to establish the MHRs for each machine as in the previous examples. Taking the first machine in **Table 3.12**, we have:

$$\text{kVA MHR} = \frac{\text{kVA rating of each machine}}{\text{Total kVA rating of all machines}} \times £1{,}100$$

$$= \frac{8}{474} \times £1{,}100 = £18.57$$

It can be seen from this analysis that there are some significant differences between the machine lock MHRs listed in table 3.11 and those obtained using the kVA method shown in Table 3.12.

3.4.2 Selecting the Best Method

3.4.2.1 Capital Cost Method

Clearly, this method weights the MHR strongly in favour of the newer and more expensive machines. The lower the original cost of the machine, the lower the MHR and *vice versa*.

If two machines have the same locking force but one cost more than the other, this is reflected in the MHR and thus the prices charged out.

Different MHRs for the same locking values could also be due to one machine being older than the other. Alternatively the machines could have been purchased at the same time, with one being more sophisticated than the other.

This method has the advantage of lower MHRs for older and less sophisticated machines and higher MHRs for newer machines and those with higher specifications and thus capital cost.

3.4.2.2 Machine Lock Method

This is one of the most widely used methods in the injection moulding industry and is a straightforward system related to the locking force irrespective of the original or written down values of the machines.

It does not take account of differences of quality or age of machines of the same locking force. Therefore the same MHR would be charged for an old basic workhorse as a new high-specification machine of the same lock.

3.4.2.3 Book Value Method

This method does take account of the age and value of machines and clearly weights the MHR in favour of newer more expensive machines. Once the book value of a machine reaches zero, the theoretical MHR of the machine would also be zero.

In practice, of course, a charge would still have be made for such a case since the machine would still require energy to run as well as possibly more maintenance and repair.

The effect of zero rating an MHR for a fully written down machine is to increase the MHRs of all the remaining machines, which are still being depreciated.

Whilst this method is used, it is not as widely used as the capital cost and machine lock methods. Where a machine has been fully written down, a decision has to be made regarding what should be charged. In some cases a quite low MHR is used to attract very competitive business which otherwise may be lost.

However, once a machine has been fully depreciated or written off, it should be replaced by using the funds acquired from the depreciation account – which is the whole purpose of depreciation in the first place.

3.4.2.4 kVA Rating Method

This is a similar but more accurate method than the machine lock method, but it also takes no account of the age or original cost of the machines. This method is becoming more widely used as electric-drive machines are introduced.

It also has the advantage of allowing the selection of the lowest cost machine to run a job on in the same locking group. For example, if a job requires the mould to be run on a 250 tonne machine, Table 3.12 shows which machine would be the cheapest on which to run it. By contrast, the machine lock method does not make this distinction.

3.5 Adjusting the MHR

So far, we have arrived at an MHR by grouping machines into four categories or groups:

- capital cost of the machines;
- locking force;

- book value of the machines; and
- machine kVA rating.

As we have mentioned, the actual method selected to use would depend upon the nature of the work a company undertakes.

3.5.1 Normal Difficulty Work Mix

For general trade moulding, the usual MHR method would be that based on the locking force grouping of the machines. This would not reflect the age of machines or the original prices paid for them. A company may estimate a job on their newest most expensive machine but may not be able to use a higher MHR than the oldest least expensive machine in the same locking group.

This is often simply because their competitors may estimate on the basis of running the same job on a less expensive machine within the same locking group at a lower MHR. In other words a higher MHR cannot be charged because it would not be competitive.

Should the occasional job come along that was more demanding than normal then a higher than normal MHR charge *should* be made to reflect this. In this case a moulder may either apply a factor of difficulty *on cost* to the normal MHR as discussed below or use an isolated MHR computed using the capital cost method.

3.5.2 Varied Difficulty Work Mix

If the work mixture ranges from reasonably straightforward to quite complex and technical, a company may have to purchase a range of machines with differing degrees of sophistication but within the same locking force groups.

Hence if, say, three 100 tonne machines were purchased at different prices reflecting their differing quality and sophistication, the MHR of each should be different. Each MHR would reflect the degree of difficulty, cost of running and the original cost of each machine.

This situation is a clear candidate for the capital cost method, providing the same spread of work applied generally over all machines. Should an extremely difficult job occur, a company may decide to apply a ***degree of difficulty factor*** for that one job to reflect this.

This is often applied as a percentage *on cost* on top of the MHR. For example, if the normal MHR for a difficult job on the 'best' machine was £100, then for this situation an on cost of 25% may be warranted, giving a new MHR of £125. Each case is considered on its merits and charged out accordingly.

3.6 Discussion

In practice each company will adopt its own customised costing procedure which reflects the nature of the type of work it processes. This can take the form of completely different MHR systems for different categories of work being run on the same machines: for example, one MHR for straightforward standard products and another for general trade work.

Companies that specialise in a particular field may apply a wide range of modified MHRs to cover the varying job requirements within that field. If, for example, a company does a large amount of assembly work as well as moulding, the running costs may well be split into two cost groups: one for the assembly and one for the moulding.

Each of these groups may have separate hourly charging systems for each process. In these cases the same approach may be taken by dividing the appropriate costs for each activity by the expected number of productive hours.

3.6.1 Varying MHR System

Some companies keep a very close control over costs and monitor these on a continual basis. These costs are analysed and projected forward for the remainder of that financial year. This enables the MHR figures to be continually reviewed and changed if necessary.

This gives the company the advantage of being able to offer lower prices when the predicted costs decrease and increase prices when the predicted costs rise. This system may be combined with any of the MHR systems described above.

3.6.2 Observation

Although, the examples presented above are based on injection moulding, the same approach may be used with blow moulding (based on machine size) and with extrusion processes (based on machine size or plasticising capacity).

3.7 Checking the Calculated MHR

All the calculations carried out so far are theoretical. They are modelled on predictions about turnover and hence costs. These predictions, however, are based on previous trends and results and represent the best basis we can use in advance of the event.

In view of this, it is important to continuously monitor the ***actual costs*** and review the MHR being charged.

Often, the most vulnerable predicted cost is the material usage factor. This can represent up to 50% of the total running costs of a company and is, therefore, highly significant.

Once a new financial year has started, it is vital to regularly check that this cost is within the budgeted amount. If it is significantly greater than budget, then action should be taken immediately as this could lead to a depleted profit margin or even a loss.

Indeed, all costs should be carefully checked to ensure the MHR is neither too high nor too low.

3.8 Observation

- MHR figures are rarely checked frequently enough to guarantee their accuracy.
- If each job makes a profit there should be an overall profit at the end of the year.

3.9 Summary

3.9.1 Standard Costing

- A widely used method for manufacturing industries.
- Must be based on realistic, achievable performance.
- Must not be based on targets or goals.
- Can cover a wide range of labour-based and machine-based production. Often used for a combination of both.
- Provides a standard to compare company performance and competitiveness.

3.9.2 Absorption Costing

- A method that ensures that all the manufacturing costs are absorbed (or recovered) by the products produced.
- It provides a standard or base selling price for discounting sales prices to national and local distributors and own sales force.
- The absorption rate (also known as the recovery rate) is the method of assigning overheads to a product or service and may be based on:
  - direct labour hours
  - direct material costs
  - machine production hours
  - units of output
  - percentage of the product sales prices.
- Non-specific overhead or other costs may be added as follows:
  - as a percentage of the selling price
  - as a rate per unit
  - as a percentage of the manufacturing costs.

3.9.3 Marginal Costing

- Marginal costing measures relative effects rather than total costing.
- It determines the change in cost that occurs when the output volume changes by one unit. This is quantified by the total variable cost for a single unit.
- It is a very good method for quantifying the additional profit that occurs after the break-even point has been reached.

3.9.4 Machine Hourly Rate

- The most commonly used costing system in the injection moulding industry is based on the MHR.
- The basic MHR is the total running cost (except the material cost) divided by the

number of productive hours worked in the financial year. This is further refined depending on the requirements of each company.

- The most commonly used MHR systems are based on:
    - capital costs of the machines
    - machine locking groups
    - machine book values
    - kVA machine power ratings.
- MHR systems may vary or be combined depending on the nature of the business.
- Whatever MHR system is used, it must ensure all costs (other than material costs) are recovered.
- The MHR must be checked frequently to check its accuracy.

Figure 3.4 shows a summary of the different MHR methods.

All the above analyses are based on charging out the material cost as a separate cost to the MHR due to the widely varying types and costs number of materials.

There is, however, an important exception to charging the material cost separately. If a company is using a single material only for all its products then it is easier to include this in the MHR. For example, a company producing, say, disposable tableware comprising cups, saucers, cutlery, beakers and so on all in high-impact polystyrene, the material cost would be included in the MHR.

3.10 Combined Costing Systems

There are many occasions when a company may choose to operate a number of different costing methods simultaneously. This can occur when a company is producing a range of standard products that require a number of different manufacturing processes of which the injection moulding process is just one. In this case, it is usual to adopt a costing system that may include all the different costing methods so far described treating each operation as a separate cost centre. For example, a company manufacturing a hair dryer may have the following production stages:

- injection moulding to produce the main body parts;
- insertion of metal inserts into body mouldings;

- printing;
- electrical subassembly; and
- final assembly.

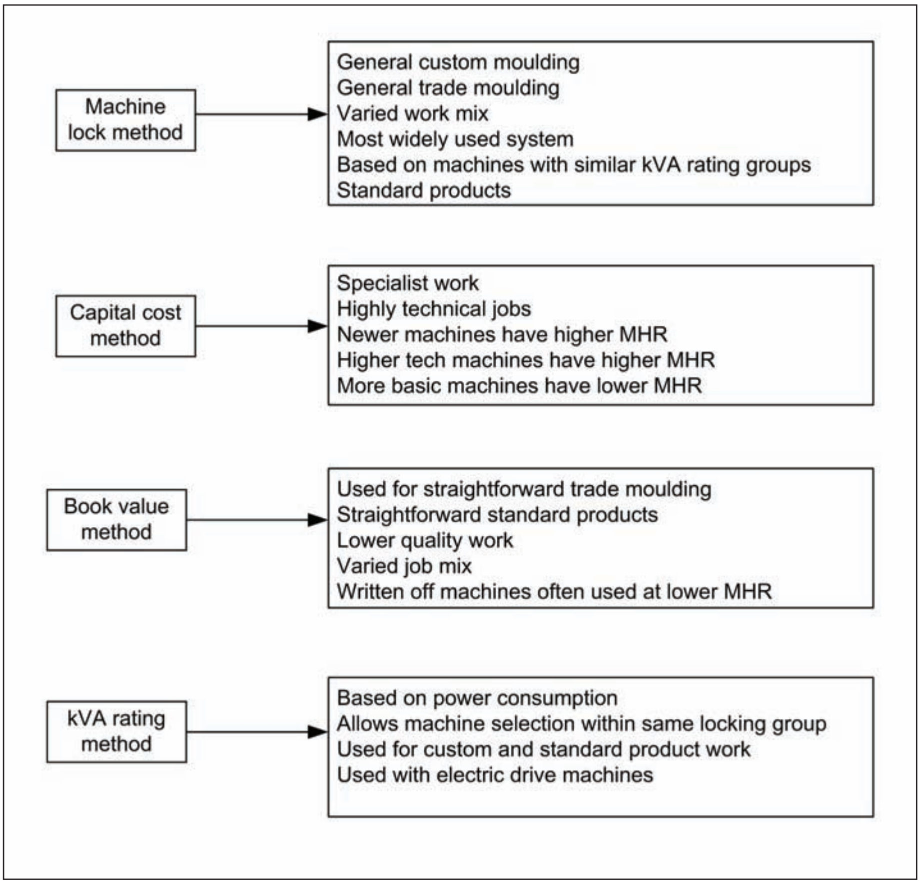


Figure 3.4 MHR costing summary

In this case, the costing system may look like that shown in **Figure 3.5**.

If a company were making several standard products all of which use injection moulded parts made from the same material, the costing model may change. In such cases, the company will try to minimise the number of machine locking groups it has for maximum versatility and economy to ensure:

- interchangeability of mould tools between several machines in the same locking group;
- purchasing advantages in buying several machines of the same locking group at the same time; and
- standardisation of support equipment on identical moulding machines.

For example, this operation may be based on just three locking groups, say 10 of each of 50, 150 and 250 tonne machines.

With large production volumes, the material would be stored in silos and delivered automatically to the moulding machines thus eliminating contamination and labour costs.

Production Stage	Activity	Costing method	Materials
Injection moulding	Manufacture of main body parts and smaller components	MHR system for machines based on locking groups or kVA rating	Costed separately
Inserting	Primarily a labour based activity on pre-assembly stage	Based on standard costing method	Included in costing
Printing	Fully automated process	MHR system for machines.	Costed separately
Sub assembly	Mainly labour based.	Based on standard costing method	Included in costing
Final assembly	Semi automatic	Based on standard costing method or absorption method	Included in costing

Figure 3.5 Costing model for hair drier production

Such an operation is a prime candidate for the standard costing model since:

- only one moulding material is being used for the moulding operations;
- the moulding machine costs should be well known as relatively few mould tools are being used; and
- all the other operating costs and material costs will be accurately known through continual reassessment.

Frequently, companies will develop their own custom costing methods that consist of a combination of the methods previously discussed. Costing systems will naturally evolve to suit the type of business and the markets each company is serving. As market trends change, costing systems may have to change to stay in tune with that particular market.

4 Job Costing

4.1 Discussion

Several costing methods have already been discussed but none of these systems will be of any use unless all the cost elements associated with each job or product are identified and quantified.

If the product is an existing one, then all the costs associated with it should have already been established. However, these costs still have to be monitored on an ongoing basis to take account of changed materials, improved production methods, price increases and so on, which will be discussed later.

For a new product we have to start from scratch and estimate the product cost by allocating costs to different production processes and other costs.

We have already seen that each product cost has to include certain cost elements which may include one or more of the following:

- Materials
- Direct Costs
- Indirect costs
- Fixed costs
- Variable costs.

However, first it is necessary to identify the different production processes that will be used to manufacture the product and any subsequent activities. The following is a typical list of contributory cost elements for most products:

- Materials
- Labour
- Use of machines

- Assembly
- Bought out parts
- Packaging
- Distribution.

If the new product is a standard one that the manufacturing company itself is going to market to increase its product range, then the overall cost can be computed and a sales price established. This can be achieved by using previous experience of similar existing products in allocating costs and determining production methods. This will involve a joint analysis by the accountant and the other managers involved.

However, if a company custom manufactures products for other companies, a different situation applies. In this case the product cost will normally be different for each new product manufactured. This presents additional problems, which we will now discuss.

4.2 Job Costing for Trade and Custom Moulding

A schematic flow diagram for job costing is shown in **Figure 4.1**. This consists of several stages depending on the nature of the parts and the processes involved.

4.2.1 Stage A

The procedure starts by identifying the processes required. These usually include:

1. Machine-based operations.
2. The materials that will be used.
3. Assembly operations.
4. Additional support services.

4.2.1.1 Machine-based Operations

Any machine-based production that may be used should be identified. For example:

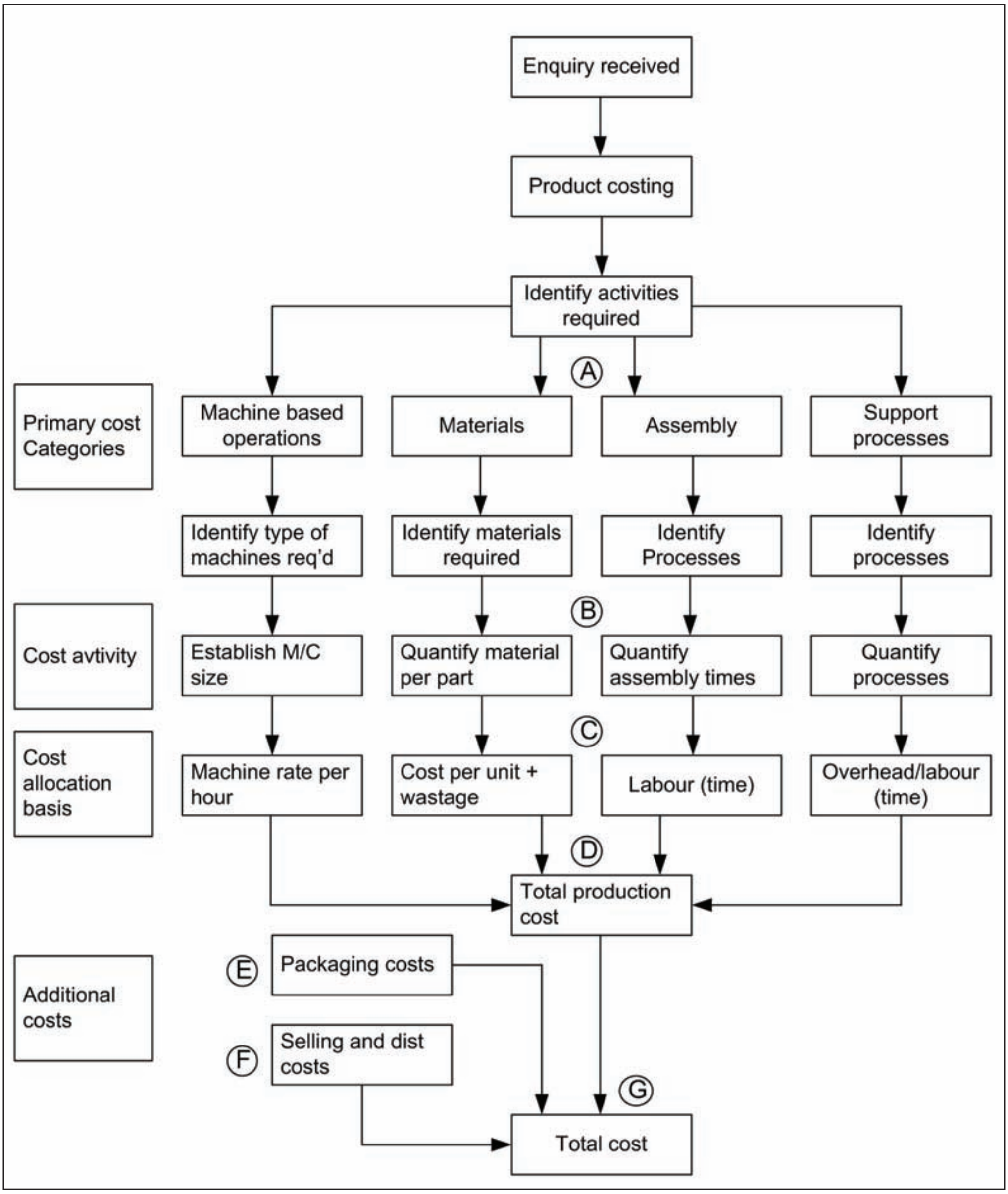


Figure 4.1 Basic flow chart for job costing

- Injection moulding
- Robotics
- Hot stamping
- Printing
- Machining.

4.2.1.2 Materials

These may include

- Injection moulding materials
- Any bought out items; for example:
    - metal inserts;
    - electrical components;
    - metallic foil for printing; and
    - assembly items (seals, washers, mechanisms, etc.).

4.2.1.3 Assembly Operations

- Gluing
- Inserting
- Joining
- Welding.

4.2.1.4 Support Services

- Quality control
- In process statistical process contro (SPC) inspection
- Certification documentation
- Material testing/verification.

4.2.2 Stage B

At this stage, the following are decided:

- The types of machines to be used (vertical/horizontal/two colour, etc.).
- The machine size (tonnage, plasticising capacity, shot weight, etc.).
- The quantity of materials needed (including bought out items).
- The machines/labour needed and times for assembly.
- The amount of time allocated to support services.

4.2.3 Stage C

This is the point where the costs are allocated and quantified. For example:

- Machine rate per hour
- Labour costs
- Direct costs
- Overheads
- Variable costs.

4.2.4 Stage D

This stage involves establishing the total production or works cost for the job.

4.2.5 Stages E and F

At these stages any remaining costs associated with the job are identified and quantified.

4.2.6 Stage G

This stage gives the total cost for the job.

4.3 Job Costing for Trade/Custom Moulding

To illustrate the costing procedure for a typical trade moulding we will now follow through the outline stages in the following example.

Example. Company ABC has been asked to provide a quotation for manufacturing a plastic cam wheel part shown in **Figure 4.2**. The material is polyacetal and a metal striker pin has to be secured to the part as shown. ABC has decided to manufacture this item by injection moulding the main part and inserting the metal pin as a secondary assembly operation. The basic flow chart for costing is shown in **Figure 4.3**.

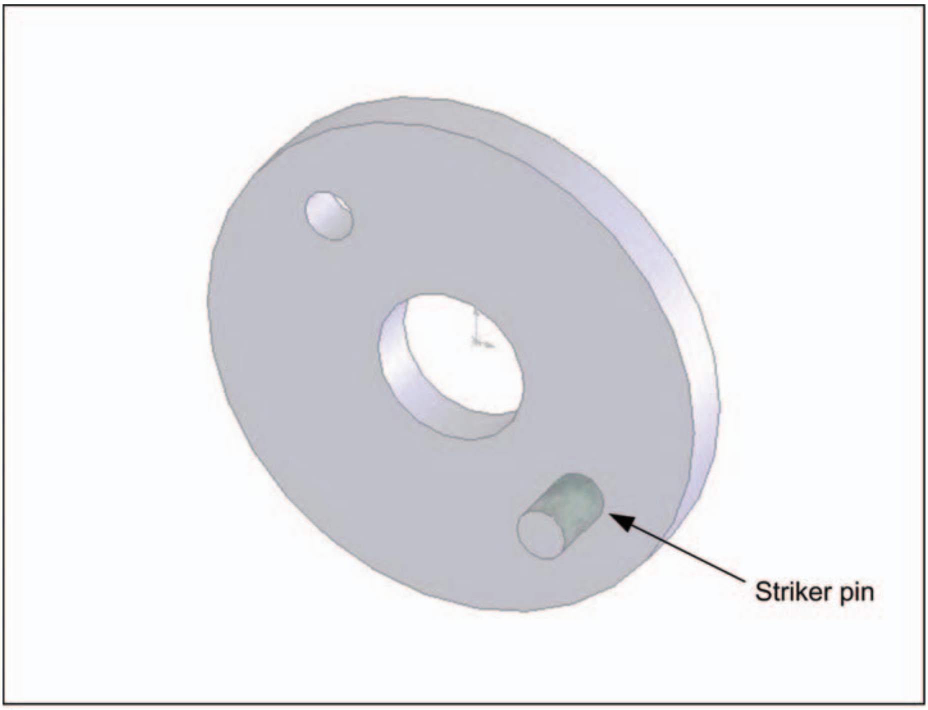


Figure 4.2 Plastic Cam Wheel

4.3.1 Supplementary Notes

1. The main component is to be injection moulded in polyacetal.
2. The metal striker pin will be inserted with an air tool after the parts have been moulded.
3. Quality control dictates that the part will require two stages of inspection which will be classified as an overhead cost:

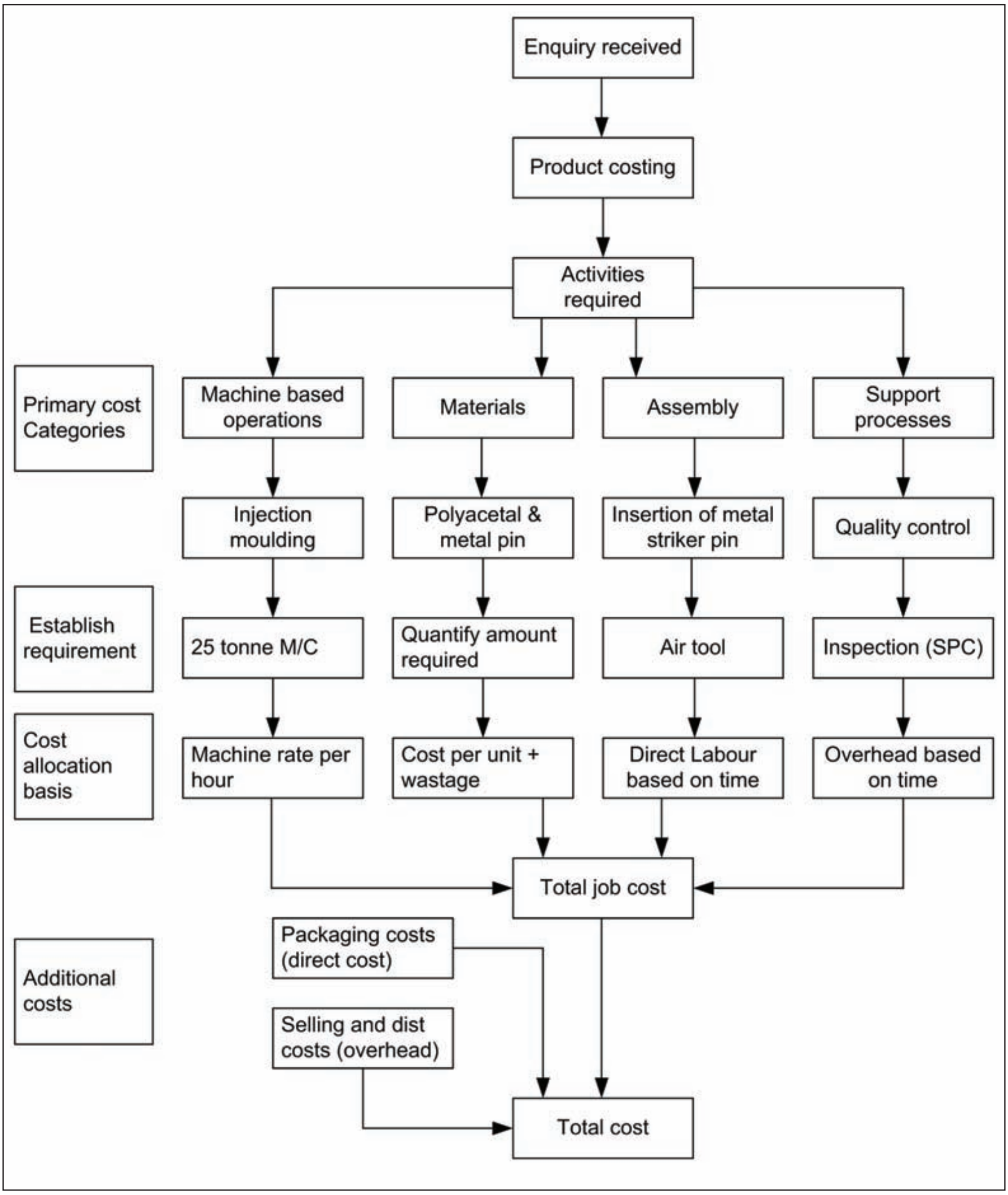


Figure 4.3 Flow chart for costing Cam Wheel

  - SPC – to measure control dimensions during the moulding operation; and
  - a final inspection after the striker pin has been inserted.

4. The main manufacturing activity of ABC is injection moulding which will be costed on an MHR basis.
5. The material costs (plastic + metal insert) are both bought out items which will be costed on a per unit basis with an allowance included for rejects.
6. The assembly stage where the pin is inserted will be costed on a direct labour basis.
7. The sum of these costs gives the total production cost of the job.
8. Finally, packaging, selling and distribution costs have been added to give a total cost for the job.

5

Overlooked Costs

5.1 Introduction

It is essential that *all* costs are recovered in every category; however, frequently certain costs are overlooked or underestimated. These will clearly affect a company's performance and adversely affect the profit. There are several areas that can be identified as follows:

- poor electrical power factor;
- rejects occurring during production;
- material spillages;
- failure to identify difficult work;
- excessive breakdowns to plant and equipment;
- repairs to plant and equipment;
- repairs to tools, jigs and dies;
- poor housekeeping;
- use of overtime;
- running jobs on higher MHRs than planned;
- tooling changes, colour changing and purging;
- use of reprocessed materials;
- poor storage of tools and materials;
- material contamination;
- blanking off impressions;
- running loss leaders;

- ineffective inspection;
- poor machine scheduling;
- poor storage of finished goods;
- inadequate control systems; and
- ineffective management.

5.1.1 Poor Electrical Power Factor

The power factor (PF) is a measure of how efficiently the electricity supply is being used. The higher the PF, the lower the electricity costs will be.

Many companies do not know what their PF actually is and could save a substantial amount by installing PF correction equipment. The appendix contains a more detailed discussion of this topic.

5.1.2 Rejects Occurring During Production

Every costing should include an allowance for rejects during a production run. Rejects will inevitably occur in almost all production processes, which can be due to:

- incomplete, trapped or distorted parts;
- machine breakdowns that require restarting the job – generating rejects until full processing conditions are re-established;
- tool breakages;
- overoptimistic production rates resulting in distorted parts;
- material problems associated with varying quality, wrong specification, wrong colour or shade; and
- parts that fail quality control requirements.

To a certain extent, these types of rejects are normally to be expected in most production processes and an overall allowance must be made to cover these, usually through a global percentage on cost. For normal straightforward products this is normally around 5% but for more difficult work it may be a higher value. As long as these contingencies are covered at the initial costing stage all should be well.

However, there are other areas where unforeseen costs occur where the reject level will increase above these levels – sometimes substantially:

- incorrect processing conditions producing variable results;
- trying to manufacture too many parts at the same time (e.g., running a 64-impression injection moulding tool when it should be only a 32-impression tool to achieve the necessary control and quality);
- using machines that are not accurate enough for the purpose because of age, wear or lack of sufficient control systems; and
- using substandard processing materials or excessive amounts of reprocessed materials.

5.1.3 Material Spillages

Large-scale manufacturing plants using high quantities of raw materials quite often use silos for storage and distribute them to their machines. This is a closed loop system largely preventing accidental material spillages.

However, with smaller scale production, material is usually off-loaded with fork-lift trucks and transferred to a designated storage area, normally on palettes.

In the course of moving materials from the stores to the machines material spillages often occur through:

- bags that get punctured or torn; and
- slipshod loading of material into machine hoppers or hopper loaders.

It is not unknown for companies to lose up to 10% of their material for these reasons. This is a clear area where cost can be saved and material usage should be carefully monitored. This is discussed further in **Chapter 6**.

5.1.4 Failure to Identify Difficult Work

This is a fundamental problem that easily leads to disaster. The main reasons for this occurring are:

- inexperienced technical staff allowing the company to accept work that is beyond the company's ability and experience to process;

- plant and equipment that are not sophisticated enough for processing the work to the standards required; and
- companies that may be desperate for work accepting specialist work outside their area of expertise or the capability of their plant.

5.1.5 Excessive Breakdowns of Plant

This can be attributed to:

- companies running old, outdated machinery which might be because of underinvestment;
- failure to have plant and equipment serviced regularly; and
- inexperienced production technicians/maintenance engineers without the expertise necessary to run and maintain the plant.

5.1.6 Repairs to Plant and Equipment

Every budget should include an allowance for repairs to plant and equipment. It is inevitable that in any volume production process there will be occasions when equipment breaks down even with regular servicing.

It is essential that a realistic allowance be made for this category of cost and should be part of the efficiency factor discussed in **Chapter 1**.

5.1.7 Repairs to Tools, Jigs and Dies (Tooling)

Repairs to tooling are needed in almost all plastic processing activities. It is also inevitable that through damage or wear, some mould components will need to be repaired or replaced during the production life of the product. Whilst an allowance is normally made to cover these situations, it frequently does not cover all the costs that are likely to occur. A global fixed percentage based on the overall cost of tools, dies, jigs and fixtures may result in non-differentiation between basic and more complex tooling which can lead to:

- too small a cost added to expensive complex items; or
- too large a cost added to simple straightforward items.

This means that the more complex items will be under-costed leading to under-quoting this type of work leading to attracting more work of this nature through appearing to be more competitive than others are.

Clearly the opposite is true for simple straightforward work leading to reduced competitiveness. This is illustrated in the following example.

Example. A global on cost of 7.5% is applied for all tools, jigs, dies and fixtures (items). **Table 5.1** shows a global on cost approach applied to all tooling whatever the cost of it. (In this example, tooling A is complex and tooling B straightforward.) In view of the original cost of the tooling, it is unlikely that the on cost of £6,000 would be sufficient in the case of damage to it during a working lifetime of, say, five years as this only amounts to £1,200 per year for servicing and repairs. Repair costs to expensive tooling can be very large so it is necessary to apply a realistic on cost at the start. Comparing this with the £225 per year for the straightforward tooling B (which is much less likely to break down as much because it is simpler), the on cost for tooling A is inadequate and a higher on cost of, say, 10–15% may be more realistic.

Table 5.1 Global on cost

Tooling	Cost (£)	On cost (%)	Amount (£)	Total (£)
A	80,000	7.5	6,000	86,000
B	15,000	7.5	1,125	16,125

The scatter diagram in **Figure 5.1** shows the results of a survey from three companies manufacturing custom-made technical parts. It shows the on cost required as a percentage of the original tooling costs to repair the tooling over a five-year period.

It can be seen that the on cost percentage clearly increases as the original cost of the tooling increases. Hence, for the example in **Table 5.1**, the on cost for the original tooling is inadequate, and based on these results should be about 14.8%.

However, the results shown in **Figure 5.1** may not apply to every case. For example, it may be proportionally less expensive to repair tooling manufacturing simple parts but of an equivalent value – perhaps because of a large number of impressions being used.

In view of this, it is recommended that companies should carefully analyse their own costs for repairs and establish their own basis for adding on costs related to the size and complexity of the mould in the future. This can be achieved by using a mould estimating program like the one described in **Chapter 15**.

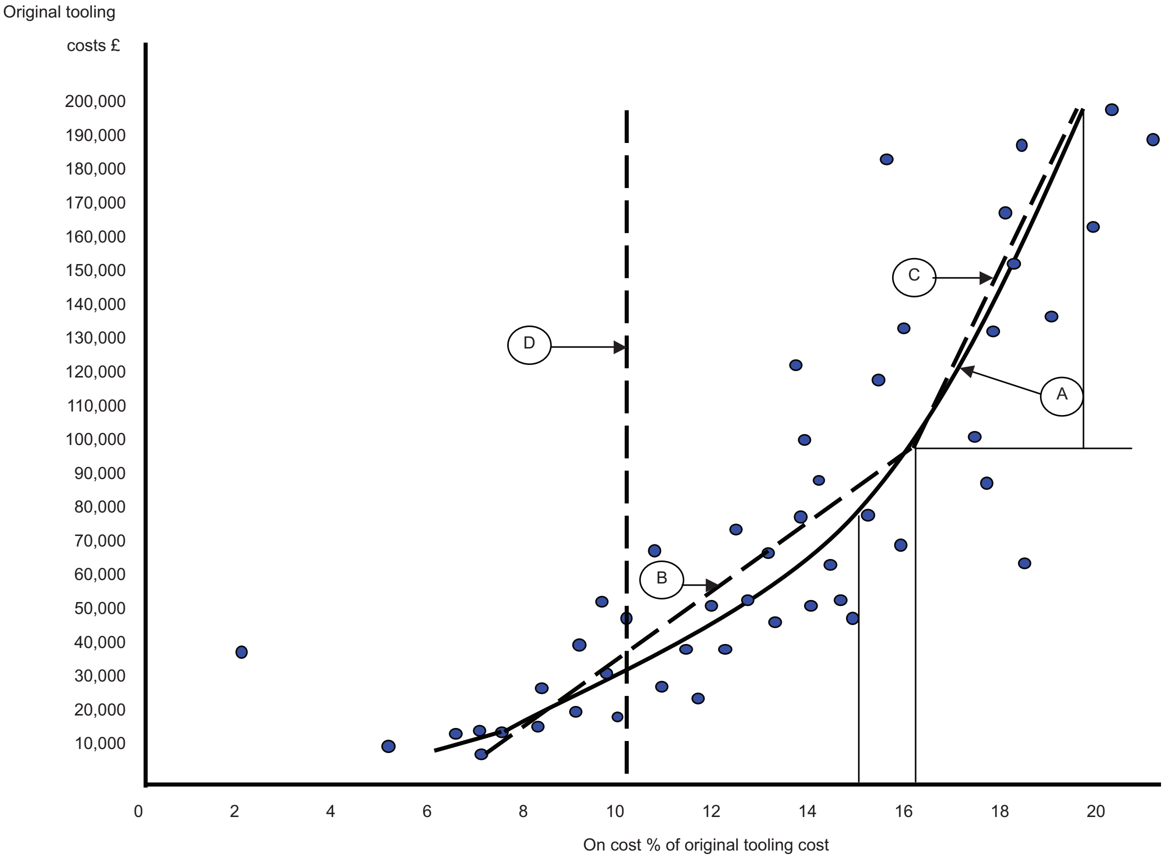


Figure 5.1 Mould repair costs

5.1.8 Poor Housekeeping

There is no doubt that poor housekeeping can be costly. Whilst the factory should generally be kept clean, the three most common reasons for unnecessary costs being incurred are material or mould related:

- Spilled material cannot (or should not) be reused because of potential contamination problems.
- Materials stored in open bags are obvious candidates for contamination. Cross-contamination between materials can be very expensive, as the materials normally have to be disposed of.
- Tooling stored without protection may rust and be prone to damage.

5.1.9 Overtime

Without doubt, overtime can be a huge cost generator if not kept under control. Frequently, overtime is used for:

- manufacturing more goods in the belief that this will increase profits;
- meeting imminent deadlines for delivery of parts that otherwise cannot be achieved; and
- using overtime as means of temporarily expanding the labour force as opposed to employing new labour.

All of these activities can cause runaway costs if not carefully monitored. The following example illustrates a typical problem.

Example. We take another look at the example in **Chapter 3**, as summarised in **Table 3.8**. First of all, we will assume that the sales of £200,000 have been achieved and an opportunity has arisen to produce more parts for an immediate sale. The decision is taken to produce a further 100,000 parts but this can only be achieved by using overtime at time and a third. If we assume that the labour cost element for the variable costs is, say, £30,000 to produce the initial 160,000 parts, then the labour cost is clearly going to increase.

To see the effect of this we will first establish what would happen if we were going to produce an extra 160,000 parts using overtime only, which will increase the labour cost to £30,000 × 4/3 = £40,000: an extra £10,000 resulting in the variable costs increasing to £77,500 and the total profit reducing to £17,000. This is summarised in **Table 5.2**.

Using these figures, we must first draw another graph to see what happens when we produce an additional 160,000 parts. From this, we can establish the result of producing only 100,000 parts. The result is shown in **Figure 5.2**. This clearly shows

Table 5.2 Marginal costing for 160,000 parts using overtime

	Value (£)	**Value per unit (£)**
Sales	200,000	1.25
Less variable costs	77,500	0.48
Contribution	122,500	0.77
Less fixed costs	105,500	0.66
Net profit	17,000	0.11

that break even occurs at approximately 137,000 parts, with a loss of around £30,000 for producing 100,000 parts. We can confirm these results by using the equation established in **Chapter 3** as follows. Using **Equation (3.2)**:

$$B = \frac{N \times F}{S - V}$$

$$\begin{aligned} B &= \frac{160,000 \times 105,500}{200,000 - 77,500} \\ &= 137,796 \end{aligned}$$

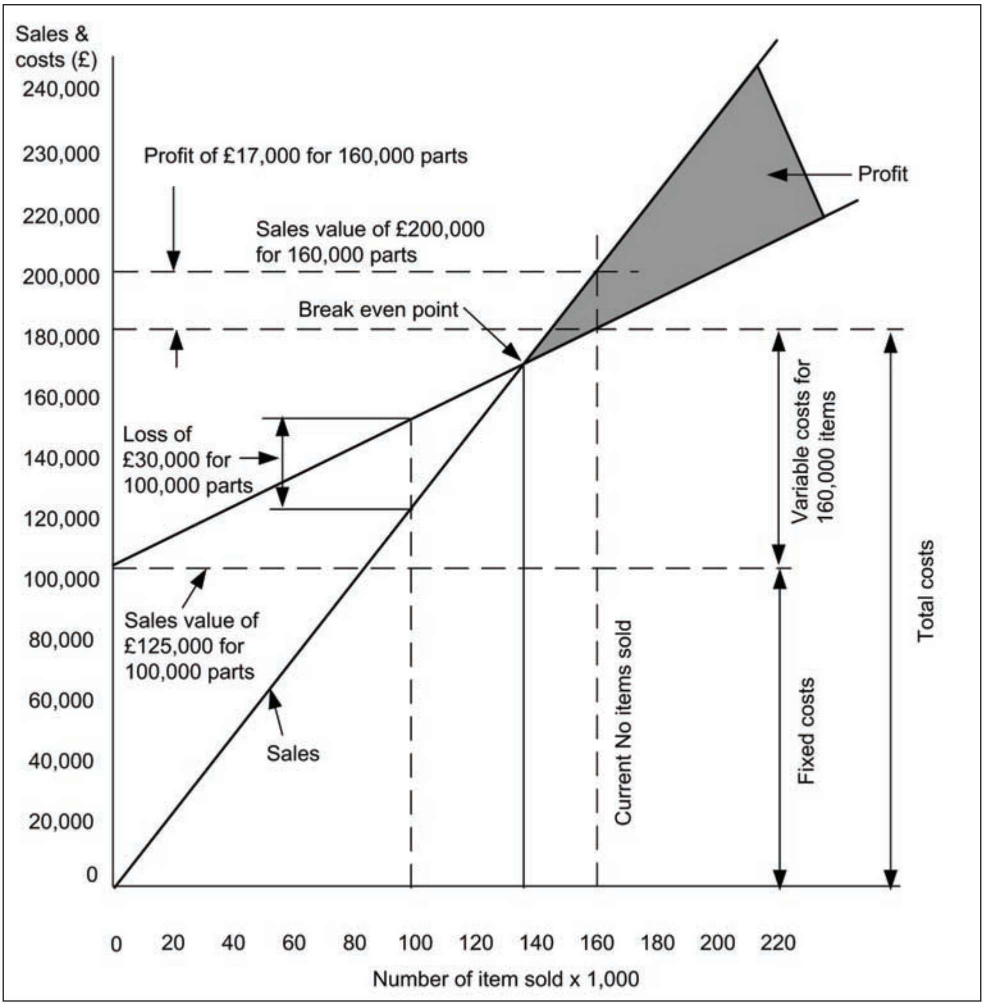


Figure 5.2 Break even graph for data in **Table 5.2**

Hence, if 100,000 parts were produced, this would result in a loss since we would need to produce 137,796 to break even.

We can quantify this loss using **Equation (3.4)**:

$$P = \frac{(S - V)N_{\text{v}}}{N} - F$$

where V = £77,500, N_{v} = 100,000, N = £160,000 and F = £105,500. Therefore

$$\begin{aligned} P &= \left(\frac{200{,}000 - 77{,}500}{160{,}000} \right) \times 100{,}000 - 105{,}500 \\ &= 0.766 \times 100{,}000 - 105{,}500 \\ &= £76{,}600 - 105{,}500 \\ &= -£28{,}900 \end{aligned}$$

To summarise, if 100,000 items were made using overtime at time and a third, there would be a loss of £28,900 and at least 137,796 items would have to be produced to break even.

The fact that a loss would result can be seen from the original analysis where the break-even figure for the number of items required to be sold to break even was 127,396 without any overtime being used.

To complete the picture, we can evaluate the profit generated if 160,000 parts were made to give a direct comparison between the original costing and the one based on overtime for the same number of parts. Profit with overtime using **Equation (3.4)** is

$$\begin{aligned} P &= \left(\frac{200{,}000 - 77{,}500}{160{,}000} \right) \times 160{,}000 - 105{,}500 \\ &= 0.766 \times 160{,}000 - 105{,}500 \\ &= £122{,}560 - 105{,}500 \\ &= £17{,}060 \end{aligned}$$

This compares with the original profit of £27,100 (established in **Chapter 3**).

Whilst it would have been realised that the profits would be reduced by using overtime, it is essential that the full analysis is undertaken so that a more informed decision may be made before embarking on production based on overtime.

5.1.10 Tooling Changes, Colour Changing and Purging

In most plastic production processes, there will be a need to change the tooling and colour of the polymer several times during the course of a year. This is true even if the company only uses one base material. For example, a company manufacturing plastic cutlery and tableware may use a particular grade of polystyrene for all the products it sells. However, the company may manufacture its product line in a range of colours for different markets – or indeed some products may be required in clear material. While such a company would try to plan its production so that a minimum of tooling and colour changes is involved – some changing is inevitable.

In contrast, a company that makes custom parts will usually have no control over the materials or colours of the raw materials that will be used as these will be normally specified by the customer. So we can broadly identify two groups:

1. The manufacture of a standard product or a range of standard products.

2. The manufacture of custom components.

In the case of the standard component manufacturer, the amount of tooling and colour changing or ***purging*** will be considerably less that the custom component manufacturer. Therefore the custom manufacturer will usually have to bear much higher costs for three reasons:

1. The range of materials processed will be greater.

2. The range of coloured materials processed will be greater.

3. The number of tooling changes will be greater.

Frequently, the machines used will also have to be purged out to change the material and/or colour.

Whilst efficient production planning is important for standard parts, it is of particular importance for custom manufactured parts. In either case there are three primary costs involved:

1. Non-productive machine time,

2. Material costs.

3. The cost of technicians needed to carry out the purging and tooling changes.

5.1.10.1 Non-productive Machine Time

Non-productive machine time can be significant. This is the reason why a realistic efficiency factor, as defined in **Chapter 1**, should be established and must not be overoptimistic. A realistically computed efficiency factor will cover these costs and has to be applied globally.

It is not possible to assign a cost for each tooling change operation since the same tooling change operation may take a different amount of time on each occasion for several reasons. The following are a few that the author has experienced.

- Parts of the tooling are missing or damaged (missing safety switches, control devices, rust on tooling, etc.).
- The raw material is not available (not in stock, not delivered in time or not ready for production – for example, it needs drying prior to use).
- Essential support equipment is not available or not working properly due to a previous malfunction, which has not yet been resolved.
- Many others!

These are problems that can be attributed to poor planning, but they do occur in most companies to greater or lesser degrees.

5.1.10.2 Material Costs

The cost of purging to change material or colour must be taken into account for the following reasons.

1. Some materials may be difficult to purge through.
2. Existing colours may be persistent and take a long time to remove from the machine. In extreme cases, traces of the old colour may persist for a day or more, resulting in a significant amount of purging and job material and rejects.
3. Even if the same material and colour is to be used an amount of material will still be lost in setting up the conditions for the new job.

In cases (1) and (2) the existing material will have to be purged out until the new material or colour is established. There will be less material waste in case (3) but an allowance should still be made for the material lost in achieving the required production conditions.

5.1.10.3 Technician Costs

In most cases, a trained technician will be needed to carry out tooling and material changes. This is particularly true for companies manufacturing technical components where more time will be spent on these procedures since:

- the tooling may be more complex involving more setting-up time;
- the materials may be more difficult to process;
- stable production conditions may take longer to establish; and
- quality requirements are usually more difficult to achieve.

The recovery of all these individual (and variable) costs may be difficult to quantify since different costs may occur each time a tooling or colour change takes place.

Furthermore, in the case of a company manufacturing custom components, it is often necessary for it to manufacture parts in materials it has not used before resulting in extra time being spent in establishing the correct moulding conditions for the material.

Similarly, a company may be asked to manufacture existing parts in a material it is familiar with but in a different grade to those it already has experience of using – for example, a ***different melt flow index*** or perhaps a new lubricated grade. In both cases a different set of production conditions may have to be established.

Even a change of colour for a product can present unforeseen problems where totally different setting conditions may have to be used for certain colours.

It is for these reasons, and several others, where costs cannot be accurately established that the MHR costing system is preferred with material costs being added separately at the estimating stage. This will be discussed in more detail in **Chapter 12**.

5.1.10.4 Use of Reprocessed Materials

Whist it makes sense to ***reprocess*** (or re-granulate) materials to recover and reuse rejected parts and redundant elements of production such as runners, sprues and trimmings, the cost of these operations must be taken in account. This increases in importance as the costs of the materials increase.

In addition, the correct or maximum level of reprocessed material must be established to avoid unnecessary costs occurring. The main areas where problems can occur are:

- Failing to apply a control system. It is important that reprocessed material be mixed with ***virgin*** material in the correct proportions. Although many jobs can happily run on 100% reprocessed materials, other cannot and are much more sensitive to this procedure leading to a higher level of rejects during production.
- Overuse of reprocessed material. All polymers have a ***thermal memory*** and each time the material passes through the cylinder properties will be adversely affected, for example:
    - physical properties will be impaired;
    - material ***shrinkage*** may decrease leading to incorrect sizes; and
    - the material may degrade with overuse, affecting the colour and sometimes displaying streaks, again leading to higher reject levels.

5.1.10.5 Material Contamination

Whilst a certain amount of material contamination may occur by unavoidable accident, it is otherwise an inexcusable cost for a company to have to bear. Contamination is usually due to:

- cross-contamination between unlike materials or different coloured material of the same type;
- spillages of materials; and
- material coming into contact with oil, water and other fluids.

All of these are non-recoverable costs and exemplify inadequate control, poor housekeeping in general and poor management.

5.1.10.6 Running Production on Machines Rated at a Higher MHR Cost

In most production environments the machines will be heavily loaded with work (assuming it is available) and rightly so. Clearly it is the task of the production manager to ensure that maximum production of saleable products is achieved from all the machines available.

With such critical machine loading schedules there will inevitably be occasions when emergencies occur through machine or tooling breakdowns preventing scheduled jobs from running. With a tooling breakdown, there is no instant solution. The tooling will have to be repaired before it can be used.

In the case of a machine breakdown, the production manager will naturally look to see if there are any other machines available to use instead. A common problem is that there may not be an equivalent machine available so an alternative machine may be used which may not fit into the same cost category.

If a suitable available machine is rated at a higher cost than the designated one, the cost of doing this should be determined first. Clearly, there will be a lower contribution and reduced profit. A decision will then have to made as to whether the job should be run on this machine or not.

However, this is not the ideal time to make this decision. The procedure for making these decisions should have been determined in advance!

With each product or process, the initial costing should include a schedule of the costs of running it on all suitable machines. All those machines that show a satisfactory return can then be allocated as ‘useable’ machines based on a scale of cost. Obviously, the lowest machine cost rate would be selected as the first choice as this will give the greatest return.

This ensures that an automatic procedure is already in force to guide the production manager in selecting pre-approved, suitable, alternative machines.

If the company uses a MHR basis for costing, it makes life very much easier as the cost category for each machine has already been established. However, a cut-off point must be established as shown in the following example.

Table 5.3 MHR values based on capital cost

M/C lock	Capital cost MHR(£)
25	15
50	21
50	24
100	42
250	89
250	125
350	224
350	89

Example. Using the data in **Table 3.11** in **Chapter 3**, we will assume that company ABC has selected the capital cost method for an MHR basis for costing. The details are listed here for convenience (**Table 5.3**).

For this example, we will assume an additional cost is to be applied for material over that normally used, to cover the greater amount of material being used for purging and sampling since the machine will have a larger cylinder.

The parameters for this example are as follows: no. of impressions, 4; machine cycle, 20 s; material shot weight, 35 g (see glossary); material cost, £2,000 per tonne; machine required, 50 tonne; MHR, £21. The original costing for this job would then be:

$$\begin{aligned}\text{Machine cost per second} &= \frac{\text{MHR}}{3,600}\\ &= \frac{21}{3,600} = £0.00583\end{aligned}$$

Machine cost to produce 4 parts =

$$0.00583 \times 20 = £0.117$$

Therefore,

Machine cost to produce 1 part =

$$\frac{0.117}{4} = £0.0293 = £2.93 \text{ per 100 parts}$$

Material cost for 4 parts =

$$\frac{2,000 \times 35}{1,000,000} = £0.07$$

Material cost for 1 part =

$$\frac{0.07}{4} = £0.0175 = £1.75 \text{ per 100 parts}$$

Total cost = £4.68 per 100 parts

This figure represents the original job cost on the designated 50 tonne machine with an MHR of £21. However, due to a machine breakdown, this job will now have to run on another machine instead due to the customer needing parts urgently.

The technical department has determined that this job can only run on machines between 50 and 250 tonnes lock. We now carry out the same costing procedure for all the suitable machines with the results shown in **Table 5.4**. The shaded rows indicate this job cannot be run on these machines for technical reasons, basically because they are either too small or too large.

The results in **Table 5.4** reveal the substantial increase in MHR cost that can occur when work is transferred to a higher cost machine in an emergency. Although the material costs here have increased, these increases are small compared with the increased machine costs.

The cost per 100 parts is the amount that would normally be charged to a customer before the profit has been added. It would be an understatement to say that a customer would not be prepared to accept such increases simply because of a machine breakdown on the part of the supplier. Therefore, the job will have to be run on one of the higher cost machines at the moulder's cost to prevent supplies to the customer being halted.

In such circumstances, a common argument goes something like this: 'If the larger

Table 5.4 MHR costing schedule for bearing hub

M/C lock (tonnes)	Capital cost MHR	Comments	Material premium factor (%)	Material cost per 100 (£)	MHR cost per 100 (£)	Cost per 100 (£)
25	15	Unsuitable				
50	21	Designated M/C	0	1.75	2.93	4.68
50	24	First alternative	0	1.75	3.52	5.27
100	42	Second alternative	2.5	1.79	5.86	7.65
250	89	Third alternative	3.5	1.81	12.40	13.58
250	125	Fourth alternative	3.5	1.81	23.39	25.19
350	224	Unsuitable				
350	89	Unsuitable				

machines are not actually producing any saleable work at this time, then running *any* work on them would provide a contribution where there otherwise would be none. Hence it is worthwhile running them on this basis.' There is an element of truth in this, but it should not be forgotten that the larger the machine, the more expensive it will be to run in terms of increased power, water and other costs.

In this example, if the cost of running the job exceeds £4.68 per 100 parts, a net loss will result.

If we assume for this job that the base costs of running each machine amount on average to 30% of the MHR then we can compute a direct comparison of costs for the alternative machines based on just two cost categories:

- power consumption of machine; and
- water consumption and other energy costs.

To this, we must also add the increased material costs that are incurred because of the extra material needed for purging, colour changing, etc.

This example assumes that all the actual running costs of the machine are at least recovered. *It does not include costs that would still occur if the machine were standing idle.*

Table 5.5 shows the modified MHR costs based on this approach with the previously defined unsuitable machines removed. The modified MHR costs marked with asterisks represent the energy and water costs only estimated at 30% of the normal MHR.

1. The second row shows the base cost per 100 parts (£4.68). This is the original part cost charged when they are run on the machine that has broken down.
2. The third and fourth rows show we could run the job on these machines because the cost of running them is less that the base cost of £4.68 per 100. Hence, they would also generate a small contribution.
3. The fifth and sixth rows (shaded) show that we would lose money in real terms if the job were to be run on these machines because the cost of running them exceeds the base cost.
4. The fourth column represents a percentage 'on cost' to the material to cover wastage (rejects, purging, etc.). Note that on the originally designated machine there will be no material premium since this would have been included in the original costing.
5. Columns five and six represent the material cost per hundred for this part and the computed MHR cost as normal, respectively.

Table 5.5 MHR costing comparison for bearing hub

M/C lock (tonnes)	Original capital cost MHR	Comments	Material premium factor (%)	Material cost per 100 (£)	MHR cost per 100 (£)	Modified MHR cost per 100 (£)	Cost per 100 (£)
50	21	Designated M/C	0	1.75	2.93	2.93	4.68
50	24	First alternative	1	1.75	3.52	1.06	2.81
100	42	Second alternative	2.5	1.79	5.86	1.76	3.55
250	89	Third alternative	3.5	1.81	12.40	3,72	5.33
250	125	Fourth alternative	3.5	1.81	23.39	7.17	8.98

6. Column seven represents 30% of the MHR in each case to cover *only the energy costs* that are incurred.
7. Column eight is the total of columns five and seven, which gives the total material cost + the modified MHR.
8. It must be noted that this analysis is based on the assumption that all these machines are free and have no work available to run on them at their normal (full) MHR rating.

The question arises as to how the figure for the percentage cost for the power and water running costs (30% in this example) can be calculated as there are several variables that make this difficult to assess. Some of these variables include:

1. The machine cycle time.
2. The shot weight of the material.
3. Extra power costs for using a larger machine cylinder incurring larger heating costs.

Item (2) is known, but to try to determine items (1) and (3) accurately would involve actually measuring these values and could not be determined until the job was running on the machines anyway.

However, a reasonable estimate of these can be obtained by examining the actual costs for previous years as follows:

1. Find the average annual power costs and water costs.
2. Link these costs proportionately to the MHR of each machine.

The analysis in **Table 5.5** may be carried out algebraically as follows. A = original MHR cost per 100 items; B = energy cost expressed as a percentage of normal MHR; C = normal material cost for job per 100 items; D = material premium percentage; E = modified material cost per 100 items; F = modified MHR per 100 items (based on total annual energy costs only); G = modified item cost per 100 items; and J = original item cost per 100 items. Then

$$E = C\left(1 + \frac{D}{100}\right) \tag{5.1}$$

$$F = \frac{B \times A}{100} \tag{5.2}$$

$$G = E + F \tag{5.3}$$

If G is greater than J then there will be direct loss of $G - J$; if J is greater than G then there will be a net contribution of $J - G$.

All of this discussion assumes a job is being run on a larger machine than that originally designated and that it is idle. If the job could have been run on lower MHR machine then, clearly, it should be more profitable but the question should be asked why the job had been selected to run on a higher MHR machine than necessary in the first place.

It should be apparent, however, that although the selected machines will provide a small contribution, this is much less than that achieved by running them at their normal MHR. Hence, this technique should only be used if the alternative machines are genuinely free of work at the time.

6 Controlling the Costs: Measuring the True Cost of a Job

6.1 Discussion

The edict that if each job makes a profit, the company will make a profit at the end of the year is basically true. Expanding on this a little, we could also say that if each job makes at least the originally budgeted profit, the company would also make at least its budgeted profit at the year end.

This, of course, assumes the company achieves its overall budgeted sales target and that all the costs are kept within budget. It makes sense, therefore, to monitor all production jobs to ensure that they are meeting the production budget in terms of volume to satisfy the customers' needs and the cost and profit elements.

The key to achieving this is ***control***. The greater the degree of control, the less there will be to go wrong and the fewer any unexpected results will be. To maintain adequate control, two essential elements are needed:

- a suitable control system; and
- a continuous assessment of the system.

However, there is little point in introducing a system for the sake of it. To do so is counterproductive and in itself introduces unnecessary extra costs. Additionally, any system that is introduced must be workable and seen to provide the desired result.

The system must be sufficiently versatile to cover all contingencies and measure with a reasonable degree of accuracy what it is supposed to. It must also in itself be cost effective and not cost more to implement than the potential cost it can save!

Production staff are nearly always under pressure. Emergencies and unforeseen problems can take a significant proportion of the available time. In view of this, new procedures or systems may meet resistance if they are not seen to be worthwhile. Such a system, therefore, must be seen to be useful and not involve the laborious recording of detailed information on endless sheets of paper or a computer keyboard.

The system introduced will, of course, vary from company to company depending on the company structure and the nature of the business. There is, however, a sufficient common core of manufacturing activity to enable us to construct a general system model that should apply to most companies.

The system itself must be assessed periodically to ensure it is actually measuring what it is supposed to be measuring. In other words the ***effectiveness*** of the system must be checked. It must either highlight areas where costs are out of control or at least verify that costs are actually under control. Establishing either result validates the introduction of such a monitoring system.

6.2 The Core System

This comprises the key elements that are essential to the effective measurement of the job cost. The following are the main cost areas that need to be checked to ensure they are within budget:

- the material cost;
- the machine cycle;
- the machine time used;
- the rate of production;
- secondary production processes; and
- delivery and packaging costs.

6.2.1 Material Cost

The amount of material used for the job should be quantified. This means the ***actual*** amount of material that has been used. This is determined by physically verifying the stock level of the material at the beginning and the end of the production period.

This automatically takes account of spillages, rejects, purgings and the material used to make ***saleable*** parts. Saleable parts mean mouldings that have been accepted as satisfactory by the ***customer***.

An accurate assessment is needed, not an approximation which may give misleading information. This physical material check also serves as a continuing stock audit, which may also highlight any errors in the material stock control system.

Once the quantity of material used has been established, the ***actual price*** invoiced by the material supplier should be used to arrive at the overall actual cost of material for the production period being assessed.

6.2.2 The Machine Cycle

This is straightforward to check with a stopwatch over a sufficient period of time to ensure the correct production rate is being achieved. The tool should also be checked to verify it is running correctly on all impressions at this time.

6.2.3 Machine Time Used

Measuring the cycle is not sufficient to determine the overall machine cost element of a job. At the time of the check, the cycle may be well within limits but this does not represent how much machine time has been lost through setting up or through stoppages or breakdowns of the tool or the machine.

To take account of these and other contingencies, it is necessary to determine the length of time the job has been on the machine from the start to the finish of the production run.

6.2.4 Production Rate

The actual production rate of ***saleable*** parts produced, as defined previously, needs to be determined. This will identify unsuspected problems like the tool running on a reduced number of impressions, which could be due to a solidified, broken off gate blocking material from entering a cavity for example.

6.2.5 Secondary Production Processes

Where secondary operations are carried out on the mouldings, these also need to be checked using the same criteria as for the moulding production. Processes like trimming, degating, printing, hot stamping, etc., should be assessed in exactly the same way as the main production using overall quantities, materials and times.

6.2.6 Delivery and Packaging Costs

These costs include the actual cost of packaging and delivery including any special deliveries that have been made.

6.3 Discussion

Once the ***true*** costs of production have been established, they should be compared to the budgeted figures and, as a further check, the actual amount being invoiced to the customer should be compared to the actual cost. It is not unknown for the wrong price to be invoiced.

It is most important that the system measures ***actual values*** and not assumed values and establishes the actual total cost of production.

Many companies that have introduced such a system have been very surprised at the actual cost compared with what they assumed it was on certain jobs. In some cases, such systems highlight very depleted returns and even direct losses.

When this type of cost check system is used in conjunction with a running profit and loss account, total control is achieved and enables corrective action to be taken at the earliest opportunity.

6.4 Monitoring Procedures

Three procedures need to be introduced to monitor effectively all the costs that are incurred:

- in-production monitoring;
- post-production monitoring; and
- global monitoring.

Each of these stages is important and should not be missed out. The details of these processes will now be discussed.

6.4.1 In-production Monitoring

This is a check that should be carried out as soon as the part is in production. It measures all the basic parameters. It must at least measure:

- the amount of material being used;
- the machine cycle; and
- the cost of any secondary operations required.

The first check will identify any major problems at the earliest opportunity, so that action can be taken if the production rates, cycle times, material usage, etc., do not meet the estimated values.

This same check should also be carried out at regular intervals throughout the first and subsequent production runs. This is simply because unforeseen things can happen during a production run: for example, a blocked gate preventing a part from being moulded on multi-cavity tools.

One example encountered by the author on an eight-impression mould tool occurred after the mould tool had been in production for just a few days. It was noticed that the expected numbers of parts were not being produced despite the cycle time being as it should be. One hour of observation showed no problems with the correct number of parts produced.

However, on observing the moulding operation for a longer period, it suddenly became apparent that, occasionally, only six parts were being produced each cycle instead of eight. Then a short while later production was back to normal. This problem was difficult to detect but was quickly resolved. This shows clearly why it is important to carry out regular checks during all production runs.

Figure 6.1 shows a block diagram for the in-production check.

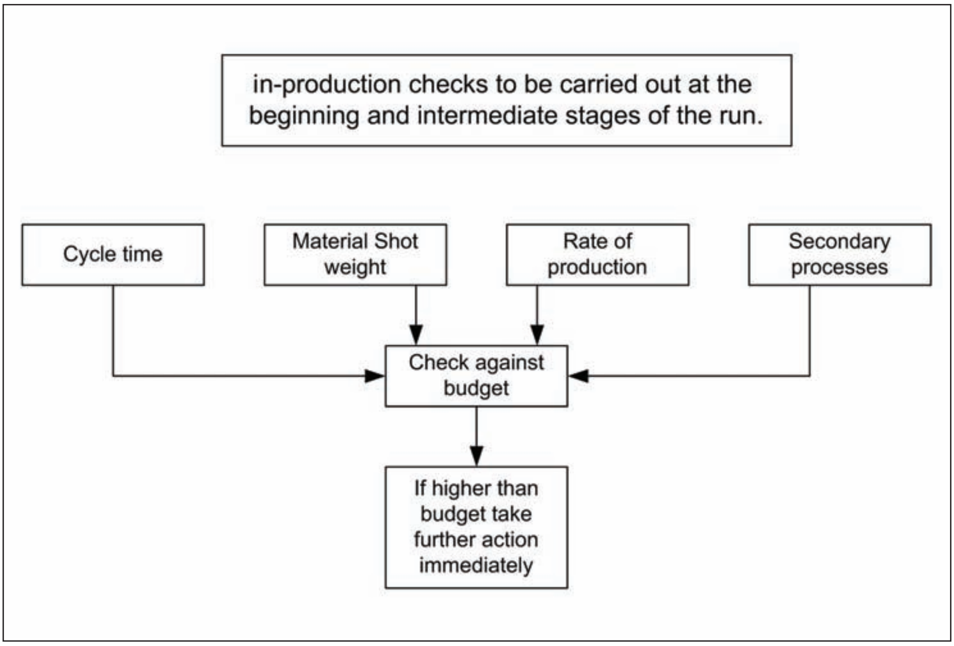


Figure 6.1 In – Production volume and cost checks

6.4.2 Post-production Monitoring

This check provides feedback on all the material used, production quantities and total machine time used during the entire production run. Thus, it will show up time lost due to machine breakdowns, mould breakdowns, excessive rejects, material spillages, etc.

It gives a clearer picture of what is happening throughout a typical production run. **Figure 6.2** shows a block diagram of this procedure.

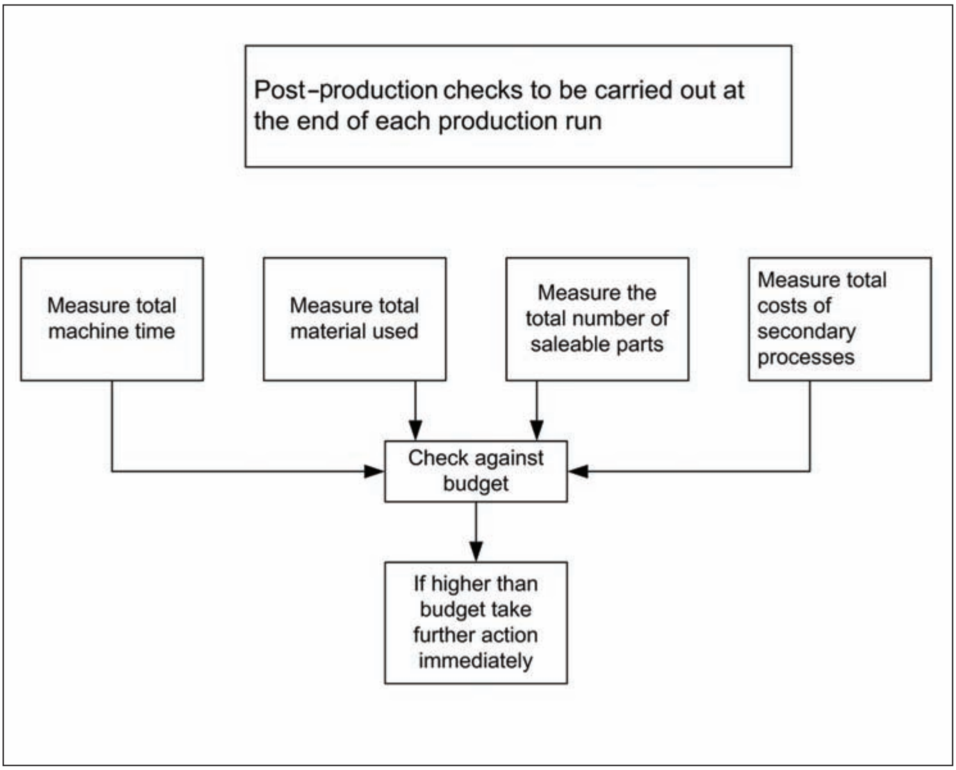


Figure 6.2 Post-production costs

6.4.3 Global Monitoring

This is the most accurate measurement we can make of the overall cost of supplying a part to a customer to date, and this increases in accuracy each time it is carried out.

In essence, it measures the performance and overall costs for producing a particular part over the total production carried out to date.

It is designed to measure:

- the total amount of material that has been used to date;
- the total machine time used to date; and
- the total cost of all secondary operations including all problems encountered, like breakdowns and waiting for inserts or materials, etc.

Figure 6.3 summarises the global monitoring procedure. Note that the global check is not just simply the sum total of all the end-of-production checks. There are several reasons for this:

- material bags or containers may have been punctured between production runs (during storage or movement);
- a mould tool may have been damaged in storage and have to be repaired before it can be used, thus wasting machine time;
- varying volumes of parts may have produced on each run; and
- scheduled deliveries may be made from stock with differing packaging and delivery costs each time.

6.5 Observations

- Many companies do not know the true costs of production.
- A large number of companies believe the actual cost of production is less than it really is.
- If each job makes a profit, the company is much more likely to make an overall trading profit on a continuing basis.
- The introduction of a satisfactory cost measurement and control system will increase efficiency and profitability.
- Producing production quantities of mouldings without such a system is like driving a car without a fuel gauge.

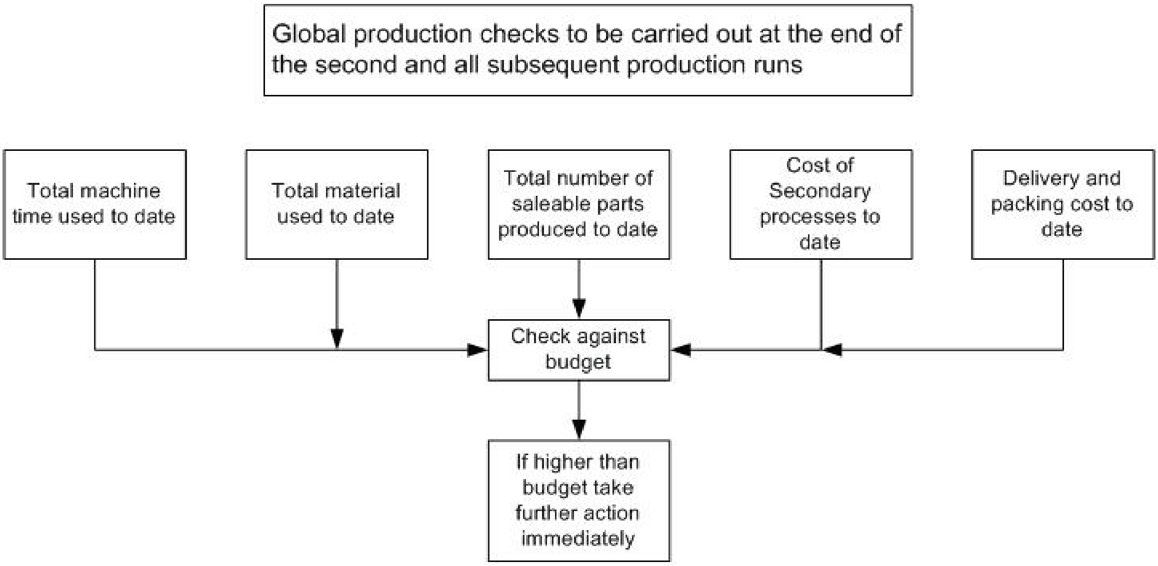


Figure 6.3 Global Production volume and cost checks

6.6 Summary

- Meaningful cost measurement systems provide accurate information on which effective decision-making can be based.
- Such systems must be maintained and assessed for their effectiveness.
- All systems must be based on measuring actual values not theoretical ones.
- When a system highlights a cost problem, action must be taken.

6.7 Material Usage Factor

6.7.1 Discussion

As already mentioned, the material usage factor is one of the most significant costs in the injection moulding process. Other direct costs like labour and electricity are very much easier to check for accuracy as the year progresses. If these are too high the appropriate action can be taken quite quickly.

Material costs, in contrast, are more difficult to assess and, to make matters worse, are often wrongly calculated. In some cases the actual amount of material used is greater than that charged to customers as a result of an underestimate. It is essential, therefore, to know the ***actual material usage factor*** (AMUF).

As a company gains experience within its own area of expertise, it should be able to predict material usage with increasing accuracy and develop a more precise ***budgeted material usage factor*** (BMUF) for use in estimating. In all cases, however, the AMUF should be checked for each individual job and globally.

As the term implies, the AMUF consists of checking the *actual material used*. Unfortunately this can only be checked properly after a run has finished. If 'in-production' monitoring has been carried out properly as described previously, there should not be any great discrepancies, regarding the part and runner weights. It will highlight, however, material losses due to poor housekeeping, accidental spillages, etc.

Since the cost of materials used can be 30% or more of the total costs, the measurement of the material usage is now discussed in more detail.

6.7.2 In-production Monitoring of Material Usage

There are two stages involved:

1. Weigh the individual parts – runner, sprue and the overall shot weight.
2. Compare these to the ***estimated material content*** (EMC) for the job.

If this is equal to or less than the EMC all is well; if not, action needs to be taken quickly to remedy the situation.

There should be frequent checks made during the production run, as unforeseen events can occur as described earlier, where the mould does always produce the full number of parts every cycle.

If there appears to be a variation in the weight of the parts, this should be investigated immediately as it usually indicates a material feeding problem – like a partially blocked gate or nozzle that periodically clears itself – or incorrect moulding parameters.

6.7.3 Post-production Monitoring

This also consists of two stages:

1. Measure the actual amount of material used for the production run by comparing the stock level of material before and after the production run. This will automatically take into account rejects, spillage, purging, etc.
2. Again compare this to the EMC.

6.7.4 Global Monitoring

This is the most accurate check of all on actual material usage. It consists of two stages:

1. Checking *all* material used monthly or quarterly, by measuring the stock level at the beginning and end of the period.
2. Comparing this with the BMUF.

6.7.5 Remedial Action

6.7.5.1 In-production and/or Post-production Check Negative

If either of these two checks reveals the AMUF being greater than the EMC, the following action may be taken.

1. See if reducing the sizes of the sprue and runner or even the volume of the moulding (see later) can lower the material content of the job.
2. Check if the material can be purchased at a lower price with the existing or alternative suppliers. This is not as silly as it sounds, particularly if large quantities of other materials are being purchased from the supplier. A full explanation of the problem and negotiation skills can yield positive results.
3. If the error is a really serious one, try to re-negotiate the contract with the customer. It is not in the interests of either party for a company to produce parts at a loss. This can be tried in conjunction with action (4) below.
4. Try to obtain further work from the same customer in the same material to secure better prices for larger material quantities.

5. Check to make sure the job cannot be run on a smaller machine or on one of the same size but with a lower MHR. This will not, of course, reduce the material content but can reduce the overall cost to compensate.
6. There may be a possibility that the job could be subcontracted to another moulder who is short of work and may offer a competitive price, providing they are reliable of course. This would, of course, not reduce the material cost but such a moulder may be able to run the job at a lower MHR. This can result in the primary moulder breaking even on the arrangement, or even making a small profit.
7. Investigate with the customer whether it may be possible to use another (suitable) material that is less expensive.
8. If the problem relates to high rejection rates, the mould tool should be examined and corrective action taken wherever possible.

6.7.5.2 Global Monitoring Check Negative

This is very serious and should trigger immediate action by management. In fact, there should have been an indication of this problem with the ‘in-production’ and ‘post-production’ checks. If the actual material usage is greater than that budgeted, this could be due to the following:

- the original BMUF was wrong;
- previous costing checks were inaccurate;
- consistent errors in estimates have occurred;
- sloppy housekeeping (excessive spillages, etc.); or
- excessive rejects have been produced.

There may be other more complex reasons but whatever they are, the reasons must be identified and remedial action taken as quickly as possible.

Once the AMUF exceeds the BMUF it can be extremely difficult to redeem the situation. One solution is to increase the EMC of each new job (slightly) to make up for the shortfall. This in turn makes the prices offered to customers a little less competitive, but if this action is spread over a period of time, it can yield positive results.

6.8 Observations

- Carrying out the in- and post-production monitoring for every job makes the possibility of the AMUF exceeding the BMUF much less likely.
- For meaningful post-production and global monitoring to take place, a satisfactory stock control system must be employed. To make sure it is working efficiently, material audit checks should be made at least every quarter. Between the audits, it should not be difficult to devise a simple computer-based system for recording material when it is issued and returned to the stores.
- Some companies are not aware of their AMUF until the year-end accounts are published.

The spreadsheet shown in **Figure 6.4** illustrates a simple method of checking costs during production. In this case the total production cost can be compared to the estimated cost. The material weights and the cycle should also be compared with the estimated values. Note that all data entered must be actual values and not assumed values. The example in this spreadsheet shows that this part is being produced below the estimated cost. This would immediately trigger off an investigation as to which cost elements are causing the shortfall – the material or the machine cycle.

Part Wt gms	Runner & Sprue wt	No Imps	Shot wt gms	Matl Cost per tonne	Matl Cost per 1000	Cycle secs	MHR	M/C Cost per 1000	Total Cost per 1000	Est Cost per 1000	Surplus/ Deficit
10	15	8	95.00	1,200	14.25	12	35	14.58	28.83	28.21	-0.62
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00
			0.00		0.00			0.00			0.00

Fig 6.4 IN PRODUCTION COST CHECK

6.9 Summary

- Always check estimated material costs against actual costs.
- Costing checks should be carried out using:
  - in-production monitoring;
  - post-production monitoring; and
  - global monitoring.

Should any discrepancies occur, remedial action should be taken as soon as possible to avoid the problem getting worse.

7 Reducing the Costs of Production

7.1 Discussion

Costs can be reduced in several major areas:

- reducing the scrap level;
- minimising the amount of material used;
- avoiding blanking off impressions;
- optimising the processing parameters to reduce the cycle time; and
- optimising processing parameters to increase part quality.

7.2 The Cost of Producing Scrap

It is an inevitable consequence of any production process that some scrap will be generated. The level of scrap will clearly vary, depending upon the nature of the production process and the type of work being produced.

Within the context of this book, scrap is defined as production of items that either have failed internal quality checks or have failed customers' goods inwards inspection. These include rejects failed for dimensional, functional, appearance and other faults. The causes of producing scrap are many and varied. However, there are four main areas where scrap is generated that we will now examine.

- Mould related
- Machine related
- Post-moulding operations
- Housekeeping.

7.2.1 Mould Related

Damage to the mould tool is a very common cause of the production of scrap. Worn, damaged and bruised impressions, general wear, broken ejector pins, core pin deflection and corroded or blocked waterways are just a few of the well-known causes of the production of scrap.

7.2.2 Machine Related

There can be many reasons why moulding machines can be responsible for scrap being produced. Erratic locking, incomplete ejection, shorting and flashing are a few of the main ones. This can often be the result of inaccurate mould setting, or alternatively a machine malfunction.

The condition of the machine can also give rise to scrap. For example, poorly maintained machines with oil leaks can contaminate mouldings. The age of a machine may be another factor. Older machines may not have sufficiently accurate control systems for certain work, even if they are well maintained and otherwise in good working order.

Worn cylinders, screws and hydraulic valves, inefficient heater bands and generally poorly maintained machines are also a common cause of loss of production time and rejects.

7.2.3 Post-moulding Operations

Scrap will also be produced if any post-moulding operations are required. Printing, hot stamping, degating, assembly and similar operations will inevitably generate some scrap for many different reasons including those mentioned in **Section 7.2.2**.

7.2.4 Housekeeping

By housekeeping is meant the general standard of cleanliness of the entire manufacturing area including the moulding shop, the raw material and finished product stores, tool room (if any) and any other production or storage areas with which mouldings may come into contact.

Poor housekeeping is often responsible for raw material contamination. It can also be a cause of contamination of otherwise good mouldings through poor storage or through contact with oil, grease and water.

In extreme cases, foreign materials can make their way into bags of good mouldings awaiting despatch. It is not unknown for gate fragments, raw material, floor sweepings (yes it's true!) and other contaminants to arrive at the customer's goods inwards inspection.

7.3 Discussion

It has to be accepted that scrap will be generated whenever a production process takes place. What should not be accepted is an unnecessarily high level of scrap. High scrap levels are usually (but not always) indicative of poor control and management.

It is clear that high scrap rates are costly and even if such costs are identified and recovered through increasing prices, this has the inevitable consequence of reducing competitiveness. This in turn is self-defeating, as business may be lost with associated loss of future profits.

High levels of scrap are often associated with poor housekeeping and a laissez faire attitude being adopted by management and staff alike. Such practices are usually forced to stop as they are nearly always accompanied by poor results which are unacceptable to the company's board or ultimately to the shareholders or to institutions from which the company has secured finance.

Poor housekeeping not only generates scrap but also actively dissuades visiting potential customers from placing business through lack of confidence in the operation. Good housekeeping will reduce scrap levels, instil a greater sense of pride in the workforce and will generate a sense of confidence in potential customers.

7.4 Observations

- Poor housekeeping and general lack of control in production generate unnecessary costs and often result in very poor financial performance.
- In severe cases, it can lead directly to a major reorganisation or the closure of a company.
- Poor control and housekeeping can contribute to low employee morale and efficiency.

7.5 Discussion

Many companies, however, do have sufficient control and adequate housekeeping procedures. The degree to which such procedures are implemented depends on the nature of the business. The medical, pharmaceutical and microchip industries must have very high levels of control and housekeeping. These can include clean room conditions with filtered air and very rigorous quality assurance procedures.

These are, however, specialised areas of manufacture and the costs of maintaining such quality assurance levels are significant and reflected in the prices charged to customers. Conversely, the use of very rigorous total quality assurance procedures is not cost effective if the nature of the business does not warrant it.

There is an increasing tendency for customers to insist on *their* quality standards being adopted for any work they place with a moulder. These often form part of the contract and moulders' works may be subject to periodic quality assessment visits by customers' quality assurance officers. Failure to comply can result in cancellations of orders and loss of future business.

This does not mean that such companies do not produce scrap or reject parts. All moulding operations do. However, there would be stringent control systems in operation to identify and quarantine non-usable parts. This will prevent material contamination or any other problem that may affect the quality of the parts being supplied to the customer.

Having identified the main areas where scrap is being generated, the introduction of a simple system is all that is needed to quantify the amount of scrap produced and to isolate it.

If the job costing exercise indicates a good result, then by definition there cannot be a high scrap rate. A negative result would indicate that further investigation is necessary, including an accurate assessment of the scrap level.

To check the scrap, all reject mouldings and other scrap must be kept, identified and isolated during production including all scrap from post-moulding operations whatever the cause. The amount of scrap can then be quantified.

It should be noted that in certain industries this is an essential requirement and part of customers' quality procedures. Identification and isolation of scrap prevent any possibility of rejected parts accidentally being delivered.

The production of high rates of scrap is costly and it is often quoted as, say, 1 or 2% of the quantity produced. Unfortunately this does not convey the full impact of the ***cost*** of the scrap. The only way for scrap figures to have any impact is to express them in terms of money.

The following example illustrates this point. If we take a situation where 1,000,000 parts are produced and a scrap level of 1% is recorded, then this represents 10,000 parts, which seems quite a lot but it does not have sufficient impact.

If the invoiced sales value is £20 per 1000, this can then be translated into a cost of £200 which still does not seem too startling, but if we now extend this scenario and assume the general overall scrap level is 1% the figures will assume more impact.

Let us now suppose the moulding turnover of this company is £10,000,000 per year. Then 1% represents £100,000 per year. Whilst all this cost cannot be saved, it is a cost worth attacking. In view of the fact that total scrap levels of up to 5% are not uncommon, such rates can represent very substantial sums of money.

7.6 Observations

- Many companies are unaware of the value of the scrap they produce.
- To have sufficient impact, scrap should be quantified in terms of cost.
- The actual cost of scrap can be very high – often higher than believed.
- Mould tool and machine-related problems account for a high proportion of all scrap.

7.7 Summary

- Scrap is generated not only during production but also during post-moulding operations and by bad housekeeping. It also includes rejects returned by customers.
- The job costing check will indicate whether further investigation is necessary. If it does, the scrap level should be investigated.
- To enable scrap levels to be checked, all scrap should be identified, isolated and stored.
- To have the necessary impact, scrap levels should be quantified in terms of cost.

7.8 Reducing the Material Cost

The material usage factor can represent a very large proportion of the total running costs of a company. We have seen in the example in **Chapter 3** that a material usage factor of 30% of the turnover was estimated. Note that this is 30% of the ***turnover***. If we take the total costs from the same example, these are:

Turnover less profit = £10,000,000 – £1,500,000 = £8,500,000

The material cost = 30% of £10,000,000 = £3,000,000

Hence the percentage material cost compared to the total costs is:

$$\frac{3,000,000}{8,500,000}\times 100\% = 37.27\%$$

Another way of looking at this is that each 1% of material cost = £30,000. Hence, if the actual material cost exceeds the budgeted material cost by this amount, £30,000 is lost from the profit.

A level of 3%, therefore, represents £90,000, equal to the cost of perhaps three new members of staff or a new machine or two.

When seen in this context it is clear that material costs must be kept under control and that an effort must be made to introduce effective stock control programmes and accurate material audit checks.

7.9 Cost Reduction Techniques

We can reduce the material cost by:

- less wastage;
- moulding fewer rejects;
- using just-in-time (JIT) techniques;
- reducing the shot weight; and
- using reprocessed material.

7.9.1 Wastage

This should be one of the easiest costs to attack. Wastage includes spillage, contamination and deterioration.

It is really a question of introducing good housekeeping techniques and promoting as clean a working environment as possible. Punctured bags and spillages through poor material handling whether by hand or machine are an unnecessary loss of money.

Similarly, allowing materials to become contaminated through poor storage arrangements is avoidable. Excess materials, which are never used and left to deteriorate and thrown away, is an obvious case of wasting money. In such cases, some effort should be made to try to sell surplus or redundant material so that at least some of the cost can be recovered.

7.9.2 Rejects

As previously mentioned, producing an excessive level of rejects is highly undesirable. Any job that shows a high level of rejections should be carefully investigated. The reasons for this must be identified and the appropriate action taken.

If the reason is an inability to hold drawing dimensions or other quality problems because these are found to be unachievable, the job should be stopped. Not only is material being wasted but also many other costs as well. If the problem is due to unachievable quality requirements, this should be discussed with the customer as soon as possible to secure a solution.

High rejection levels may also be due to machine malfunctions, poor mould tool design, wrong gating or substandard material. In practice, there may be several reasons why this happens.

It could also be the failure to apply ***wide operating window*** (WOW) techniques where the moulder is struggling to achieve closely toleranced dimensions.

7.9.3 Just-in-Time (JIT) Techniques

A material supplier usually requires payment for material supplied considerably before payment for the moulded parts is received from a customer. Often the difference can be a month or more.

In such circumstances, all material left sitting in the stores, which is not shortly required for use, is costly. Many smaller companies borrow money to supplement their working capital and consequently they are paying interest on it. Some of this money is often used to finance material held in stock.

Even if borrowing is not necessary, excessive material stocks still represent a loss of return on money that could otherwise be left on deposit or invested elsewhere.

The implementation of JIT techniques is neither new nor difficult but seems less used in the moulding industry than in others.

There are some exceptions, however, where components manufactured by a moulder are almost immediately despatched and arrive at a customer's works 24 hours after being manufactured. In order to do this, strict JIT controls are necessary to ensure material is always available but only a minimum amount is kept in stock.

There are clear cost advantages to using JIT principles, particularly for companies involved in high-volume production of standard components.

7.9.4 Reducing the Shot Weight

Clearly, the lower the shot weight, the less the material cost. Therefore, sufficient thought should go into minimising the shot weight at the tool design stage. Runner lengths and diameters should be minimised (but sufficient).

Runner lengths are normally determined by the layout of the mould tool. This suggests that sufficient time be taken to establish an economic layout at the tool design stage. Once the tool has been made, reducing the runner length is usually impossible without major alterations to it.

Another way in which the material content of a part may be reduced is by adjusting the cavity sizes. The smaller the part sizes, the smaller the material content. Optimising the part sizes to minimise material cost (and cycle time) can be carried out using a suitable computer-aided design program or even a calculator. This topic is discussed in Section 7.10.

The runner sizes, layout of the cavities, gating and the cavity sizes should be determined by the moulder and not the toolmaker. Moulders have more experience in producing parts from their machines than anyone else. Therefore, they should have an active role in determining the major mould tool design parameters.

The current trend is to pass the drawing for a new part straight to the toolmaker and allow them to design the mould with hardly any input from the moulder – except perhaps for the number of impressions and the type of gate. Whilst this approach may work for straightforward parts, it can lead to problems with more complex parts where the cavity construction, cavity sizes, ejection features, etc., should be given more consideration.

Disputes can sometimes arise through failure to think through the total quality requirement of the part, which can lead to litigation in some cases.

7.9.5 Use of Reprocessed Material

There are some moulded parts where it is imperative that the full physical properties of the material are used. In such cases, it is not unusual for the customer to specify that only virgin material should be used.

Adding reprocessed material in such cases can result in the physical properties not being fully achieved, possibly leading to failure of the part in its operating environment.

Where virgin material only is specified, the moulder should not be tempted to introduce reprocessed material to save cost. This can easily be detected by customer quality checks on the parts after moulding. However, the runners, sprues and any rejects from a 'virgin only' job can be collected and reprocessed for use on other less demanding jobs.

There are many cases where reprocessed material may be safely used and, where this applies, the amount that can be used depends upon the material and the geometry of the part. Particularly with semi-crystalline materials, the introduction of reprocessed material can result in reduced shrinkage, which will affect the dimensions of the part.

Polymers have a thermal memory and the physical properties of the part will depend upon how many times the material has been processed. When using high levels of reprocessed material continuously, thermal degradation is a distinct possibility. This in turn may generate further rejects.

7.10 Reduction of Part Volumes

It is evident that the smaller the volume of the part, the smaller the weight of the part will be. Normally, all parts are fully specified on an engineering drawing, which shows the dimensions and tolerances to which the part is to be made. If this is the case and the tolerances are suitable, the sizes may be adjusted to give as small a volume as possible.

Note, however, that this technique may not be possible if the part is a highly technical, very closely toleranced one where there may be very little room for manoeuvre.

If a drawing does not exist and parts are being made to a sample, the moulder should request a fully dimensioned drawing from the customer. Working without a drawing can be risky and confusing. In practice, working without a drawing may lead to acrimonious disagreements between one or more parties involved.

An example of minimising the weight of a part is now illustrated.

Example. The component is a part tube form in polypropylene. The basic mould construction for this part is shown in **Figure 7.1**.

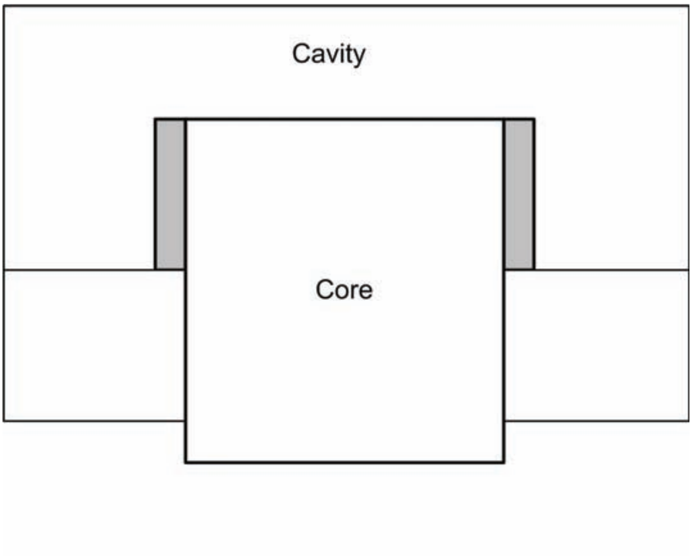


Figure 7.1 Mould construction

If we increase the diameter of the core pin, the volume of material used will be smaller. Similarly, if we decrease the cavity diameter, this would also make the volume of material used smaller. Clearly, if we can reduce the volume of material used to make the part, the cost of the material for each part will also be reduced.

This, then, is the principle we need to adopt to optimise the volume of material in order to keep the material cost to a minimum:

- make the male components in the mould larger; and
- make the female components in the mould smaller.

This can only be achieved if the part geometry, tolerances on the original drawing and the production sizes are compatible with this approach.

In this example, the original drawing is shown in **Figure 7.2** (drawing A). This specifies the final, finished sizes of the parts. If they do not conform to these sizes, the parts will be deemed to be rejects. **Figure 7.3** (drawing B) shows the sizes of the resulting mouldings measured over a sufficiently large production period of time and sample size to ensure valid results. The object of the exercise is to make the larger diameter smaller and the smaller diameter larger so that the resulting moulding will still lie within tolerance. Similarly, we want the depth to be as small as possible.

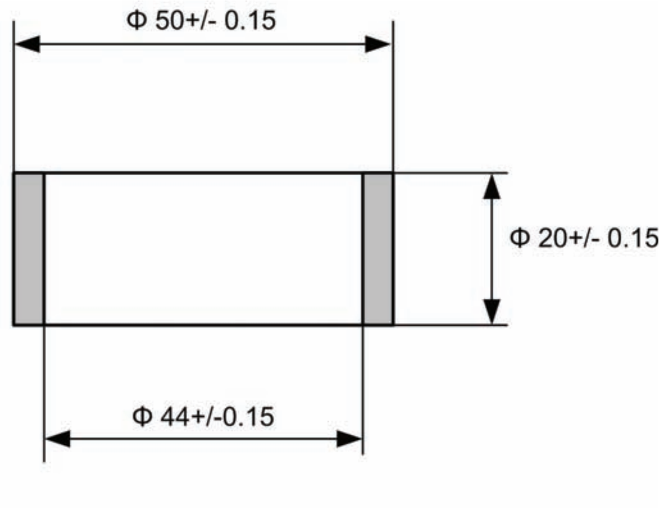


Figure 7.2 Drawing A – drawing sizes - all dimensions are in mm

7.10.1 Large Diameter (Cavity Size)

- Lower drawing limit = 49.85 mm
- Lowest size from moulding trial = 49.96 mm.

As we are trying to reduce the cavity diameter, we must avoid it becoming too small; hence, we need to use the smallest drawing size and the smallest moulded size.

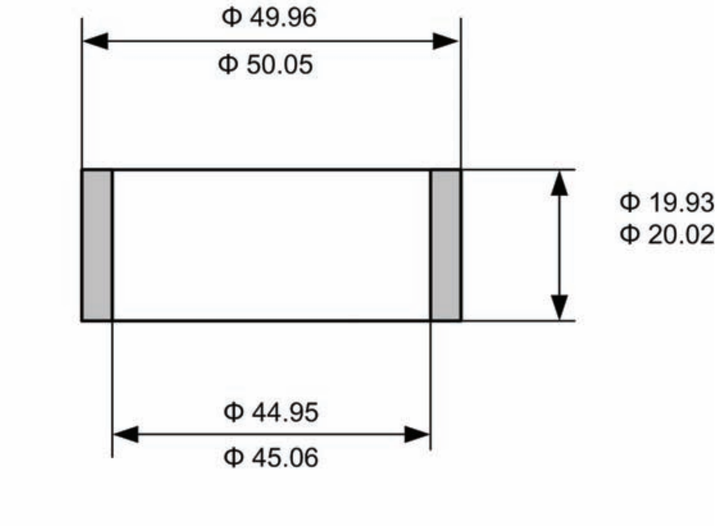


Figure 7.3 Drawing B – actual production sizes - all dimensions are in mm

Thus if we *reduce* the *cavity* size by 0.08 mm, the *moulding* size will become 49.88 mm – still within the drawing tolerance and with a safety margin of 0.03 mm.

7.10.2 Smaller Diameter (Core Size)

- Upper drawing limit = 45.15 mm
- Largest size from moulding trial = 45.06 mm.

In this case, the opposite is true. As we are trying to increase the core diameter, we must avoid it becoming too large; hence, we need to use the largest drawing size and the largest moulding size.

Thus if we *increase* the *core* size by 0.06 mm, the *moulding* size will become 45.12 mm, again within drawing limits with a safety margin of 0.03 mm.

7.10.3 Depth

- Lower drawing limit = 19.85 mm
- Lowest size from moulding trial = 19.93 mm.

As this is a cavity dimension, we need to take the smallest sizes as before.

In this case we do not have as much room to manoeuvre but we can still reduce the cavity depth by 0.04 mm leaving a safety margin of 0.02 mm. The toolmaker is then instructed to adjust the cavity and core sizes by these amounts.

7.10.4 Calculating the Saving in Material

All we need to do now is to calculate the difference in volume resulting from these changes:

$$\text{(Original volume from pre-production trial} - \text{New volume resulting from cavity adjustments)} \\ \times \text{specific gravity of material}$$

In this case we have for the original minimum moulding volume:

$$\begin{aligned} &\frac{\pi}{4}[(49.96)^2 - (45.06)^2] \times 19.93 \\ &\quad = 0.785 \times 466 \times 19.93 \\ &\quad = 7,291 \text{ mm}^3 \\ &\quad = 7.29 \text{ cm}^3 \end{aligned}$$

and for the new volume:

$$\begin{aligned} &\frac{\pi}{4}[(49.88)^2 - (45.12)^2] \times 18.89 \\ &\quad = 0.785 \times 452 \times 18.89 \\ &\quad = 6,703 \text{ mm}^3 \\ &\quad = 6.7 \text{ cm}^3 \end{aligned}$$

Therefore, the reduction in volume = 7.29 – 6.70 = 0.59 cm^3.

The specific gravity of the material is 1.2. Hence the weight of material saved is 0.59 × 1.2 = 0.708 g. Thus the saving per 1,000 parts = 0.708 × 1,000 = 708 g. If the material cost is £1,200 per tonne, this represents:

$$\frac{1,200 \times 708}{1,000,000} = \text{£0.85 or 85p per 1,000 parts}$$

If the job consists of producing an average quantity of 1,000,000 parts per year over, say, a five-year period, this amounts to a saving of 5 × 1,000 × £0.85 = £4,250.

7.10.5 Procedure Summary

7.10.5.1 For Cavities

Use the smallest drawing size (*a*) and the smallest moulded size (*b*). Then (*b* – *a*) would represent the amount by which to reduce the cavity, and would result in the cavity size being the same as the lowest drawing size. To allow a small factor of safety, this amount must be reduced slightly. In most cases, 0.03 should be sufficient.

Hence, in this example for the cavity diameter we get

$$(b-a)-0.03=(49.96-49.85)-0.03=0.08 \text{ mm}$$

7.10.5.2 For Cores

Use the largest drawing size (*c*) and the largest moulded size (*d*). Then (*c* – *d*) would represent the amount by which to increase the core, and would result in the core size being the same as the greatest drawing size. To allow a small factor of safety, this amount must be reduced slightly. Again, in most cases 0.03 should be sufficient.

Hence, in the example for the core diameter we get

$$(c-d)=(45.15-45.06)-0.03=0.06 \text{ mm}$$

Note that because there is not as much room to manoeuvre with the depth we would use a smaller factor of safety of 0.02 mm.

Clearly, the saving in cost is substantial if this technique is applied across all jobs in the moulding shop. The savings are also, of course, very much greater if more expensive materials are involved and larger parts are being produced.

The obvious disadvantage of this technique is that it can necessitate the re-making of the cavities and the cores. This can obviously be expensive and outweigh the advantages gained in savings on material costs.

Nevertheless, on long running non-complex jobs, there can still be a significant saving in overall cost. In view of this, each job should be evaluated carefully to see if this technique is viable.

However, this technique can be applied very effectively and at minimum cost in a large number of cases, if it is combined with the MMC technique discussed in **Chapter 8**.

7.11 Summary

Material costs can be lowered by:

- reducing the level of wastage (spillages, contamination, etc.);
- reducing the rejection level where this is excessive;
- using JIT techniques;
- reducing the material content of the part where circumstances permit; and
- using controlled levels of reprocessed material if permissible.

7.12 Effect of Blanking Off Impressions

Very rarely do large multi-impression injection mould tools run consistently on all impressions. This can happen for a variety of reasons:

- incorrect mould tool design;
- poor quality of tool construction;
- unsuitable machines;
- unbalanced runner systems and incorrect gates;
- too many impressions to control and fill properly; or
- damage to the cavity or cores.

Of course, in practice, there may be several other reasons, but it is quite common to see mould tools that are not moulding on all cavities in many mould shops.

Everyone is aware that running tools under these conditions is undesirable and uneconomic but very rarely is the loss of profit quantified at the time. Unfortunately, the true effect often comes as an unpleasant surprise when the figures become known later.

As in other industries, custom or trade moulding production is customer driven and losing impressions on a mould tool places an extra strain on production to keep up with the customer's delivery requirements. When a tool is producing fewer parts per hour than it should, it makes it almost essential to keep moulding on it to maintain a sufficient supply of parts to prevent the customer running out.

To avoid losing too much money it is desirable to have some means of quickly computing the actual cost and profit so that action may be taken if desired. To develop this procedure we will consider an example based on an 8-impression tool.

This example is taken from the *Mould Design Guide* [1] and reflects an actual case history of a job in production in a trade moulding shop and illustrates just how uneconomic it can be to lose impressions (in this case through damage) and how difficult it can be to recover the situation.

Example

(a) Original estimate

- Part: flanged housing
- Number of impressions: 8
- Part weight: 15 g
- Runner and sprue weight: 20 g
- Material: polypropylene
- Material cost: £2,000 per tonne
- Machine lock: 80 tonnes
- MHR: £60
- Cycle: 20 s

The analysis is as follows:

$$\text{Shot weight} = (8 \times 15) + 20 = 140 \text{ g}$$

$$\text{Material required to make 1,000 parts} = \frac{140}{8} \times 1{,}000 = 17{,}500 \text{ g}$$

$$\text{Cost of material for 1,000 parts} = \frac{17{,}500 \times 2{,}000}{1{,}000{,}000} = £35.00$$

$$\text{Time taken to produce 1,000 parts} = \frac{20 \times 1{,}000}{8} = 2{,}500 \text{ s}$$

$$\text{MHR cost to produce 1,000 parts} = \frac{2{,}500 \times 60}{3{,}600} = £41.67$$

$$\text{Total cost} = \text{material cost} + \text{MHR cost} = £76.67$$

$$\text{Profit to be added at 15\%} = \frac{15 \times 76.67}{100} = £11.50$$

Selling price = £88.17 per 1,000 parts

After three weeks' production the actual conditions were very close to those in the original estimate. The tool, however, subsequently suffered damage on two impressions, which were 'blanked off' to keep production going on the remaining six impressions.

(b) Effect of running on six impressions

$$\text{New shot weight} = (6 \times 15) + 20 = 110 \text{ g}$$

$$\text{Material required to make 1,000 parts} = \frac{110}{6} \times 1{,}000 = 18{,}333 \text{ g}$$

$$\text{Cost of material for 1,000 parts} = \frac{18{,}333 \times 2{,}000}{1{,}000{,}000} = £36.67$$

$$\text{Time taken to produce 1,000 parts} = \frac{20 \times 1{,}000}{6} = 3{,}333 \text{ s}$$

$$\text{MHR cost to produce 1,000 parts} = \frac{3,333 \times 60}{3,600} = \pounds 55.55$$

$$\text{Total cost} = \text{material cost} + \text{MHR cost} = \pounds 92.22 \text{ per 1,000 parts}$$

(c) Analysis

The original cost for the job on an 8-impression basis = £76.67 but the cost to run the mould on a 6-impression basis = £92.22. The simple comparison of selling price and the cost price tells its own story: in this case £88.17 – £92.22, a hefty loss of £4.05 per 1,000!

Whilst at the time the actual loss had not been quantified, it was, of course, realised that at least the job was not as profitable as it should be.

In an attempt to reduce the cost of production under these conditions, progressively fine adjustments were made to the moulding parameters and mould cooling to reduce the cycle time. As a result of this a two-second reduction in the cycle was achieved (with some difficulty).

(d) Effect of running on a 6-impression basis with an 18 s cycle

$$\text{As before, cost of material for 1,000 parts} = \pounds 36.67$$

$$\text{Time taken to produce 1,000 parts} = \frac{18 \times 1,000}{6} = 3,000 \text{ s}$$

$$\text{MHR cost to produce 1,000 parts} = \frac{3,000 \times 60}{3,600} = \pounds 50.00$$

$$\text{Total cost} = \text{material cost} + \text{MHR cost} = \pounds 86.67 \text{ per 1,000 parts}$$

$$\text{Profit} = \text{selling price} - \text{cost price} = \pounds 88.17 - \pounds 86.67 = \pounds 1.51 \text{ per 1,000 parts}$$

This represents a very small return indeed but at least it avoids a loss. Nevertheless, a better return than this could be achieved by directly investing the money elsewhere instead.

Where the problem of running on a reduced number of impressions occurs, an immediate effort should be made to quantify the reduced profit level (or loss).

It is also a salutary experience to calculate the cycle that is required to achieve the original profit level. This calculation is normally sufficient to convince even the most optimistic that it is not possible before spending time and effort in pursuit of this goal.

7.12.1 Cycle Required to Achieve Original Profit Level

$$\text{Let } A = \text{material cost per 1,000} = \frac{\text{Shot weight} \times \text{material cost per tonne}}{\text{No. impressions} \times 1{,}000}$$

$$\text{Let } B = \text{machine cost per 1,000} \quad = \frac{\text{Cycle time (s)} \times \text{MHR} \times 1{,}000}{3{,}600 \times \text{no. impressions}}$$

$$= \frac{C \times \text{MHR}}{3.6 \times N}$$

Let P = total original cost (MHR + material cost)

Then: $B = P - A$

Hence:

$$\frac{C \times \text{MHR}}{3.6 \times N} = P - A \tag{7.1}$$

Transposing this expression in terms of C we get:

$$C = \frac{(P - A) \times (3.6 \times N)}{\text{MHR}} \tag{7.2}$$

Substituting the appropriate values from (b) above into Equation (7.2), we get A = £36.67. Hence:

$$C \quad = \frac{(76.67 - 36.67) \times (3.6 \times 6)}{60}$$

$$= \frac{40 \times 21.6}{60} = 14.4 \text{ s}$$

Whilst it may be possible to reduce the cycle by a small amount, it should not be possible to reduce it by this extent. If it were, the original cycle would have been severely inaccurate.

It is also useful to be able to calculate quickly and perhaps more realistically the cycle required to break even. It may still not be possible to achieve this, but it does give a 'bench mark' to determine quickly whether the job is losing money.

7.12.2 Cycle Required to Break Even

From the above analysis we require: selling price (SP) = $A + B$. Hence $B = \text{SP} - A$. That is:

$$\frac{C \times \text{MHR}}{3.6 \times N} = \text{SP} - A$$

Transposing this expression in terms of C, we obtain:

$$C = \frac{(\text{SP} - A) \times (3.6 \times N)}{\text{MHR}} \tag{7.3}$$

Substituting the appropriate values from (b) above into Equation (7.3), we get:

$$\begin{aligned} C &= \frac{(88.17 - 36.67) \times (3.6 \times 6)}{60} \\ &= \frac{51.6 \times 21.6}{60} \\ &= 18.4 \text{ s} \end{aligned}$$

7.12.3 Observations

- Many tools that are run on a reduced number of impressions have out-of-balance runner layouts, which give rise to further problems and can actually increase the cycle time and the rejection level.
- Blanking off tools can result in additional damage to the tool.
- It can take a great period of time to recover the original profit position. In many cases, this is never recovered.

- Many companies have no idea of the *true* cost of running on a reduced number of impressions until it is too late to take any effective action.

7.12.4 Summary

- Blanking off impressions by definition loses money. How much money depends on the number of impressions on the tool, the material and certain other factors. As the number of impressions on the tool decreases, the amount of money lost increases.
- It is normally impossible to reduce the cycle to a level that preserves the original profit.
- It is recommended that the cycle to achieve break even is calculated, which will give a concrete indication of whether a profit or loss is being made.

7.13 Effect of Processing Parameters

7.13.1 Discussion

This book is not designed to discuss injection mould processing in great depth. This is a major topic in its own right and can be a highly specialist area. This does not prevent us, however, from having an overview of how the major processing parameters affect cost.

Although some ‘hi tech’ moulding companies may have a high degree of awareness of this topic, unfortunately many others do not. The purpose of this section is, therefore, to identify, and where possible to quantify, the major areas of interest. In particular, we will try to highlight any processing factors that can have a significant impact on the cost of production.

When a new mould tool arrives, the normal procedure is that it is booked in for sampling trials. The only guidance the sampling technician has is:

- the relevant information for the original cost estimate (material, cycle, etc.);
- previous experience of this type of job/material/tool; and
- other information provided (type of tool, special features, etc.).

7.13.1.1 Original Cost Estimate

Normally, in most cases, an order is placed with a moulder to have a new mould tool made and to also produce the mouldings from it. Sometimes, however, the customer will pass an existing mould tool to a moulder, and in almost all cases the price for the parts will have been pre-agreed between the moulder and customer in principle. The agreed price will be based on the assumption that the mould will run satisfactorily in production. If it does not, the price will have to be re-negotiated.

In either case, in order for the moulder to have agreed such a price, it will have compiled an estimate of all the contributory costs of production together with an element of profit as discussed earlier.

In arriving at this estimate, the two major cost items are the material and the machine cycle. In most moulding companies, a senior member of staff with wide experience of design, processing and secondary operations computes all estimates, but in this case certain details will not be fully known. Much of the information supplied by the customer will have to be taken ‘on trust’ at this stage.

The sampling technician will then be expected to make sure the ***actual cycle*** is less than or not more than the ***estimated cycle***. If the sampling trials do not achieve this, the profit element of the job will be compromised and further action will have to be taken.

If the estimated price is too low, the processing parameters should be double-checked to see if they can be improved before the customer is approached to try to secure a price increase.

Should the sampling trials give rise to satisfactory results with an actual cycle less than the estimated cycle; this will clearly increase the profit element of the job.

7.13.1.2 Experience

The senior sampling technician should be suitably experienced, preferably having had several years’ experience of sampling and maintaining production on similar products. This should include:

- Familiarity with the material, preferably with similar geometric forms. If, however, the technician has not used this material before, full assistance should be sought from the material supplier. With unfamiliar materials, it is particularly important to double check with the material supplier the suitability of the runners, gate ejection and cooling recommendations *before* having any changes to the mould made.

- The technician should preferably have previous experience of sampling and running similar types of mould tools and jobs in the past.

7.13.1.3 Information Provided

As with all technical processes, the more information that is made available, the more informed decisions will be.

- With *all* new mould tools it is advisable for a *full mould GA* to be available and for the design to be fully understood before sampling trials take place. Tools are often damaged due to lack of understanding.
- With new tools that have complex mechanical design features, it is *essential* for the full GA to be available and, if necessary, for the mould tool designer to be present to explain the principal design features before expensive mistakes are made.
- Due to pressures of time, and errors discovered in the mould design, the toolmaker will often make changes to the design 'on the fly' during construction of the tool. Again, due to pressures of time, these changes are seldom recorded or incorporated in the mould design GA.

This 'system' relies on the toolmaker remembering to inform the moulder of such changes. This is clearly not good practice and leads to misunderstandings, errors and, often, physical damage to the mould. Such events are time consuming, costly, frustrating and of course entirely unnecessary.

7.13.1.4 Discussion

In the great majority of cases, the sampling technician will establish the conditions under which the mould tool will be run in production. It is at this stage that nearly all the moulding parameters are established, including the all-important cycle time and the actual shot weight – the two major cost factors.

In view of this, it is important that sufficient attention be paid to all the individual components that contribute to the total cycle. A systematic approach is recommended for the most efficient and cost-effective results. The following major parameters merit some discussion, as the effects of these are frequently misunderstood in terms of efficiency.

7.13.1.5 Screw Forward Time

This should only be sufficient to pressurise the cavities to obtain the desired properties in the final mouldings. Generally, components made from semi-crystalline materials where physical properties and dimensional stability are important should be moulded with higher injection pressures. Over-pressurisation should be avoided as this can lead to flash and cavity over-packing making parts difficult to eject.

Follow-up pressures should compensate for volumetric shrinkage of the material in the cavities. Once the gates have frozen off there is clearly no point continuing the holding pressure stages as no more material can physically enter the cavities. Some machines have facilities for determining this point and should be used.

In other cases (and as a secondary check) the mouldings can be progressively weighed as sampling continues until no further increase in weight is observed. When this point is reached, further pressurisation has no effect on the mouldings and therefore should be stopped.

Weighing the individual mouldings from a multi-cavity mould tool also gives useful information. A spread of different weights indicates a poorly balanced system with a spread of different conditions across the cavities.

A sensitive weighing scale is needed to perform these checks and, to obtain meaningful results, several consecutive checks should be made and the mouldings allowed to cool before weighing.

7.13.1.6 Injection Speed

The speed of injection will largely be determined by the type of material, the part geometry and appearance requirements. This presupposes that the gates are satisfactory and that the gates and runners have been properly balanced.

As a general rule, the speed of injection should be as low as is possible to achieve a satisfactory moulding. High injection speeds coupled with high injection pressures lead to greater possibility of flash. High injection speeds also lead to increased risk of gassing and burning taking place.

With heat-sensitive materials like certain types of polyvinyl chloride (PVC), high injection speeds must be avoided. This minimises thermal degradation occurring due to the high shear rates involved with high injection and screw speeds.

7.13.1.7 Screw Back Phase

In general terms, this should be as long as possible so that material is kept on the move all the time and not allowed to remain stationary and stagnate. This avoids the problems associated with thermal degradation caused by excessively high screw speeds where the material remains stationary for long periods. This is particularly important for heat-sensitive materials.

Ideally, the screw speed should be adjusted so that the screw reaches its stop position and ceases rotating just before the tool-opening phase of the cycle.

Some programs are available that will optimise the screw back time. These are usually based on duration of material contact per unit surface area of the screw.

7.13.1.8 Melt Temperature

This is another important factor in the moulding process. When initial sampling takes place, the melt temperature should be checked with a good quality handheld pyrometer. This is the most effective and direct way of measuring the melt temperature. A good homogeneous melt is required.

This test measures the actual melt temperatures and the cylinder temperature controllers can be adjusted if necessary.

Excessively high or low material temperatures can affect the quality of the mouldings and the energy costs. In view of this, it is advisable to periodically carry out this check during production.

7.13.1.9 Cooling Phase

We have already discussed the importance of mould temperature control and its effect on the cooling cycle. We will discuss this topic in more detail in **Chapter 9** where we will demonstrate that small decreases in the cooling phase can result in significant savings in cost.

In view of this, every effort should be made at the sampling stage to ensure an efficient cooling cycle is achieved. Normally, this is done by progressively reducing the cooling time until the part becomes too hot or soft to eject properly. Clearly, using a lower melt temperature will assist in this respect.

The procedure described above, however, should only be used *after* it has been established that the cooling system in the mould is satisfactory. A new tool should be critically inspected *before* sampling to make sure:

- the cooling channels are clear of swarf or other obstructions;
- the cooling system is connected correctly;
- the cooling system conforms *at least* to that approved on the original mould tool GA;
- the cooling channels are of sufficient size to permit efficient passage of coolant;
- the temperature controller is working properly; and
- the coolant flow is sufficient (preferably at least 2.5 m /s).

Once the mould tool has been running for sufficient time for conditions to stabilise, the inlet and outlet coolant temperatures should be checked. Ideally, the temperature differential should be 5 °C. Any significant deviation from this figure is highly undesirable and is indicative of inefficient cooling.

7.13.1.10 Summary

Unnecessarily long screw forward times and high pressures make ejection more difficult, waste energy and accelerate machine wear. The higher the melt temperature, the greater is the amount of heat that has to be removed from the mould tool.

The moulding conditions should be checked during production to ensure they are still correct. This includes temperatures, pressures, speeds and moulding weights.

Subject to achieving a satisfactory moulding, the best moulding conditions and the most cost-effective approach is for the following to be as low as possible:

- injection pressure and speed;
- screw speed; and
- material temperatures.

Lower pressures, speeds and temperatures (where this is possible) use less energy and result in less wear on the machine and the mould tool.

Reference

1. P. Jones, *The Mould Design Guide*, Smithers Rapra Technology Limited, Shawbury, UK, 2008.

8 Maximum Metal Conditions and Operating Windows

8.1 Maximum Metal Conditions

Whenever a new mould tool is received, it is normally sampled or trialled over a range of different conditions to achieve the optimum operating conditions.

The most obvious goal is to achieve as short a cycle as possible to minimise the machine operating costs and to be able to complete the job as quickly as possible.

In many cases after the sampling period, the mould tool has to be returned to the toolmaker for adjustment. This could include flash, incorrect gate sizes, water leaks, ejection problems and so on.

The cavity and core sizes are theoretically computed to include shrinkage at the design stage to allow the mould tool to be made but shrinkage predictions to achieve cavity sizes are notoriously unreliable. Quite often, the finished moulded sizes are not within drawing limits and sometimes expensive modifications are necessary.

The most expensive alterations occur as a direct result of shrinkage predictions that lead to the moulding size being oversize on a cavity and to a lesser extent undersize on cores. In either case, the cavities and cores may have to be remade if the out-of-specification sizes cannot be rectified by alterations to the moulding conditions.

All too frequently, however, oversize cavity sizes can require new cavity inserts being made, although in more marginal cases these can sometimes be plated to bring the size back within tolerance. The same applies to cores. These too may be plated to bring them back within tolerance.

How reliable are shrinkage predictions? Well even material suppliers will hedge regarding the shrinkage that should be applied on a particular component. However, they should not be criticised for this as the shrinkage of any moulding depends on a variety of factors outside their control.

Mould tool design, gate types and sizes, and processing conditions are just a few of the many variables that have an influence.

Whatever the reason, it is a fact that in a very large number of cases, new mould tools have to be returned to the toolmaker for adjustment of some sort. In view of this, it makes sense to have a system for adjusting sizes at little or no cost at the same time, immediately after the initial sampling trials have taken place.

A system that meets these requirements is called ***maximum metal conditions*** (MMC).

8.2 MMC Techniques

To avoid having to remanufacture cavities and cores, we need a system that ensures the following at the end of the final sampling trials:

- cavity dimensions are never oversize; and
- core sizes are never undersize.

8.2.1 Applying MMC to Cavity Dimensions

Before we can specify a cavity size, we need to estimate the shrinkage. We can use software to assist us with this; however, with shrinkage values quoted as being 1% to 5% for some materials, the outcome is still in doubt.

In order to make sure the cavity size is never too small, we apply considerably less shrinkage to the size than we normally would. In other words, we are making the cavity sizes deliberately too small. The intention is that after the tool is sampled the resulting moulding sizes will also be too small. The following example demonstrates the technique.

Example. The part is shown in **Figure 8.1**. We will assume that this part is to be moulded in Nylon 66 and we have been quoted shrinkage of 2% for this part. Additionally we will assume the limits on these sizes are ±0.1 mm.

If we apply the shrinkage value of 2% to both cavity dimensions, we get

$$\text{For the outside diameter: } 50 + (50 \times 0.02) = 51 \text{ mm}$$

$$\text{For the depth: } 10 + (10 \times 0.02) = 10.2 \text{ mm}$$

If we now look at a visual representation of possible shrinkage results and compare these to the drawing dimensions, we can get a clearer idea of what is required.

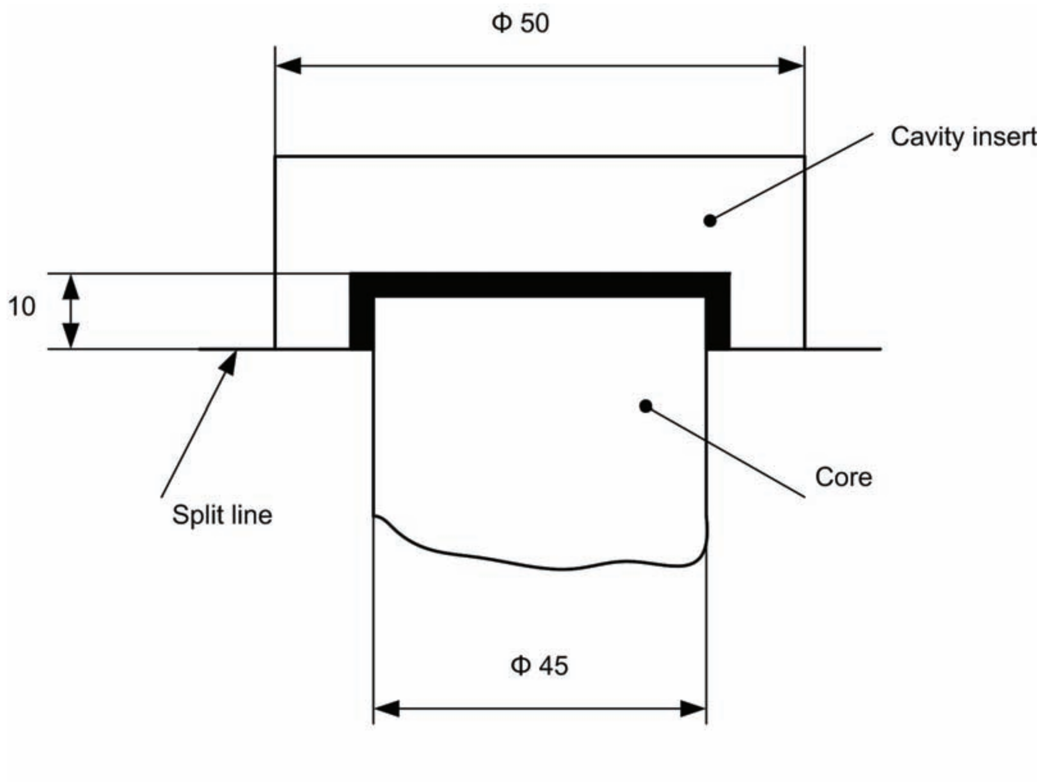


Figure 8.1 Mould construction for cap component

Figure 8.2 represents the effect of the actual amount of shrinkage acting on the 50 mm diameter cavity. If the shrinkage is exactly 1 mm as predicted, the final moulding dimension will lie right in the middle of the drawing tolerance, i.e., 50 mm.

If the shrinkage is 0.9 mm, the moulding will lie on the lower drawing limit. Should the shrinkage be lower than this, the moulding will be oversize, and therefore the cavity will be difficult to modify. If the shrinkage is 1.1 mm, the moulding will lie on the upper limit while shrinkage greater than this will result in the moulding being undersize. This condition can easily be remedied by enlarging the cavity slightly to bring it back within drawing tolerance.

We need to ensure that the cavity size is *too small*. Hence, we need to use a *lower* shrinkage allowance to achieve this. If we use a shrinkage factor of 75% of the nominal value, this should be sufficient to ensure we obtain this result.

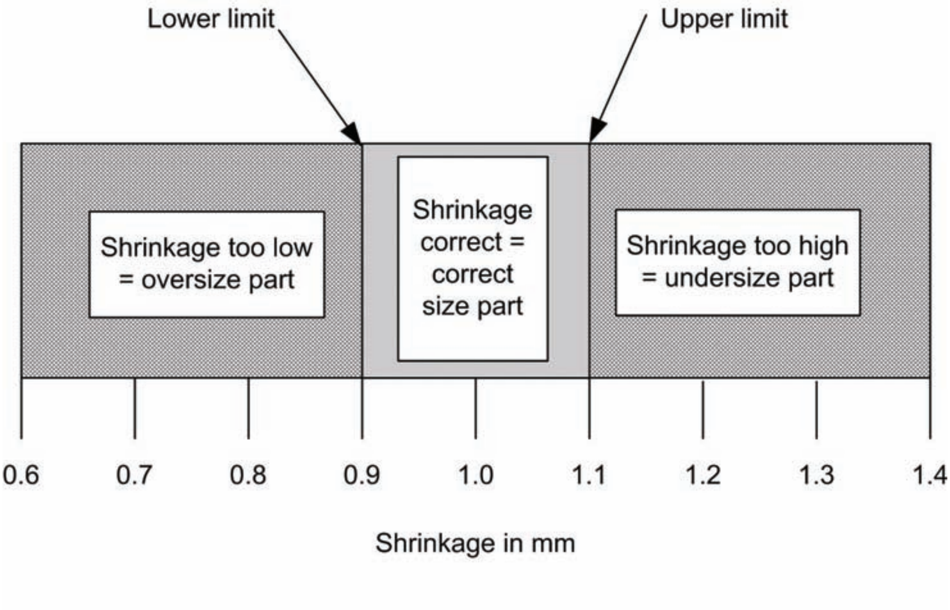


Figure 8.2 Representation of varying shrinkage in mm

Hence in this case the shrinkage allowance applied would be 75% of 2% = 1.5%. This means the cavity would be machined to 50.075 mm instead of 50.1 mm.

The opposite applies for cores. Here we need to ensure the form produced by the core is *too large*. Hence, we need to use a *higher* shrinkage allowance. In this case if we use a shrinkage allowance of 125% of 2% = 2.5% the core would have a diameter of 46.13 mm instead of the nominal allowance of 45.9 mm.

8.2.2 Summary

- Cavities: allow less shrinkage to make the cavity too small.
- Cores: allow more shrinkage to make the cores oversize.

8.3 Using MMC to Minimise the Moulding Weight

In Chapter 7 we looked at methods of reducing the material content of a moulding in order to minimise the cost. The main approach was to adjust the cavity and core sizes to reduce the volume and hence the weight of the part.

As mentioned in **Chapter 7**, it can be very expensive to optimise moulding sizes by making cavities smaller and cores larger after they have been made, as it means remaking them. It is for this reason that many people shy away from this technique.

However, if whenever we commission a new tool we deliberately make the cavity sizes too small and the core sizes too large at the design stage, it is an easy matter to adjust the sizes of both to achieve this goal.

In every case, immediately after the sampling trials, we will know exactly how much material to remove from the cavities and cores to bring the sizes of the moulding:

- just above lower tolerance for cavities; and
- just below upper tolerance for cores.

This will have the effect of automatically minimising the sizes of the cavity and cores to optimise the resulting part weight to a minimum, particularly if combined with the volume reduction principle discussed in **Chapter 7**.

8.3.1 Observations

In order for MMC and cost reduction to be successful, both analyses should be carried out by the moulder and the sizes specified to the toolmaker.

The toolmaker should be informed that the moulder is using this technique in advance so that the toolmaker will retain all jigs and fixtures necessary for the adjustments. A contingency for these alterations should be included in the original mould tool cost.

8.3.2 Summary

In practice, it is not difficult for a moulder to apply these analyses to a wide range mouldings. The effect is to lower costs.

- *One controlled* moulding sampling trial should be sufficient with only minor adjustments being necessary. There are no arguments with the toolmaker regarding expensive modifications.
- MMC ensures that all dimensions will be within tolerance in production.
- As a result, there will be fewer rejects.

- Using the MMC results enables accurate adjustments to the impression to minimise material costs.
- As a result of minimising the material, the moulding will have an optimised lower mass resulting in less material being used and the moulding will cool more quickly to the ejection temperature – often resulting in a reduced cycle time.
- The technique will also create a wide operating window, which is discussed next.

8.4 Achieving a Wide Operating Window (WOW)

8.4.1 Discussion

It is common to see jobs running in a moulding shop where small changes in processing conditions will either stop the job from running smoothly or cause the parts to be rejected through failing the quality requirements.

The reason that this type of problem occurs is that the range of processing conditions over which satisfactory mouldings can be produced is very small. It is obvious that the smaller this range or ***window*** is, the more difficult the parts will be to produce. The wider the range or window within which parts may be successfully moulded, the easier the job will be to run.

For example, a close-tolerance moulding may need a combination of extremely high injection pressure and a critical mould tool temperature in order to be within drawing limits. Even small deviations from these conditions may result in out-of-tolerance mouldings.

Such a scenario would represent a ***narrow operating window*** (NOW). The ***operating window*** (OW) is defined as the range of processing conditions within which satisfactory parts can be moulded.

Of course, some jobs are technically (or otherwise) very demanding and can only be run with narrow operating windows. In these circumstances, critical control of all the operating conditions is essential.

Presumably, in such cases it would be assumed that the degree of moulding difficulty would be reflected in the price charged. If this is not the case, then the job will inevitably be considerably under-priced.

Unfortunately, there are many cases where a job is not particularly demanding but nevertheless it has a NOW. Clearly, this situation is both undesirable and unnecessary. There may be several reasons why this happens, as discussed below.

8.4.2 Factors Contributing to Narrow Operating Windows

- The mould tool design is inadequate.
- Inadequate mould construction.
- The gate type and/or runner system is incorrect.
- Gate or runners are the wrong size.
- The runner and gate system is unbalanced.
- Cavity or core sizes are on extreme limits.
- The cooling system in the mould is inadequate.
- The material quality is inadequate.

8.4.2.1 Mould Design

Inadequate or flawed mould design is responsible for many of the problems experienced with part production and quality. It is essential that experienced designers who have a good working knowledge of toolmaking, processing and material technology design all mould tools.

Mould designs should be controlled by the moulder. This has been discussed previously in some depth, but because this is such an important point it is repeated here.

For example, in a closely toleranced moulding, if the design is passed over to the toolmaker, the *whole* tolerance range may be taken up over a number of cavities. This could result in one cavity moulding on top limit and another on bottom limit. This would result in a classic narrow operating window, which would be extremely unsatisfactory and make consistent production a nightmare.

There are many similar pitfalls waiting for the unwary. To avoid these, the moulder should contribute to, control and approve all mould designs, including the cavity and core sizes.

The importance of a correctly designed mould tool cannot be overemphasised. A correctly designed mould will always cost less to run than a poorly designed one.

8.4.2.2 Mould Construction

The quality of construction is a clear factor in determining the quality of the mouldings that are produced from it. Poor quality construction often results in large rejection rates and narrow operating windows. For example, reduced injection pressures may have to be used to avoid flashing, etc.

Poor mould construction is frequently responsible for insufficient heat transfer within the tool and many other problems. The standard of tooling construction should reflect the quality requirements of the mouldings and the life of the mould tool.

Poorly designed *and* poorly constructed mould tools are the perfect recipe for disaster and can be extremely difficult for the moulder to recover from.

8.4.2.3 Runner and Gate Geometry

Assuming that a satisfactory mould has been made in terms of general design and quality of construction, it is then important to ensure that the correct geometry for the gates and runners is present. This is a very wide-ranging topic and a full discourse is outside the scope of this book. The importance of it, however, is not.

The runner and gate geometry must be chosen to suit the material, the part size and geometry, the type of tool and the number and layout of the cavities. Balancing the runner and gate system is equally important. Failure to do this often results in being forced to use a narrow operating window.

With unfamiliar materials, the material supplier should always be consulted regarding runner and gate sizes (and of course shrinkage). For complex multi-cavity mould tools, it is often advisable to use simulation software to establish optimised runner, gate and cooling parameters.

8.4.2.4 Cavity and Core Sizes

Where a part has close drawing limits, this should signal a warning to a moulder considering taking on the job. Such work requires high-quality machines and mould tools. Additionally, the moulder should have considerable previous experience of processing this type of work.

The moulder's input into the mould design for such work is also essential. Cavity sizes, core sizes, gate and runner geometry and other parameters are critical for this type of job. Similar requirements exist for difficult appearance jobs and parts being moulded in 'difficult' materials.

8.4.2.5 Cooling System

The importance of a satisfactory system was stressed earlier. Inadequate cooling systems are frequently responsible for prolonged cycles and erratic ejection problems. This type of problem is a very common cause of difficulties in moulding and often necessitates the use of narrow operating windows.

8.4.2.6 Material

Variations in the quality of moulding materials can also be a cause of moulding difficulty. Varying material quality may mean that there is very narrow range of moulding conditions under which the job can be accomplished.

Poorly compounded materials are also a potential source of trouble, sometimes requiring extreme conditions to process them.

8.4.2.7 Discussion

We have highlighted some of the factors that contribute to narrow operating windows being necessary.

It is clear that the *narrower* the operating window, the more difficult the mould tool will be to run in production. Narrower operating windows, in turn, demand close control systems and high-quality, accurate moulding machines.

The inevitable consequence of this scenario is that the cost of production will increase. If a job is a genuinely demanding one and the moulder has taken it on knowing this to be the case it will be priced accordingly. When this is not the case, the cost of moulding the job will be greater than the estimated cost.

In all cases, the moulder should achieve as wide an operating window as possible. This will result in lower cycle times and fewer rejects. A spin-off benefit is that the job may be able to be moulded on several different machines instead of perhaps just one, as the moulding conditions are less critical.

8.4.2.8 Observations

- The wider the operating window, the less the job costs to run.
- Many jobs could have been run on a wider operating window than that on which they are currently running.

8.5 Achieving a Wide Operating Window

It is obvious that to achieve a wide operating window, the potential problems mentioned previously should be avoided. In addition to this, the following factors should be taken into account:

- mould appraisal;
- sampling procedures;
- using MMC techniques; and
- ensuring adequate control.

8.5.1 Mould Appraisal

When a mould tool is first delivered, it should be checked against the mould GA. This is important to ensure that everything that has been asked for has been provided. In practice, this is seldom done and checks are only made if there is a problem when moulding the job.

If the job runs ‘satisfactorily’, the mould will normally be accepted without checking it against the GA and the moulding conditions established. Unless the job is more difficult to mould than expected, this set of conditions will be those that are used on all future production.

This often results in a narrower operating window than is necessary, resulting in a tacit acceptance of a rejection level that could be reduced. Whether the mould runs satisfactorily first time or not, it should still be checked to make sure it conforms to the drawing.

Toolmakers can make several changes to the mould during the construction of the mould (in good faith) that may not be beneficial to the moulder. In some cases, this can lead to unnecessary moulding difficulties and an increase in the cost of the job to run.

The temptation to run the mould without checking it for errors or undesirable changes should be resisted.

8.5.2 Sampling Procedures

Sampling or trialling should be carried out over a wide range of conditions taking into account the previous discussion on the effect of processing parameters. The mouldings from each set of conditions should be bagged and identified for inspection and comment by the quality assurance department.

The results of the sampling trials should be carefully analysed to identify the parts that meet the quality requirements. Of these, the ones that require the least 'extreme' moulding conditions and those that are nearest mid-drawing tolerance should form the basis for production.

This ensures that if the moulding conditions vary a little during production, the parts should still be acceptable. In other words, we have created a ***wide operating window***.

8.5.3 Using MMC

If MMC techniques have been used before the mould is returned to the toolmaker for adjustment, the cavity, core and moulding sizes will have been noted. These figures should now be analysed carefully to establish the cavity and core sizes that will provide mid-tolerance results on the moulding. If the toolmaker adjusts the sizes to those established by the moulder, the mould should produce parts that are mid-tolerance in production.

Just as before, this ensures a wider operating window, allowing a wider variation of processing conditions as before. In the case of close-tolerance mouldings, this technique can have a dramatic effect in reducing the rejection level thus minimising costs.

8.5.4 Control

The better the control systems and accuracy of the machine, the more reliable production will be in general. If this is combined with WOW techniques, a very low level of rejections during production should be achieved.

Conversely, the use of WOW techniques enables jobs to be run successfully on a wider range of moulding machines with perhaps less control and which are less accurate. This could not be achieved with a narrow operating window.

8.5.5 Summary

- The tool design and construction must be adequate.
- The runner and gates must be satisfactory and balanced.
- The mould should be checked for conformance to the GA.
- Sampling trials should identify WOW candidates.
- MMC techniques should be applied to enable mid-tolerance moulding results.
- Cooling systems are very important in achieving WOWs and must be sufficient for adequate control.
- Suspect moulding materials should be rejected.

9 The Cooling Cycle and Its Effect on Cost

9.1 Cooling Cycle

Once the injection follow-up pressure stage has ceased, the mould tool remains closed for a further period of time to allow the moulding to cool. The moulding has to cool sufficiently to enable safe ejection to take place. However, we also require, from the point of view of cost, a minimum cycle.

These two requirements suggest that there must be a limiting condition where the cycle is a minimum *and* parts may be safely ejected.

9.1.1 Safe Ejection

Ejection of mouldings from a mould tool needs careful thought by the mould designer. The method selected must take account of the material being used and the geometric nature of the parts being produced. Clearly, a brittle material like polystyrene will need more support during the ejection phase than the same part moulded in nylon.

The nature and sizes of the ejectors used will vary considerably depending on how complex the part geometry is and other features like special surface finishes and so on. The actual process of ejection must be positive, trouble free and totally reliable.

Assuming that the ejection system has been correctly designed, production will not be successful unless the mouldings are sufficiently 'solid' enough before ejection takes place. If the parts are too 'soft', distortion of the mouldings may take place. The ejectors may also 'dig in' and prevent the mouldings falling from the tool.

9.1.2 Minimising the Cooling Phase

It is generally accepted that for the 'average' moulding job, the cooling phase may be up to 40% of the overall moulding cycle. This clearly represents a substantial proportion of the overall cost of production, and therefore any method by which this may be kept to a minimum will be highly desirable.

Unfortunately, this potential high-cost phase of the cycle is often not given sufficient attention at the mould design stage. In many cases, the cooling facility is inadequate, inefficient and simply added as an afterthought.

Clearly, such a philosophy is not only undesirable but also very unprofessional. It can directly lead to increasing costs and eats away at the profit margin.

What is needed is a more professional approach based on using the best information available. Like most things, this is a combination of experience, common sense and applying scientific principles where adequate mathematical models exist.

9.1.3 Observation

Many mould tools in current production could run on a reduced cycle if the cooling system had been correctly designed *and* constructed.

9.2 Elements of Mould Temperature Control

To successfully design an efficient cooling system, it is essential to understand the nature of the cooling phase. A major factor is the type of material, as discussed below.

9.2.1 Amorphous Materials

These are materials that have no preferred structure. During and after the injection phase, the molecular chains are randomly placed and will experience little or no change over significant periods of time. Such materials have lower shrinkage rates and may be ejected quite quickly from a mould tool.

9.2.2 Semi-crystalline Materials

These materials behave differently. During the injection phase, the molecular structure is similar to that of amorphous materials having a randomised pattern. This changes, however, as the moulding cools and starts to solidify. This amorphous structure gradually changes to a more ordered linear pattern and a semi-crystalline structure when solid.

It is highly desirable to allow the right conditions to exist for these materials to acquire their preferred crystalline structure. This is extremely important if the properties of the material are to be preserved.

Crystalline engineering materials like Nylon and acetal will not achieve their specified physical properties if they are not allowed to take up their preferred linear molecular structure.

In order for the correct structure to take place, the mould impressions must be ***heated*** and ***not cooled***. If the mould is cooled with cold water, the material will be frozen into the amorphous state. This results in loss of physical properties, long-term dimensional instability, warpage and distortion.

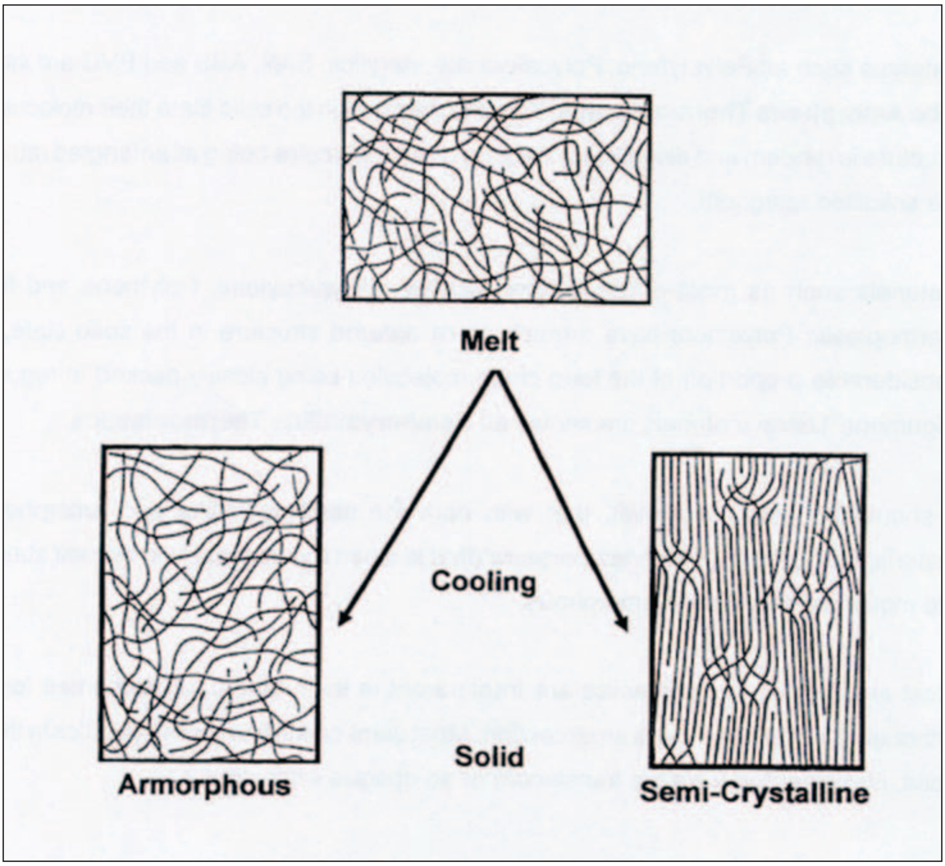


Figure 9.1 Polymer cooling behaviour

This may seem like a contradiction but, on further thought, it is not. While all materials need to be cooled, it is the rate of cooling that is important. Amorphous materials may be cooled more quickly than semi-crystalline materials. However, in order to allow the semi-crystalline parts to cool more slowly, heat must be supplied to the mould during the cooling phase.

Figure 9.1 illustrates the cooling behaviour of amorphous and semi-crystalline moulding materials.

9.3 General Principles for Efficient Cooling

A full discussion of water cooling design techniques is outside the scope of this book but this does not mean we cannot investigate the basic principles, which are quite straightforward.

- The cooling system should be balanced to cool the mouldings evenly.
- It should be sufficient to cool all the impressions and cool them equally.
- Rough-machined channels are more efficient than smooth ones.
- Mould tools generating large quantities of heat should be insulated to prevent heat transfer to the machine platens.

9.3.1 Observation

If a mould tool is made with an inadequate cooling system, it is normally not possible to rectify it without major modifications. In extreme cases, a completely new mould tool will have to be built.

9.4 Enthalpy Curves

As we know the mass of the material and the approximate melt and ejection temperatures at the mould design stage, it is possible to establish a series of equations to determine the water channel sizes.

To make this procedure easier, however, material manufacturers supply ***enthalpy curves*** from which we can read the information required. The term ***enthalpy*** simply means ***total heat content*** and the curves (Figure 9.2) show the amount of heat required to heat a material to a given temperature.

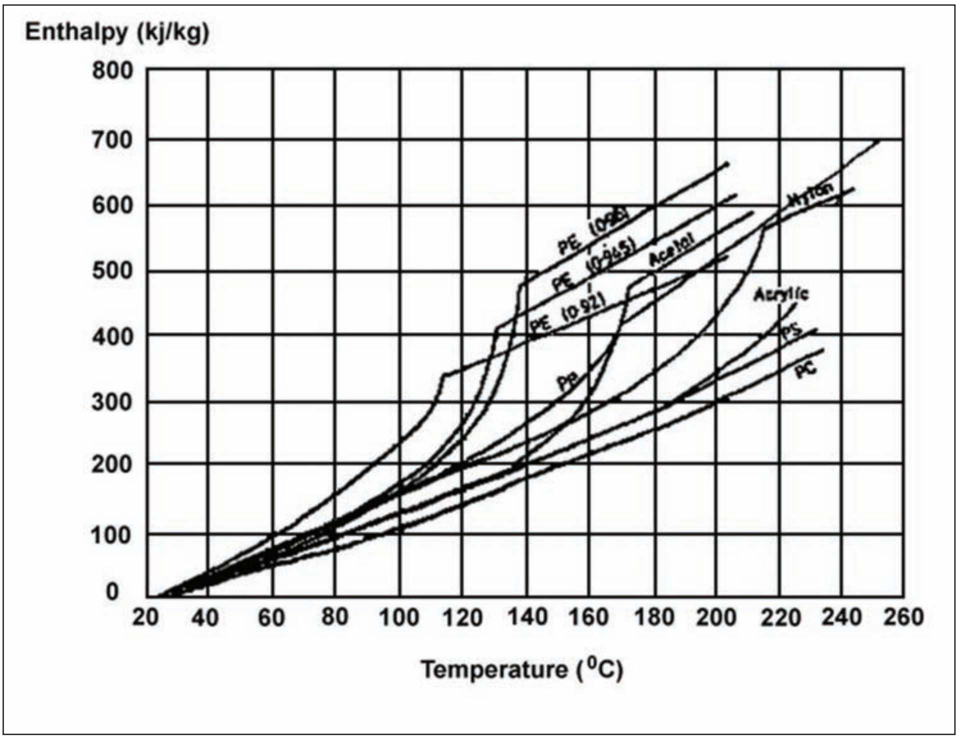


Figure 9.2 Enthalpy curves

For example, if we wish to find the enthalpy of polycarbonate (PC) at 200 °C, we look along the horizontal axis to find 200 and then project a line vertically upwards to intersect the PC curve. At this point of intersection, project a line horizontally to the left to reach the left-hand vertical axis and read off the value. In this case, we obtain 300 kJ /kg^{-1} (kilojoules per kilogram). This tells us that if we have a shot weight of 250 g, we would need:

$$\frac{250}{1000} \times 75 \text{ kJ}$$

to raise the temperature to 200 °C.

9.5 Calculating Water Channel Sizes

We can now establish the basic cooling capacity equation:

$$Q = \text{Mass} \times (\text{enthalpy at melt temperature.} - \text{enthalpy at ejection temperature.})$$

which we can write as:

$$Q = M \times (T_\mathrm{m} - T_\mathrm{e})$$

To establish the cooling capacity per second, we just divide by the cycle time:

$$Q' = \frac{M \times (T_\mathrm{m} - T_\mathrm{e})}{C}$$

where Q' is the cooling capacity in kJ/s^{-1}, M is the mass of the shot in kilograms, T_m is the enthalpy at the melt temperature of the material in kJ/kg^{-1}, T_e is the enthalpy at the temperature at which the mouldings are ejected in kJ/kg^{-1} and C is the cycle time in seconds.

For maximum flow efficiency, we need ***turbulent flow*** that occurs when the water flows with a ***linear velocity of 2.5 m/s^{-1}***.

Additionally, we need a differential of 5 °C between inlet and outlet temperatures for maximum ***transfer efficiency***. Knowing the ***specific heat of water***, we can now establish an equation for the ***volumetric flow***:

$$V_\mathrm{f} = \frac{Q'}{20.95}$$

This in turn leads to the equation:

$$d = \sqrt{\frac{4V_\mathrm{f}}{L_\mathrm{f} \times \pi}} \tag{9.1}$$

The procedure is quite straightforward and is best illustrated with an example.

Example. The details of a production mould tool are as follows:

- No. of impressions: 4
- Material: polypropylene
- Cycle time: 12 s

- Melt temperature: 240 °C
- Ejection temperature: 40 °C
- Shot weight: 45 g

Then, from enthalpy curves, enthalpy at 240 °C = 650 kJ/kg^{-1} and enthalpy at 40 °C = 40 kJ/kg^{-1}. Then

$$\begin{aligned} Q' &= \frac{0.045\times(650-40)}{12} \\ &= 2.287\ \text{kJ/s}^{-1} \\ &= 137.22\ \text{kJ/min}^{-1} \end{aligned}$$

Then:

$$V_\text{f} = \frac{137.22}{20.95} = 6.55\ \text{l/min}^{-1}$$

Hence:

$$\begin{aligned} d &= \sqrt{\frac{4\times6.55\times10^6}{2.5\times\pi\times60\times10^3}} \\ &= \sqrt{\frac{4\times6.55\times10^3}{2.5\times\pi\times60}} \\ &= \sqrt{55.6} \\ &= 7.45\ \text{mm} \end{aligned}$$

This represents the minimum diameter of a *single channel* that would remove the necessary quantity of heat. In practice it is normal to make all channels in the mould this size and the calculated channel diameters would be altered to the nearest standard size – in this case 8 mm or larger standard size.

To make the process of calculation simpler we can rewrite the equation for *d* to combine all the separate constants into one constant as follows:

$$d = \sqrt{8.5\times V_\text{f}} \tag{9.2}$$

where V_f is expressed in litres per minute and *d* in millimetres.

Whilst this procedure is not normally undertaken at the estimation stage with new mould tools, it should be carried out at the mould design stage to ensure efficient cooling.

However, when an existing mould is supplied to the moulder by a customer, it is advisable to check the cooling system on it to see that it is sufficient by comparing it with the calculation in **Equation** (**9.2**). This is necessary so that if the tool needs to have the cooling system modified, a quotation can be obtained from a toolmaker based on this calculation.

Often, the reason a customer passes on an existing mould to a new moulder is that the customer has withdrawn it from a previous moulder – usually because the customer is dissatisfied with the moulder's performance. In a significant number of cases, this can be attributed to quality problems associated with the cooling system in the tool.

9.6 Summary

- The cooling phase is frequently the longest part of the cycle and therefore the most costly.
- In view of this, the cooling system should be efficient and the channel diameters calculated.
- A *sufficient* cooling system must be incorporated into the mould design at the *design stage*. It can at least be costly, and at worst impossible, to incorporate more channels into the tool after it has been made.
- The mould tool construction *must* be adequate with no ill-fitting mating parts.
- Amorphous materials may normally be cooled more quickly than semi-crystalline materials.
- Semi-crystalline engineering materials must not be frozen into an amorphous state. Heat should be supplied to the mould tools to allow these materials to cool more slowly to enable them to achieve their preferred molecular structure.

10

The Loss Leader

10.1 Discussion

In general, terms, a loss leader is a product sold at cost or below cost. In many cases, this is a deliberate policy used to stimulate other, more profitable sales.

We can see everyday examples of this technique in supermarkets selling heavily marked down (usually popular) products to attract customers to that particular store. The intention being that, once in the store, the shopper will inevitably buy other, more profitable products.

There are many other examples of loss leaders that are offered as part of a deliberate marketing policy. These, of course, are very carefully analysed before being offered to ensure that the overall sales position, revenue and resulting profit will be acceptable.

In the plastics industry, this policy may well be operated by companies marketing standard products in exactly the same way. Products such as plastic pipe, bottles and consumer products are frequently heavily discounted with special promotional deals. This is quite acceptable as long as the overall return can be guaranteed to be satisfactory.

With custom moulded parts, however, the position can be considerably more complicated. In general, it is not recommended to deliberately offer a loss leader for this type of work. The circumstances are different, as, usually, a custom or general trade moulder makes a range of custom products for each of several different customers.

There are two occasions when a custom or trade moulder may be involved with a loss leader:

- as a deliberate policy to attract work, usually from a new customer; and
- unintentionally.

10.2 Intentional Loss Leader Policy

There are potential dangers associated with this policy which have to be taken into account before implementing it.

- If the loss leader is part of a range of products being made for a customer, there is a risk that some of the profit from the viable products may be lost. This could leave the moulder with a lower overall return.
- Often, the customer cannot guarantee the sales quantities that they have predicted and may have to cut back orders in adverse sales conditions. If the moulder's strategy was based on producing a higher volume to achieve a satisfactory return, this may backfire.
- Due to changing demand, a customer may request an increase in volume of the loss leader and not the other products in the group. This may severely damage the overall profitability of that customer's work that the moulder processes.
- A moulder might offer a loss leader on a single product in an attempt to emulate the supermarket strategy. This can backfire if the customer places an order for such a product and fails to place any more work for other products.

10.3 Unintentional Loss Leader

In many cases, however, the price of a product may have been simply, by accident, wrongly estimated, resulting in the part being under-priced. If the customer accepts this under quoted price, it can be very difficult to redeem the situation.

Despite the accuracy and care with which estimates may be prepared, there will inevitably be occasions on which the actual job cost exceeds the estimate. These occur because of overoptimistic estimates of cycle times and material costs or because of straightforward errors.

Sometimes jobs are simply very much more difficult to run consistently in production than previously envisaged at the estimating stage. As mentioned previously, to minimise such errors, the estimator should be a very senior person with a great deal of experience in all aspects of injection moulding and mould design.

10.4 Discussion

Estimating is a particularly sensitive and demanding process. Too low a price will attract work with a poor return while overpriced estimates will lose the company business. Feedback information from the customer is essential to establish whether estimates are reasonable compared with the competition.

Sometimes this can be difficult to obtain but if a good relationship exists with the customer's buyer, this information should be forthcoming. In fact it is in the interests of the customer to provide an indication of whether an estimate is close to or well away from others.

If an estimate is far too low and the work placed as a result, any buyer worth their salt must realise the problems that are likely to arise as a result. In such circumstances, the buyer should at least query why the estimate is so low, in case the moulder has misunderstood what was required.

Similarly not telling a moulder that its estimate is far higher than the others is also counterproductive. This could also be due to a misunderstanding or even a computer error for example. In either case the estimate is not a 'correct one' and cannot be compared on an equal footing with the others.

When an order is placed with a moulder at a price that is not profitable, it can be very difficult for the moulder to obtain a price increase from the customer. The customer will also have their own cost budgets and will be equally keen that they are not exceeded in exactly the same way as the moulder.

When a situation occurs where the actual job cost is greater than estimated, a decision has to be made quickly by the moulder. The decision is often political as much as economic. If the customer is an important one and places a lot of business there may be a different attitude (and decision) to a customer that is not considered very important.

Where a customer is a major one, any decision will be particularly difficult and often almost entirely political. It is impossible to generalise meaningfully in these circumstances, as each company will usually have a unique set of reasons for adopting a particular strategy. Frequently, senior management makes decisions of this nature.

The position is further complicated if a customer places a range of components with the same moulder on a 'project' basis. Often the attitude prevails that one should take the 'rough with the smooth' if one of the parts becomes a loss leader. Whatever the circumstances or reasons there is only a limited range of options that is open to the moulder where a job is under-priced, as discussed below.

10.5 Under-priced Jobs

There is a limited range of options available when a job is under-priced. As previously discussed, much will depend on the relationship with the customer and the value of the customer's account.

The main options available in the event of discovering a loss leader as follows:

1. Increase the price straight away.
2. Increase the price in stages over an agreed interval of time.
3. Increase the price of all jobs by a small amount for that particular customer to compensate if possible.
4. Take no action immediately but make up the loss on future jobs for the same customer.
5. Approach the material supplier, explain the difficulty and see if it will help with a one-off lower price for the current (customer's) order. Then re-negotiate the price with the customer on the next order.

In all cases, it is advisable to be open and honest with the customer, which often elicits a far more sympathetic and understanding response. Each moulder is uniquely placed to determine the best course of action with its own customers and will act accordingly.

Whatever the decision taken, the ramifications of that decision should be fully understood. The ***actual value*** of the loss must be quantified so that the full effect of producing mouldings at a reduced cost is known.

The following example demonstrates the effect of an under-priced part on a project of a group of six parts all placed with a moulder at the same time.

Example. The quantity required is 1,000,000 per year and the minimum life of the project is five years.

Table 10.1 lists the estimated costs and the actual costs of production determined after a representative production period. The below-cost part clearly shows up with an actual loss of £3.08 per 1,000 parts. The remaining figures illustrate a typical spread of results above and below the expected profit level.

The most important result that these figures show is a drop in the expected *total profit* from £39.17 to £20.51 per 1,000 parts. In percentage terms, this represents a return of 6.4% instead of the budgeted one of 12.2% – a serious deficit.

Table 10.1 Profit analysis (all values are in £ per 1,000 parts)

Part	Selling price	Estimated cost	Estimated profit	Actual cost	Actual profit
Bearing	35.50	31.24	4.26	32.70	2.80
Slider	46.70	41.10	5.60	42.95	3.75
Cam	75.68	65.86	9.82	78.76	(3.08)
Housing	54.96	48.36	6.60	47.54	7.42
Side grip	63.73	56.08	7.65	60.57	3.16
Frame	43.68	38.44	5.24	37.22	6.46
Totals	320.25	281.08	39.17	299.74	20.51

As recommended before, the figures have more meaning when they are presented in overall project values, in this case per year. There is a greater impact when we look at the figures in this way:

• Total cost of project per year:	£299,740
• Total turnover for project:	£320,250
• Total profit for project:	£20,510

In other words, this company is spending nearly £300,000 per year to gain, say, £21,000. Not a very attractive package when all the risks and effort required to produce this small sum are taken into account.

The position is even less attractive when the figures are projected forward for the five-year life of the project:

• Total cost of project over five years:	£1,498,700
• Total turnover for period:	£1,601,250
• Total profit for period:	£102,550

Admittedly, there may be price increases over this period, but there will also be increased costs, which will simply maintain the status quo resulting in a continuing poor return.

From a purely financial standpoint, this would be considered a very poor return indeed for this type of business. Other forms of investment with less risk may well prove more attractive.

What we have highlighted here is a typical project costing; remember that the profit of £20,510 per year will only be achieved if the whole project runs smoothly without any problems every year for the whole five years.

10.6 Observations

- All jobs should be accurately costed for sufficient return. Immediate action should be taken if any job shows a lower than budgeted return.
- The return on many projects in a significant number of moulding companies is below budget.
- Many companies have more than one loss leader.

10.7 Summary

- All jobs should be accurately costed by an experienced estimator.
- Any job showing a less than budgeted return should be identified and a decision made as to what course of action is to be taken.
- Unless there are strong political reasons for not doing so, the price of such jobs should be re-negotiated and brought back to the budgeted price as soon as possible.
- The so-called loss leaders can be very damaging and should be eliminated, if not immediately then over as short a period of time as can be achieved.

11

The Estimating Function

11.1 Background Required

Estimating is a very important function in all injection moulding companies and is a highly specialist activity, particularly if the company is a custom moulder. This is because there are usually no standard products; every part such a company makes will be different to some degree from all the other products they are currently making or have made before.

In view of the number of variables involved in costing a custom-made component, the estimator should be a highly experienced individual with in-depth knowledge of all of the following:

- Plastic material properties
- Behaviour of polymer flow
- Injection moulding
- Toolmaking
- Mould tool design
- Mechanical engineering
- Basic physics
- Basic electronics
- Robotics
- Injection moulding machine specifications and functions
- Reading and understanding engineering drawings in both printed and computer-aided design (CAD) form
- Costing techniques
- Jigs and fixtures

- Packaging
- Delivery methods.

This is quite a formidable list but all of this knowledge coupled with considerable experience is required for this role as the company will stand or fall on the ability and accuracy with which estimates and therefore quotations are prepared.

Since the requirements listed above are so important, some of these topics are discussed in more detail below.

11.1.1 Plastic Material Properties

It is necessary to be familiar with a wide range of plastic materials and their basic properties for two main reasons.

1. Before a costing can be started, the estimator must know how the material selected for the job is going to behave. For example, is the part relatively easy to mould in this material, or does it require very high temperatures, pressures or lengthy cooling cycles?

   The material may be brittle like polystyrene or styrene-acrylonitrile or quite tough and resilient like nylon or acetal. This will determine the type of ejection system that will be used. For example, more ejection support would have to provided for brittle materials than tough ones to enable them to be ejected without the danger of fracturing.

   The suitability of the specified material must be thoroughly checked to ensure it is has the necessary properties to function adequately in its intended application. The customer may not have selected the best material for the job and the estimator should discuss this with the customer at the earliest opportunity.

   For example, a visiting sales representative from a chemical company or distributor who is naturally going to recommend his company's materials may have unduly influenced the customer in its choice of material.

   Looking at all the different environments to which the part will be subjected frequently identifies potential serious mistakes being made like the following example experienced by the author. A moulding was required in polypropylene. It had a shallow recess in it that was designed to locate an aluminium insert. Despite discussing the 'in service' requirement of the part, the customer did not mention it might need to operate in a high-temperature environment. The customer in this case had not envisaged the part would be required to operate in these conditions. The net result was that the differential expansion between the two materials resulted in the aluminium insert bowing and dislodging itself from the moulding at high temperature. However, the fact that the operating conditions had been queried by the moulder protected it from any blame. In other cases, querying the part function and operating environment can prevent (and has prevented) very expensive mistakes or even disasters.

There are many other examples where the material selected by the customer may not perform as expected in its operating environment, so it is important to ensure this aspect is fully investigated. It is suggested that the estimator should have checklist that will serve as safeguard against such eventualities. A basic checklist is provided in **Chapter 12**.

2. Different materials can behave in markedly different ways from each other during processing. This can often influence the way the mould is designed and the type of mould design that should be used. It can also influence the type of machine on which the part can be moulded.

   A classic example is where a part is going to be made from polyvinyl chloride (PVC). Some PVC materials emit corrosive gases during processing which can be harmful to health if inhaled. They also require different screw geometry due their high sensitivity to heat. In view of this, the material should be run on a dedicated machine suitable for the purpose.

   If certain types of PVC are processed on non-dedicated machines without the correct facilities, many rejects may be produced due to the screw geometry of the machine and the non-return check ring being unsuitable for processing this material. Similar parallels exist with other materials that may require special processing conditions or ancillary equipment.

   Some materials are very expensive and adequate control must be provided to ensure the number of rejects are minimised during production. Processing these materials may attract a higher than normal price. An experienced estimator should recognise such potential difficulties with a job and price it accordingly.

   It is essential that the estimator is aware of the behaviour and requirements of processing many different types of material. If the estimator is unfamiliar with a material, then the properties and processing conditions must be discussed with the material supplier.

11.1.2 Toolmaking

A good working knowledge of toolmaking practices and the plant required is necessary since the basic design and construction of a mould tool is a major factor and has to be established in all estimates.

All designs have to be based on the available manufacturing techniques and processes applicable to both the moulder and the toolmaker. Even at the estimating stage, a very basic mould design has to be decided upon in order to establish a reasonable estimate of runner lengths and methods of construction.

For example, a part may be required with a pronounced textured effect and this may influence the type of mould tool category chosen. If the part were a box shape with two of the faces textured, it may not be able to be withdrawn from the mould without the textured surface becoming scuffed as shown in the two-plate mould design in **Figure 11.1**.

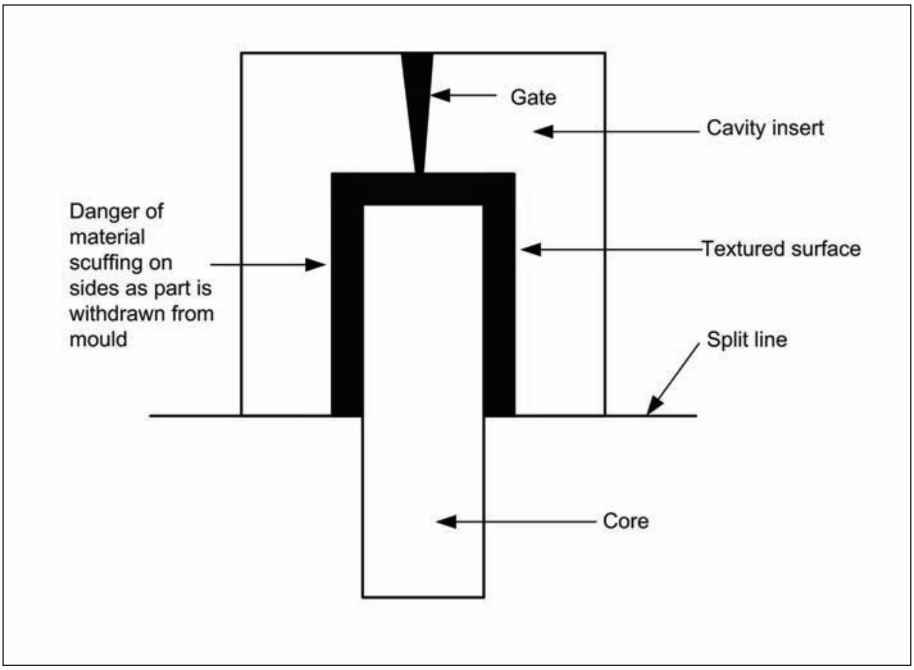


Figure 11.1 Danger of scuffing with two-plate mould

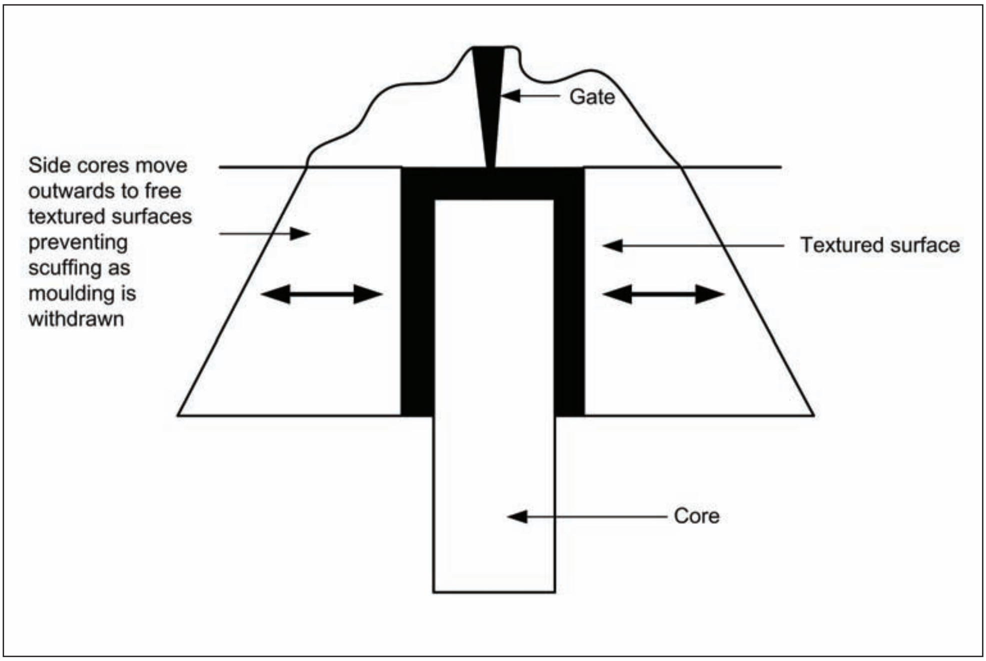


Figure 11.2 Prevention of scuffing with side-core mould

This may lead to a split tool design being selected, as shown in **Figure 11.2**, to prevent this occurring. This is just one simple illustration of the importance of potentially severe problems that may occur if they are not recognised at the estimating stage.

In every case, the estimator must be able to pre-visualise the way in which the mould will be machined to achieve the desired shape and form of the final moulding. In order to do this, the estimator must have a good background of all the basic toolmaking machining techniques including:

- Turning
- Milling
- Surface grinding
- Cylindrical grinding
- Standard electro-discharge machining
- Wire electro-discharge machining

- Polishing
- Texturing.

It is not necessary to have served a full toolmaking apprenticeship but the estimator should have spent some time in the toolroom to be conversant with these basic techniques.

11.1.3 Injection Moulding

Clearly, the estimator must have considerable experience of injection moulding. This is an obvious statement to make but in the author's experience people who have almost no direct knowledge or experience in this field sometimes prepare estimates. This frequently leads to badly over- or under-estimated jobs and can result in loss of business or loss-making jobs, respectively.

Custom moulding is a highly specialist subject with many potential pitfalls for the unwary. Estimating in this field should not be undertaken by anyone who has not had several years' experience in all aspects of this highly technical manufacturing process.

Ideally, this experience should include the processing of a very wide range of moulding materials, moulding machines, ancillary processes and secondary operations.

11.1.4 Mould Design

The two essential elements in producing injection mouldings (apart from the material) are the moulding machines and the mould tool. A moulding cannot be produced without a satisfactory mould tool. Whilst the moulding machine processes and supplies material, it is the mould tool that forms the shape of the component.

Mould tools are often quite complex with many moving plates and cores, limit switches, latches, finger cams, motors and several other components. There are also several different types of established tool designs that are used for different purposes depending on the circumstances, as discussed in the following.

11.1.4.1 Two-plate Cold Runner Tool

A two-plate tool is the simplest type of design available and is used for the production of many thousands of mouldings every year. It should always be the first choice

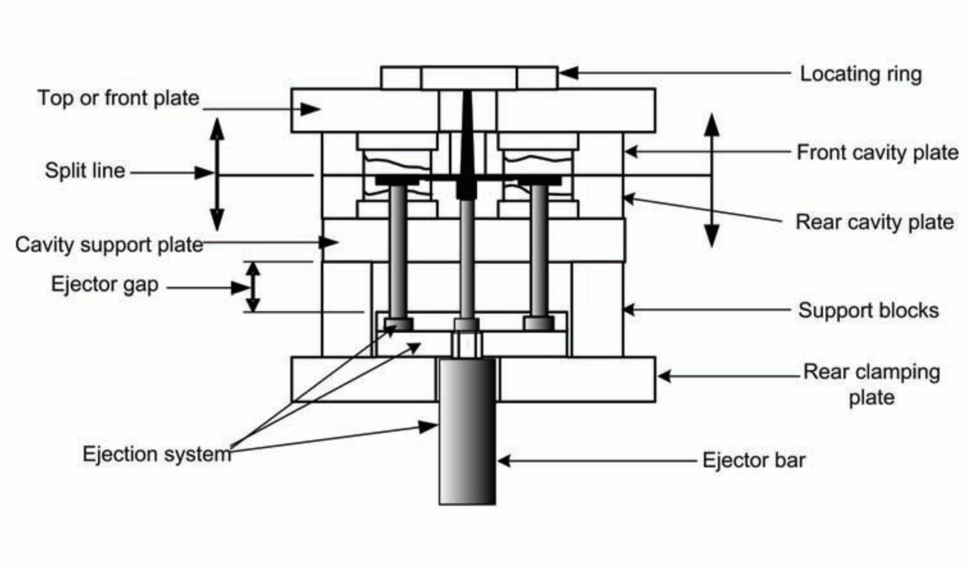


Figure 11.3 Basic two plate tool construction

design for all suitable mouldings. A typical two-plate tool is shown in **Figure 11.3**. Its simplicity of design means it has extremely good reliability in production.

This example shows a cold runner design which means the runner and sprue are a redundant piece of material only serving as channels to feed the molten material into the cavities. Once the mouldings have cooled sufficiently, the runner, sprue and the mouldings are all ejected from the mould at the same time.

Quite frequently, the runner and sprue are granulated and reused by mixing a proportion of it with the virgin (original) material to save on material costs.

This type of tool is usually selected for medium-volume production runs of up to half a million parts per year. If, however, the volume required is sufficiently large, an alternative design is chosen that eliminates the production of a cold runner and sprue each cycle – the hot runner mould.

11.1.4.2 Hot Runner Mould

To avoid producing a cold runner and sprue each cycle, a hot runner mould is used to keep these in a continuously molten state. Thus, only the finished mouldings are produced resulting in shorter cycles and generally higher quality mouldings. A typical design is shown in **Figure 11.4**.

A hot runner design may be used with many different types of tool including two plate, split, side core, auto unscrewing , multi plate and stack tools.

Figure 11.4 shows the hot runner manifold that is typical of the design used for keeping the runner system molten. It consists of a piece of steel in which the runner channels are machined. The manifold is usually heated by cartridge heaters and is fitted with a thermocouple to monitor and control the temperature. This ensures the runner material is kept molten but avoids it degrading.

The production economics of the system are obvious. As there are no runners or sprues produced, much less material is required per part compared to a cold runner two-plate tool. Even if the runner and sprue were to be reprocessed and reused in a cold runner tool, there are still costs associated with reprocessing this material.

A further advantage of this design is that the parts are gated on top of the part instead of at the side as happens in the two-plate design (**Figure 11.3**). This means

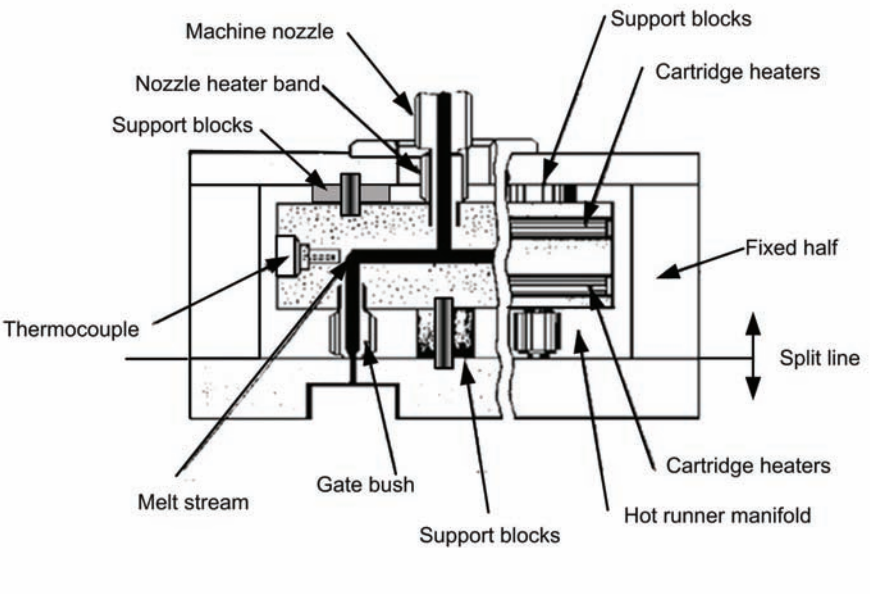


Figure 11.4 Hot runner manifold

the flow of material into the cavities is uniform and more balanced resulting in higher quality parts.

A hot runner tool is preferred to a cold runner tool wherever the costs justify this. The design and manufacture of this type of tool are considerably more expensive than the two-plate cold runner version. Therefore, the quantity of parts needed must be sufficient to make the higher cost of the hot runner tool economically viable.

There are many variations of the basic design show in **Figure 11.4** including hot tips with single impression moulds, extended nozzles and semi-insulated hot runner moulds.

11.1.4.3 Three-plate Tools

There are occasions when parts require gating on the top rather than the side but the quantities required do not justify the higher cost of a hot runner tool. Examples of this are circular components where uniform balanced flow is necessary to achieve maximum concentricity on a technical part with close tolerances.

This design is also used for materials that are very heat sensitive and may degrade if they are kept at consistently high temperatures, as they would be in a hot runner mould. A three-plate mould is more expensive to make than the two-plate design but still considerably less expensive than a hot runner design.

A basic design for a three plate tool is shown in **Figure 11.5**. In this design, a cold runner is produced just like the two-plate tool but, in this case, the gates are placed on top of the parts in the same way as the hot runner tool.

However, it can immediately be seen that the runner and gates appear to be trapped inside the tool that would prevent the mould from being filled after the very first shot. In order to overcome this, the tool splits into three separate pieces at it opens. By allowing the tool to open at the three split lines 1, 2 and 3, the runner is released via split line 1 and 3, and the main split line 2 opens last to permit the mouldings to be ejected. This design is a good compromise between the limitations of the two-plate tool and the unnecessarily expensive hot runner tool for small quantities.

The three-plate mould design is also used where a part needs to be gated on the top but the material is heat sensitive like PVC and acetal.

This design, however, requires accurate moulding machines and regular mould maintenance to prevent breakage of all the sliding control rods.

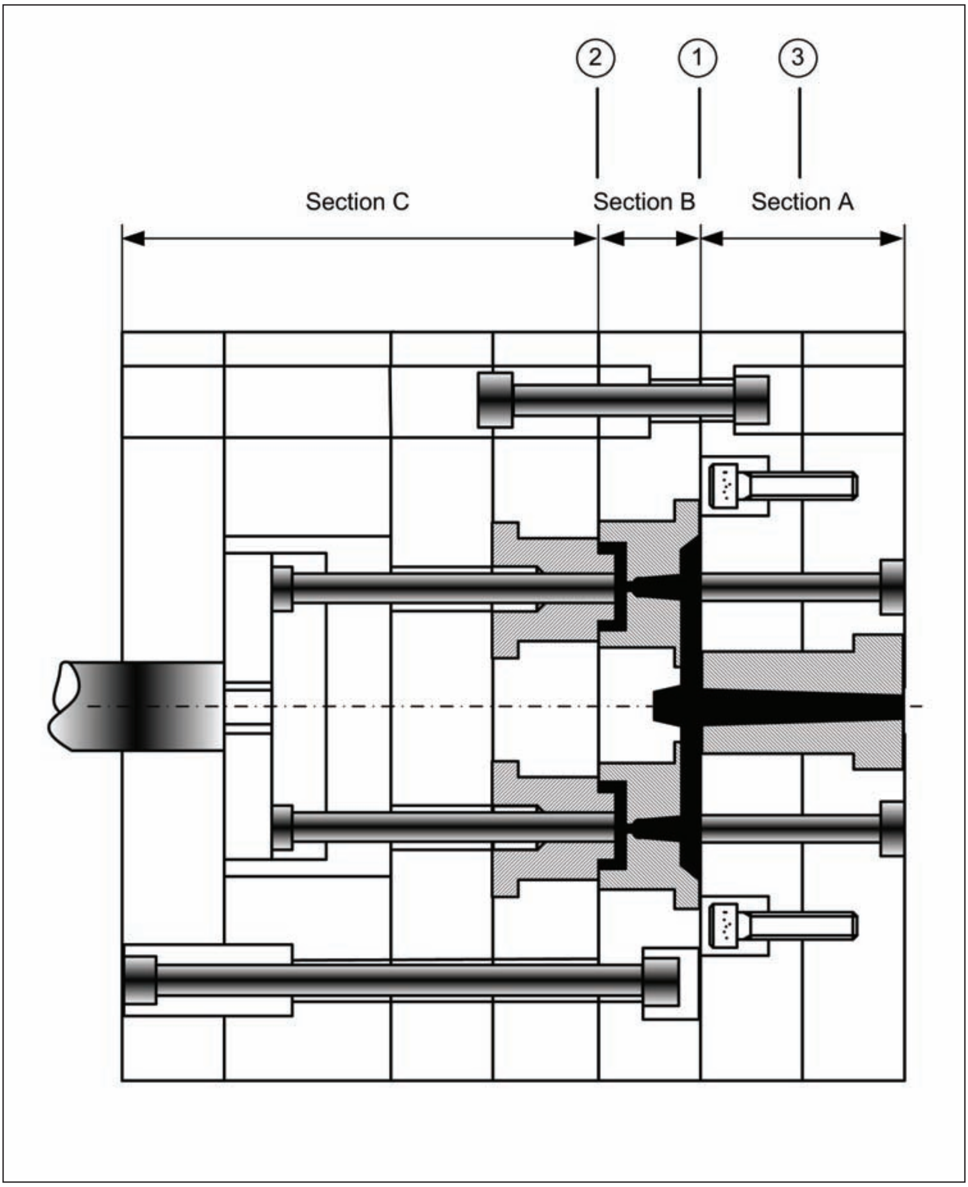


Figure 11.5 Basic three plate tool in closed position

11.1.4.4 Stack Moulds

There are many products that sell in many millions every year. These are usually standard products for the consumer market like DVD cases, closures and similar items. There are also scientific parts required in vast volumes like Petri dishes and similar disposable laboratory components.

All of these items are moulded and sold as standard parts by companies specialising in the manufacture and supply of products for specific markets. Occasionally, however, a custom-moulded part will be required in similarly high volumes.

In all these cases, a stack mould will be the preferred choice, as this design allows for the production of parts at a much lower cost than any of the previously discussed designs. This is because sets of identical components are placed directly in line with each other in a mould tool having two split lines as shown in **Figure 11.6**.

The previous designs have only one main split line, and the machine locking force is calculated by multiplying the projected area of the parts by the injection pressure to arrive at a minimum locking force. The machine selected would have to be one with a greater locking force than that calculated to ensure the mould is prevented from opening during the period when the material is injected.

By placing the components as shown, each set of two in-line parts have the same projected area as a single part. This results in a halving of the locking force required over a conventional design with the same number of impressions. Hence, the mould may be run on a machine of half the locking force at a much lower cost.

However, the plasticising capacity and the shot weight capacity of the machine would have to be sufficient to support the greater than usual shot weight. See *The Mould Design Guide* [1] by the same author for an in-depth discussion of the different types of mould designs discussed here.

11.1.4.5 Mechanical Engineering

There will be occasions when a mould design for a part needs control systems, unscrewing modules, latching mechanisms and so on. Therefore, the estimator must be familiar with general mechanical engineering concepts and design practices.

Clearly, a complete design for a mould would not be undertaken at the estimating stage as this would be time consuming and costly. This is because many quotations that are submitted to a customer do not result in an order but all enquiries have to be processed to stand a chance of gaining one.

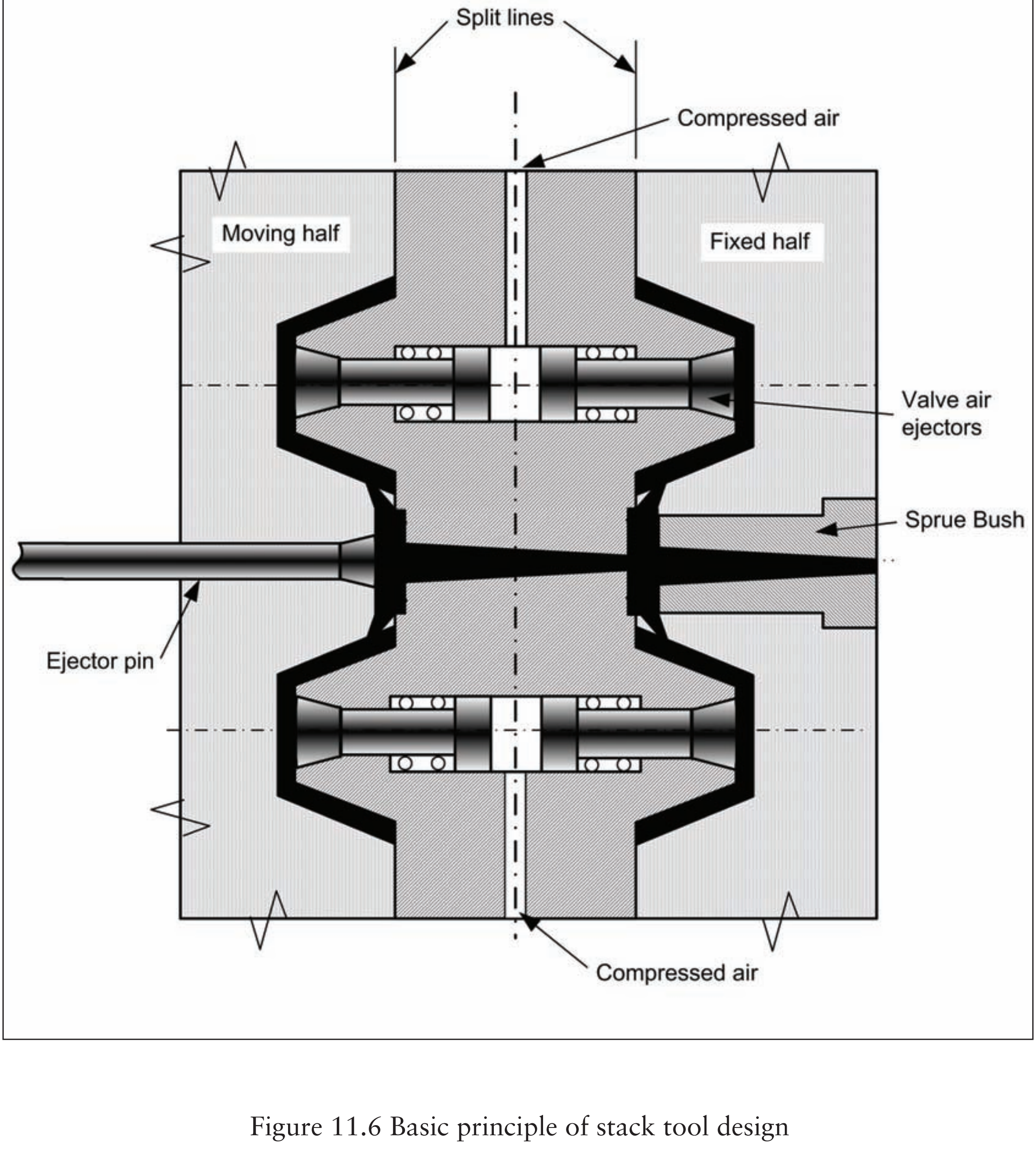


Figure 11.6 Basic principle of stack tool design

In view of this, it is not possible (or desirable) to spend too much time on each enquiry. This is why the estimator needs to be very experienced in all aspects of injection moulding from materials through mould design to production to enable estimates to be prepared quickly and efficiently.

However, it is at the estimation stage that all the major decisions on basic mould design and all the other factors involved have to be taken. If a quotation results in an order being placed, there will be little chance of redeeming the situation if a major mistake has been made at the estimation stage.

11.1.4.6 Basic Physics

A knowledge of basic physics is necessary to understand the flow properties of materials and the forces generated during the moulding process.

Again, completely detailed analyses are not carried out at this stage but certain factors like establishing the number of impressions, machine locking forces, part weights, runner sizes and weights have to be established accurately at this point.

11.1.4.7 Basic Electronics

This is included because mould tools may have to have electronic control systems from basic micro-switch control to more complex logic circuits to control complex mould sequencing functions.

A deep knowledge is not necessary but the basic elements must be known to include any necessary electronic modules into the cost of a mould. Frequently an electronics company will be consulted for more complex systems but the estimator has to have sufficient knowledge of the subject to discuss the requirement with the experts to be able to make a choice of the systems they propose.

11.1.4.8 Robotics

A robotic system may be required to remove mouldings from the tool to place them on secondary operation equipment or on jigs and fixtures to support mouldings that may have a tendency to warp or distort.

It is necessary to have an understanding of robotics to decide their suitability, the options available and the costs associated with these.

11.1.4.9 Moulding Machine Specifications

These must be known in detail, as in many moulding shops several of the machines have different specifications. For example, there are options like core pulling, multi-stage ejection, hydraulic ejection, special computer control, heated platens and so on.

The decision as to which machines a job will run on is fundamental to the estimating process since different machines will have different machine hourly rates depending on their size and degree of sophistication.

11.1.4.10 Understanding Engineering Drawings

This is another fundamental requirement. A complete understanding of this is essential.

All enquiries are normally sent with an engineering drawing that specifies the exact requirements for the moulded parts. Estimators need to able to challenge drawings that are ambiguous and to be able to assess drawing tolerances and part geometry. Close tolerances are frequently overlooked at the estimating stage and can lead to serious problems in production.

It stands to reason that parts with close tolerances will need a higher degree of control during production than those that do not. Hence, these parts should be charged at a higher rate.

Therefore, it is necessary for the drawing to be scrutinised thoroughly at the earliest opportunity to identify any potential problems.

Familiarity with CAD is also necessary as many enquiries are now supplied in CAD form.

11.4.1.11 Costing Techniques

This is another fundamental requirement. It is unlikely that estimators will have been responsible for designing a costing system, but they may have collaborated with those that have.

Usually a costing system is based on a range of foreseeable circumstances and will cover the majority of jobs on which a company is asked to quote. However, there will be occasions when a part falls outside these predetermined parameters and the estimator will have to recognise this and apply a further adjustment to the quoted price of the part. Examples of this are:

- Parts that are very complex;
- Parts with very close tolerances;
- Materials that require special moulding techniques or are difficult to process;
- Parts required in custom colours (be very wary);
- Components with special textural requirements;
- Thick wall sections;
- Extremely thin wall sections;
- Materials of which the moulder has no previous experience;
- Parts that will be used in extreme environments; and
- Parts that are difficult to eject;

This list is not exclusive and there can be many more potential pitfalls.

11.1.4.12 Jigs and Fixtures

Sometimes parts need to have secondary operations carried out on them like inserting threaded metal inserts, painting or texturing, or have to be supported while they are cooling and so on.

Such processes will incur additional costs. Hence, adequate knowledge of the methods and equipment needed is necessary. These costs are frequently underestimated!

11.1.4.13 Packaging

This cost must not be overlooked. In most cases, the parts are simply bagged, placed in cardboard boxes and despatched. The normal costing system should cater for this type of straightforward arrangement but there will be occasions when it does not and special packaging is necessary. Examples of this are:

- Delicate mouldings that may get damaged;
- Mouldings with textured or painted finishes that may get scratched; and
- Parts that may get distorted.

11.1.4.14 Delivery Methods

Once again, most delivery costs should be covered by a company's standard costing system. However, customers often want parts in a hurry and it is all too easy to arrange a special delivery. This happens with many large companies operating stringent just-in-time policies (and possibly running out of parts!).

The problem is that such special deliveries are usually very expensive compared to more normal methods. The safest way of dealing with this is to invoice such deliveries at cost or cost plus if necessary.

The estimator should make sure the customer is aware of the normal delivery arrangement at the quotation stage and make this clearly understood in the quotation.

Reference

1. P. Jones, *The Mould Design Guide*, Smithers Rapra Technology Limited, Shawbury, UK, 2008.

12

The Estimating Procedure

12.1 Information Required

The first stage in preparing an estimate is to ensure that all the relevant information is available. This sounds like an obvious statement but it can be easy for an important piece of information relevant to the enquiry to be overlooked or cause delays if it is not complete. This can be for several reasons. For example:

- The customer has not clearly defined the material required for the part;
- A drawing is missing from the enquiry and sample parts have been supplied instead; or
- The finish of the part has not been specified.

These are just a few of the many problems that can occur through insufficient information being supplied by a customer. In view of the fact that a substantial amount of information must be available before an estimate can be prepared, it is advisable to have a comprehensive checklist to ensure that nothing is missed.

The following checklist has been derived from many years of estimating experience.

12.1.1 Estimating Checklist

The following details need to be available, investigated or queried if not known:

1. An engineering drawing fully describing the part
2. Suitability of the part for the moulding process
3. Material specification
4. Material compounding requirements
5. Material drying requirements

6. Material colour specification
7. Material additives specification
8. Function of the part (operating conditions)
9. Part tolerances
10. Finish required
11. Number of parts required
12. Number of impressions required
13. Type of mould tool required
14. Machine cycle
15. Shot weight
16. Machines that will be suitable to run the part
17. Gating positions
18. Split lines and witness marks
19. Ejection positions and witness marks
20. Robotics
21. Inserts
22. Inspection
23. Secondary operations
24. Packaging requirements
25. Delivery requirements

12.1.1.1 Engineering Drawing

It is an essential requirement to have a complete, unambiguous engineering drawing that uniquely defines the customer's requirements. If a drawing does not supply this information, the estimator should advise the customer immediately to resolve any queries, like undesirable moulding geometry or any other issues (like ambiguity or impossible tolerances) that may prevent the production of mouldings to the necessary standard.

An engineering drawing can be construed as a legal document that is binding on both parties. Once an order is placed with a supplier it should be accompanied by a finished drawing with a unique drawing and issue number and dated. The customer's order must refer to this number, issue and date.

Once a customer has placed the order and the supplier has accepted it, a contract has been made between them. The order, of course, will include other details that have been agreed, like the number of impressions and other requirements for the mould tool, delivery and so on.

All the order details should be checked to see that they conform exactly to the information that the estimate has been based upon. It is not unknown for the final drawing that is issued with an order to be different from that supplied for the quotation.

The engineering drawing is of extreme importance because it represents exactly what is required and should prevent any argument by either party as to whether the resulting mouldings are satisfactory or not.

Occasionally, a drawing is not available when a supplier is asked to provide a quotation and a moulding or a machined sample is supplied instead. If this is the case, the supplier should make clear that they are supplying a 'budget' quotation only, which is based on the sample. They should reserve the right to revise their quotation once an acceptable drawing is available.

The reason for this rigid approach to the provision of a satisfactory engineering drawing is that occasionally disputes will occur regarding the quality of the parts supplied. If such a drawing has been provided then the dispute should be able to be resolved fairly quickly. If the dispute cannot be resolved and the issue goes to court, it will normally be the customer's order and drawings and the suppliers adherence to them that will determine the outcome.

In short, it is makes everything very much easier if both parties have agreed on exactly what is going to be made.

12.1.1.2 Part Suitability

This is another obvious statement. The part must be suitable for manufacture with the injection moulding process. Excessively thick- or thin-wall sections may be unachievable in production as may be unsatisfactory web or boss designs, or other unstable geometry conditions. Difficult surface finishes and very close tolerance dimensions are other potential sources of problems.

The experienced estimator should recognise obvious potential problems quite easily, but a conscious effort must be made to scrutinise the drawing as some problems can be quite subtle and sometimes they can be overlooked.

12.1.1.3 Materials

The estimator will normally be well versed in a wide variety of moulding materials and should be able to assess the suitability of the specified material for processing and production.

Where an unfamiliar material is specified, the estimator should seek information and advice from the material supplier before going any further.

Some materials are ‘difficult’ to process. This may be for a variety of reasons like very high or very low viscosity, brittleness, corrosive effects on the mould tool and so on. In such cases, a value judgment should be made as to whether to provide a quotation or to decline to. If the decision is the former, it may be advisable to add a premium to the cost of the material.

12.1.1.4 Compounded Materials

If a standard material is not available, it may have to be compounded by a recognised, specialist supplier. In most cases, this works well but sometimes problems will occur.

If this material is one with which the estimator is unfamiliar, then caution is advised and at least a sample of the material tried before any commitment to accepting the job on a production basis. Even then, problems can still occur.

However, the author has had several bad experiences with some compounded materials which performed well in pre-production trials but not when used in volume production.

12.1.1.5 Material Drying

Some materials are hygroscopic and can absorb significant amounts of water once they are exposed to air. In some cases, the use of a heated hopper with evacuation facilities may be sufficient, but in other cases materials may require drying in a vacuum oven.

In the latter case, the moulder may consider adding an on cost to the material to cover the extra costs involved. On balance, this is preferred since, if these ‘extra’ costs are included in with the general overhead, they have the tendency to make other jobs with non-hygroscopic materials less competitive as this cost will be amortised over all jobs.

12.1.1.6 Material Colour

Certain material colours can be more troublesome to process than others. In addition, the same material in different colours frequently requires different processing conditions. This is usually due to the pigments or other additives that may be used.

Remarkably, sometimes the same material moulded in another colour can pose severe difficulties. Whereas when moulded in one colour the parts can be moulded quite easily, in another colour moulding can be extremely difficult, and in a few cases almost impossible to mould at all.

In view of this, if a customer requests a colour change for a part it is advisable to run trials in the new colour first and charge this as a development cost. This is necessary, since the trials will identify tool modifications that may be necessary or moulding cycles that need to be extended.

Compounded materials in special colours can be also be troublesome with varying colour dispersion giving rise to mottled and other undesirable effects. Sometimes it can be impossible to achieve satisfactory results.

12.1.1.7 Material Additives

The flow and processing behaviour of a material may change considerably if other substances are added to it. There are many additives available; a few of the most common ones are listed below:

- Fire retardants
- Lubricants
- Flow promoters
- Nucleating agents
- Plasticisers

- Fillers like glass fibres, carbon fibres, talc, etc.
- Antioxidants
- Fungicides
- UV stabilisers.

Additives like these can significantly change the processing conditions from those required for the base or unmodified material.

12.1.1.8 Part Function

All too frequently, a customer places an order with a supplier, providing all the relevant information – except the function of the part. In other words, the customer has not mentioned the environment in which the part will be expected to operate. In such cases, the moulder cannot be held responsible if the part fails to function properly in service.

However, it is sensible for the estimator to establish that the material specified by the customer will perform satisfactorily for its intended purpose. Clearly, this will enhance customer relations if errors are discovered.

Areas where problems may occur are where parts are required to operate:

- at very high or low temperatures;
- in chemicals;
- under water;
- at high speeds;
- under extreme mechanical, hydraulic or electrical conditions;
- when glued or stapled to other surfaces;
- as electrical insulators;
- as bearings;
- in abrasive environments;
- as appearance products;

- in a gas other than air; or
- in medical or pharmaceutical applications.

This list is not exclusive but it is representative of the types of conditions under which parts may have to operate. A quick call to the customer can prevent disasters occurring through the wrong choice of material.

12.1.1.9 Tolerances

One of the major problems that moulders face is achieving all the tolerances specified on the drawing. Sometimes, the tool dimensions will have to be modified, but frequently there can be some dimensions that prove difficult to hold within tolerance during production whatever the dimensions of the cavities and cores.

Parts that have close tolerances and could be difficult to produce should be recognised at the estimating stage. Among the things that should be considered are:

- The number of impressions required to mould to the required level of accuracy on a continuous production basis. In too many cases, this is not given sufficient consideration.
- Are the moulding machines the correct shot weight rating for the job? The shot weight of the machines should ideally be no more than 15–25% greater than the shot weight being moulded. This will give more control and higher quality.
- Are the moulding machines accurate enough?
- Is the material satisfactory for close tolerances to be held?
- Does the company have sufficient expertise in this area?

12.1.1.10 Finishes

The normal finish specified for a moulding is a polished one. It is a straightforward (but laborious) procedure for a toolmaker to polish cores and cavities, and, in general, there are not too many problems associated with this type of finish.

However, polished finishes can cause trouble with certain types of parts. These problems occur where parts are difficult to eject, where the moulding ‘sticks’ firmly to a highly polished core. This problem can be worse for a component with a closed end. As ejection takes place, a partial vacuum is formed at the closed end due to the highly polished core not allowing any air into this area. This problem increases as the length of the polished core increases.

If this is recognised at the estimation stage, provision for a valve ejector in the tool should be made. This can be designed to provide atmospheric or compressed air to release the vacuum.

Clearly, this will increase the tool cost, so this potential problem should be recognised with these types of components with this type of finish.

Textured finishes may also require special consideration as previously discussed. These finishes may need a side core design to release the undercut formed by the texture, as shown in **Figures 11.1** and **11.2**.

It can also be difficult to mould matt finishes. These often require precise moulding conditions combined with close control over mould tool temperatures.

12.1.1.11 Number of Parts Required

The customer will specify the number of parts required on the enquiry. Very often, the customer will ask for price breaks for a number of different quantities.

Naturally, they will be expecting lower prices as the quantities increase, and in most cases the estimator will apply a sliding scale of charges that reflect the amount of business each quantity would generate. The sliding scale of charges should be based on the amount of expected revenue from each quantity. Usually a predetermined scale of charges exists to cover most eventualities.

Note that in some larger industries, the customer will expect a ***price reduction*** 12 months after a new part goes into production. The philosophy behind this is that during this period the moulder will have had time to optimise all the costs (and therefore should be able reduce them). Clearly, this is a significant factor and all estimates subject to such downward price revisions must be very carefully analysed before a quotation is submitted.

This system of annual price reductions can also cause severe problems if the original quantities on which the estimate was based start to decrease due to market changes. In these circumstances, it would be reasonable to expect that the contract be re-negotiated.

12.1.1.12 Number of Impressions

This is one of the most important decisions that has to be made since it will determine:

- the production rate;
- the degree of control over the quality of the mouldings, including dimensional accuracy, surface finish, voiding, physical properties and so on; and
- the cost of the mould tool.

The number of impressions selected for a job cannot be changed other than by 'blanking off' once a mould tool is made, so mistakes when a tool does not perform as expected often cannot be rectified.

This topic is such an important one that it is discussed in more detail at the end of this chapter.

12.1.1.13 Type of Mould Tool

This is another fundamental decision that has to be made. The vast majority of mould designs fall into the five basic categories broadly discussed in **Chapter 11** (**Figures 11.1–11.5**).

Experience in mould design and general mechanical engineering is essential to ensure the correct mould tool design is chosen to achieve satisfactory production.

There is one golden rule in every field of design – the simpler the design, the better it will work in production and *vice versa*.

12.1.1.14 Machine Cycle

This is one of the main cost components of a job and has to be quite accurate since:

- if it is too short, the job will be under-priced; and
- if it is too long, the job will be overpriced which can lead to the quotation being non-competitive.

Previous experience in this area is essential as there are no ‘magic formulae’ that will provide this information with the required degree of accuracy.

There are some programs available that will simulate mould flow and basic moulding cycles, but these are very expensive. However, some larger companies already use this or other computer-aided design (CAD) software for mould design purposes.

However, such programs do not always produce accurate results, as many of the variables existing during the moulding process cannot be quantified. These conditions can also be different in different moulding companies but CAD software does offer a reasonable guide.

Another drawback is that, from the estimation point of view, it is not normally cost effective to use these programs at this stage since they can take a long time to set up and would seriously reduce the time available for estimating.

Consequently, most companies rely on the experience of the estimator who should have considerable familiarity with a sufficient number of previous jobs to estimate a quite accurate cycle time. Material manufacturers will supply information that usually relates cooling times to the wall thickness of the part that can be useful when using unfamiliar materials.

It should be remembered that with a cold runner tool it is usually the runner and sprue that have the thickest sections. Hence they will determine the cooling period and not the mouldings.

12.1.1.15 Shot Weight

This comprises the total weight of all the mouldings, runners and the sprue (if present) that are produced each time the mould opens. The estimator normally draws a portion of the mould layout that is sufficient to show the arrangement of the impressions and the runner system. This will determine the dimensions of any runner system and sprue present.

These weights are easy to work out by hand either with a calculator or by using CAD. However, an accurate result is necessary as the material cost together with the machine hour rate (MHR) cost for the machines are the most significant costs in any job.

12.1.1.16 Machine Requirements

One of the first requirements is to make sure a job can actually be produced using the machines the moulder has available. Therefore, a careful analysis of the job is vital at the earliest stage of estimation. Assuming the moulder has machines that are capable of moulding the job, the main considerations are:

- the shot weight of the job;
- the projected area of the mould tool;
- the physical dimensions of the mould tool (estimated at this stage);
- machine facilities required including locking force, stroke, mould height, ejection facilities, etc.

It is recognised that the physical dimensions of the mould tool cannot be determined accurately at the estimation stage, but the estimate must be near enough to prevent expensive mistakes being made. The others must be reasonably accurate as they form the basis for selecting an appropriate machine.

For example, the locking force determines the MHR in most cases. Therefore, if the estimator bases the estimate on an incorrect value, the job either will be under- or overpriced.

12.1.1.17 Gating

The gating position has to be decided from the outset, as this frequently determines the type of mould tool required. It will often determine:

- the quality of the part (dimensional accuracy, physical properties, sinks, voids, appearance and cycle times, etc.);
- the method of degating (automatic, semi-automatic or hand); and
- the performance of the mould in production.

If the part is a closely toleranced one, has critical appearance requirements or has very thin- or very thick-wall sections, the gating position may be critical to the successful moulding of such parts.

In these cases, it is suggested that the estimator discusses these issues with the customer to agree gating positions before proceeding any further with the estimate.

Such discussions sometimes lead to modified part design to accommodate critical gating positions.

If the customer is not advised of these potential difficulties at this stage and an order is subsequently placed for the manufacture of the part, these issues will simply be deferred until the mould design stage. This in turn may lead to the customer redesigning the part or even abandoning the part altogether in favour of a different approach at this point. This would mean time (and therefore cost) has been wasted in preparing a full estimate and a partial mould design.

12.1.1.18 Mould Split Lines

These have to be determined at the beginning of the estimate to enable a decision to be made on the basic design and construction of the mould tool. This again can be critical to the correct functioning of the mould in production and the part quality. Sometimes, more than one choice is available, in which case the simplest option that will work should be chosen.

In the same way that the gating position may cause functional or appearance problems with the part, so too can the split line positions. Hence, these should be checked with the customer at an early stage if a problem is envisaged.

12.1.1.19 Ejection

The position of the ejectors in a mould tool is also very important. They must be positioned so that they fully support the moulding as they eject it from the mould at the end of the cooling period.

A balanced ejection system is desirable wherever possible to prevent excessive deflection of slender ejector pins. However, at the estimation stage, we only need to establish the ejection system in principle. The more detailed analysis of the ejection system is usually left until the mould design stage.

The only exception to this is if the desired ejection positions clash with obvious appearance or functional faces. If this is the case, the problems should again be discussed with the customer as soon as they are detected.

12.1.1.20 Robotics

As previously discussed, some components may require removing from the mould with a robot to support fragile mouldings whilst moving them to a cooling jig to prevent distortion while they are cooling.

Robotic devices may also be used to transfer mouldings to a jig for some secondary operations like drilling or automatic insertion of other components. With high volume closure parts, robotics are sometimes used to perform 'in mould closure' functions (where a closure consisting of a body and a lid has been moulded and the lid needs to be closed over the body in the mould tool).

If a company only uses a few robotics devices then these should be charged to that particular job. Otherwise, the charge for these will be amortised out over all the machines and have the effect of making all the MHR for the non-robotic machines more expensive. This again will make such work more expensive and, thus, less competitive.

If, however, robot systems are used extensively for most work, it may be preferable to amortise the cost over all the machines.

12.1.1.21 Inserts

These usually fall into two broad categories:

1. Metal components that are placed into the mould while it is still open. After the mould has closed and the injection phase has finished, the insert has become an integral part of the moulding. Examples are threaded metal inserts and, sometimes, metal bearings.
2. Components that are force fitted or screwed into the moulding after the mould cooling phase has finished and the part ejected.

Depending on the volume required and the complexity of the operation, robotics systems may or may not be used.

It is necessary to determine the loading or insertion method in principle at the estimation stage as this will affect the cost considerably.

12.1.1.22 Inspection/Quality Assurance

Quality assurance is normally considered a works overhead and should be included in the MHR costing being used. However, some jobs require much heavier monitoring and inspection than others and these jobs should attract an ‘on cost’ to cover this.

For example, a job may need someone to be present at a machine to inspect a critical dimension or feature on a continual basis. Clearly, a special charge would have to made for this. This is usually the basic cost plus a profit element.

12.1.1.23 Secondary Operations

There are occasions when a moulding requires a second operation to be carried out. Examples of these are:

- Painting
- Printing
- Hot stamping
- Drilling
- Tapping
- Welding
- Hot staking
- Gluing

In each case, some special-purpose machinery will have to be designed or purchased to suit the job and the operation required. Some companies may have a large amount of work that has to have secondary operations like these, and in these cases the machinery used should be costed in the same way as that suggested for the moulding machine MHR.

12.1.1.24 Packaging

Usually, a company has a standard charge for packaging based on a variety of different sized cardboard boxes. This cost can be applied for a large range of mouldings.

On other occasions, special packing costs will have to be applied where extra protection or special stacking may be necessary to protect mouldings during transit and storage. These should be charged at cost or a cost plus basis.

12.1.1.25 Delivery

Once again, a standard charge is usually made for this. This can be included as a separate standard charge or, if a suitable relationship exists, it can be included as part of an MHR cost.

12.2 Using the Right Number of Impressions

The decision concerning how many impressions a mould tool should have is frequently given insufficient thought. The usual approach is as follows. The production rate of any mould tool is given by the expression:

$$\text{Production rate per hour} = \frac{3{,}600}{\text{Cycle}} \times \text{no. of impressions}$$

When a new mould tool is being considered, however, the expression is rearranged to estimate the number of impressions necessary to achieve a desired production rate:

$$\text{No. of impressions} = \frac{\text{Production rate per hour} \times \text{cycle}}{3{,}600}$$

If we take the example of a required production rate of 1,800 per hour being necessary to meet production schedules, the number of impressions required to achieve this with an estimated cycle of 15 seconds is:

$$\frac{1{,}800 \times 15}{3{,}600} = 7.5$$

Clearly, this result would be rounded up to 8 impressions or sometimes a higher number to accommodate rejections and provide buffer stocks.

Having established this, the next stage is to determine on which machine the mould tool will run. Apart from the physical size of the tool, the other main limiting factors are the shot weight and the projected area of the mould. Once these factors have been resolved, the mould tool may be designed to fit on the selected machine.

In many cases, this approach is satisfactory but a significant number of projects do not prove satisfactory in production when designed on this basis. This is often because the moulded parts do not meet the quality requirements. There are three main reasons for this:

- the mould tool design is unsatisfactory;
- the machine is not capable of producing the parts to the required quality; and
- the machine and the mould are adequate but the number of impressions being used is too great for proper control.

If the mould tool design is incorrect, this can prove to be a very costly mistake. Major alterations to tools can be very expensive and time consuming. Worse than this, some tools that do not run properly due to errors in design cannot always be rectified – new ones often have to be made.

Putting the job on another more suitable machine, if one exists, may address the second reason. The third reason, however, is more difficult to resolve, and frequently even impossible.

12.2.1 Quality versus Quantity

This is an age-old expression, but it illustrates perfectly the situation described above. The term ***quality*** covers a wide range of conditions that a part may have to conform to in order to meet a customer's requirements. Among these are:

- the appearance of the part;
- the part geometry; and
- the drawing tolerances.

Assuming the mould design is not at fault, a frequent cause of failure to meet quality requirements is due to using too great a number of impressions. In general, the greater the number of impressions a mould tool has, the less control there is over the individual impressions. Variations will exist between the impressions owing to differences in manufacture, pressure, temperature, gate sizes and so on.

In order to minimise these differences, runner layouts and gate sizes may be balanced, but despite this there will still be finite variations in pressure, thermal gradients, impression sizes and other parameters that make multi-impression tools sometimes difficult to run.

The three categories mentioned above are those that many moulders may have difficulty with, through using too high a number of impressions.

12.2.2 Appearance

Many mouldings are required to fulfil an appearance role as well as a functional one. Any moulding that will be used as part of a point of sale product has to be free of obvious blemishes: a sub-standard-looking part is clearly undesirable.

The greater the number of impressions, the more variation there will be in any sinking, voids and other internal and external defects. As the runner system gets longer, the more difficult it is to properly pressurise every cavity.

As a result of this, pressures are often increased to try to eliminate sinking and to preserve special surface finishes. This in turn can lead to some parts being over pressurised and perhaps flashed while others are under pressurised. Carefully balanced systems will help reduce this effect, but inevitably unsatisfactory variations can remain with large cavity-number mould tools.

Sometimes very small variations are acceptable and will be deemed to be within specification by the moulder and the customer. This can only happen if both parties are clearly aware of the likely results and if these are fully defined and understood.

If the appearance requirements are critical or demanding, careful consideration must be given to using a smaller rather than a larger number of impressions.

12.2.3 Part Geometry

Owing to the same variations, mouldings with complex part geometry need a great deal of control during processing. To avoid warpage, distortion or shorts (with thin-walled parts), the same philosophy applies.

The fewer the number of impressions, the greater the control and consistency will be between different impressions. Strict control of moulding conditions and the mould temperature is necessary for consistency.

12.2.4 Drawing Tolerances

If the tolerances required on the mouldings are very small, a high-quality mould tool and a good-quality machine with adequate closed-loop control are necessary.

In addition, the mould tool cavities will have to be machined very accurately and as close to the same dimensions on all impressions where the close tolerances apply. In other words, for such parts it is necessary to get as near to identical cavity and core sizes as possible.

Again, the greater the number of impressions employed, the less control there will be and the greater the dimensional variance between mouldings from different cavities. Accurate mould temperature control is also essential for such parts and high thermal gradients should be avoided. All of these requirements get increasingly difficult to achieve as the number of impressions increases.

12.2.5 Discussion

Much experimental evidence exists that supports the proposition that consistency of quality decreases as the number of impressions increase. Trials carried out in trade moulding shops also support this view.

The problem gets worse with high-shrinkage materials where greater variations are often experienced. The same is true of materials that are difficult to mould (those with high processing temperatures and certain filled materials). High-viscosity materials are always difficult to mould consistently and large numbers of impressions are to be avoided in many cases.

Using software to simulate the filling of mould cavities will help to achieve more balanced filling conditions, but the same principle applies: *more cavities = less control*.

On the other hand, mould tools must have sufficient capacity to support production levels wherever this is possible. As the number of impressions on a tool is almost always decided at the estimating stage, the number actually selected will clearly influence the part price and hence how likely a moulder will be to obtain the work.

However, the temptation when estimating is to select a higher rather than lower number of impressions to make the part price more attractive to the customer. The perennial problem is that when a moulder provides a quote to a customer, the moulder does not know on what basis its competitors have quoted.

In many cases, where a moulder has responsibly decided on a low number of impressions for a part, another moulder may have based its quotation on using a higher number and this frequently leads to the responsible moulder losing the job. This is often due to the customer's lack of understanding of the relationship between large numbers of impressions and part quality.

Despite this, moulders in general should be more aware of the repercussions of basing quotations on tools with large numbers of impressions that will be unlikely to provide the required quality. This can lead to failure to supply parts to the quality required and to the disaffection of the customer.

However, customers are increasingly becoming aware of some of the pitfalls in accepting superficially 'attractive deals' and are themselves becoming more knowledgeable. This has come about in 'self-defence' in trying to avoid costly failures and delays on production lines.

The question arises: how is the correct number of impressions to be established? The answer is not straightforward. Much will depend upon the experience and expertise of the moulder, the nature of the part and what type of processing equipment and material are used.

Clearly, there are situations where the number of impressions is not so important. Open-tolerance washers, for example, can be moulded with large numbers of impressions quite happily. With this type of part, the emphasis changes to finding a machine large enough to accommodate a large tool with a high number of impressions.

On the other hand, some quite complex, closely toleranced parts are very small. The shrinkage on these will be almost zero and the sizes of the moulding very close to the cavity sizes. This is another case where a larger numbers of impressions may be used.

Table 12.1 Recommended numbers of impressions (A, amorphous materials; SC, semi-crystalline materials)

Part diameter (mm)	Material	Maximum number of impressions
≤5	A or SC	Unimportant
5–10	A	16
5–10	SC	12
11–20	A	8
11–20	SC	6
20–30	A	6
20–30	SC	4
>30	A	2
>30	SC	1–2

However, for the majority of typical 'trade mouldings' applications, the number of impressions used is important.

It difficult to quantify the actual number of impressions that should be used, but **Table 12.1** provides a rough guide based on past experiences. This table is based on a smallest tolerance of ±0.05 mm. Clearly, these figures are very general and the actual number chosen will depend on the geometry and the complexity of the part, but beware if your chosen number of impressions starts to exceed these significantly. As a guide, but again a generalisation: as the tolerances double, the number of impressions can increase by 50%. If the appearance of the part is very critical, use the semi-crystalline material suggestions.

The following guidelines are suggested as a 'checklist' to avoid expensive mistakes.

1. If any of the following apply to a moulding, *select a lower rather than higher number of impressions*. Decide on the maximum number of impressions for adequate control *before* calculating (2) below:

- Close tolerances
- Complex geometry
- Very thin-walled sections
- Demanding appearance requirements
- High-shrinkage material
- High-viscosity material
- High-melting-temperature material
- A semi-crystalline engineering polymer
- Mouldings that may be difficult to eject
- Materials with high levels of filler
- Parts that have to be made in special colours.

2. Determine the number of impressions required to fulfil production requirements using the expression

$$\text{No. of impressions} = \frac{\text{Production rate required per hour} \times \text{cycle (seconds)}}{3{,}600}$$

To allow for contingencies, increase this number by between 10% and 25% depending on the individual job.

3. If result (1) above is equal to or greater than result (2), choose (2) for the number of impressions. If result (1) is lower than result (2), choose the lower number of impressions indicated by (1). In this case, the potential customer should be given reasons why this is the case. There is little point in moulding high quantities of mouldings from mould tools with a large number of impressions if they fail to achieve the necessary quality.
4. Once the number has been established, select a suitable machine on which to run the job.

12.2.6 Summary

- Demanding parts are more difficult to mould require more control.
- Using fewer rather than a greater number of impressions achieves better control, quality and accuracy.
- Using too high a number of impressions can lead to quality problems, incurring extra cost and possibly damaging customer relations.

13 Estimating a Typical Job

13.1 Estimate Example

We have dealt with a large number of the elements that are involved in estimating. It is now time to draw all of these together with an illustration of a typical estimate. This will follow all the stages that an estimator would have to work through in order to provide a finished quotation for a custom-moulded part. The estimate will be based on an machine hour rate (MHR) costing.

Our fictitious company ABC has received an enquiry from another fictitious company, Valve Products. The basic elements are discussed in the following sections.

13.1.1 The Enquiry

Please provide your best price and delivery for supplying the following items to our drawing number XZP1247M:

- Part: valve head
- Part no: 1438B
- Material: polypropylene
- Colour: blue
- Quantities required: 250,000; 500,000; 750,000

Your quotation should include following:

1. The price for supplying finished mouldings to our works inclusive of all packaging and delivery charges for each of the above quantities.
2. The cost of all moulds, tooling, jigs and fixtures required.

Note that all tooling, jigs and fixtures must have a guaranteed minimum life of five years.

13.1.2 Initial Evaluation

On receiving the enquiry, the estimator looks at the drawing. This is shown in **Figure 13.1** (only the essential elements of the drawing are shown). After studying the drawing and reading through the enquiry, there are a few queries that need to be clarified as follows:

- the material specification has been omitted;
- the colour specification has been omitted;
- the finish of the part has not been stated; and
- the function of the part is not known.

It is decided not pursue these queries at this stage, as there may be more after other aspects of the enquiry have been studied.

13.1.2.1 Stage 1: Split Line Options

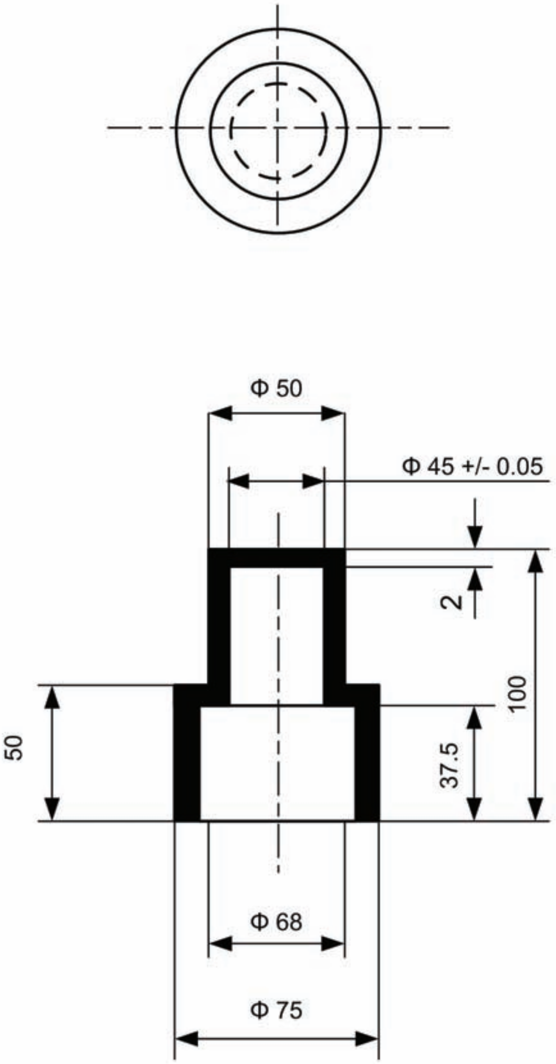
Next, we look at the split line, gating and ejection options. There are two possible positions for the main split line of the tool (**Figure 13.2**): at split line A and split line B. Either of these would allow the component to be moulded satisfactorily, but split line B is selected.

This is because all the cavity form can be machined into the front or fixed half of the tool, which is easier for the toolmaker. If split line A had been chosen, the toolmaker would have to machine the 50 mm diameter form into the front half and the 75 mm diameter into the rear or moving half of the tool. This in turn would mean that the toolmaker has the extra difficulty of matching these two forms to ensure that when the tool is closed they will be concentric with each other.

13.1.2.2 Stage 2: Gating Options

The next issue to be resolved is the question of where the part can be gated. There are only three basic options available, illustrated in **Figures 13.3–13.5**.

Figure 13.3 shows an overhead gating option. This would give uniform flow through the moulding, preserve concentricity and maximise quality. It would also provide a good path for the air to be displaced at the front of the incoming melt via the split line.



Material: Polypropylene

Colour: Blue

All dimensions have a tolerance of +/- 0.1 unless otherwise stated

All dimension are in millimetres

Figure 13.1 Valve body

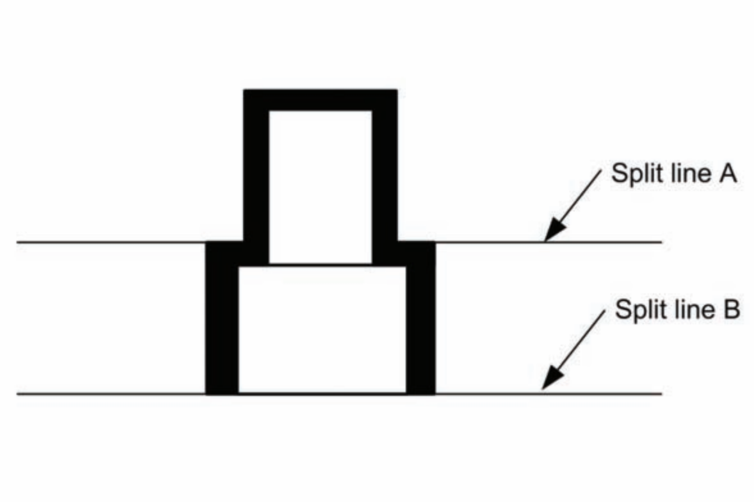


Figure 13.2 Split line options

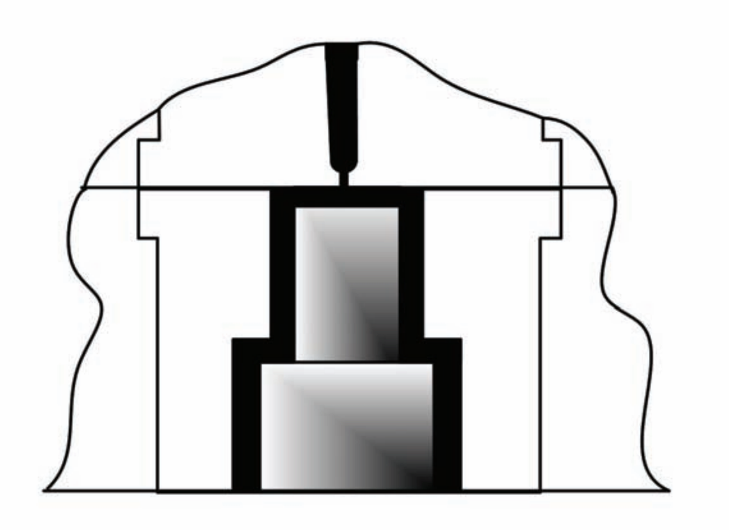


Figure 13.3 Overhead gating

The only way this type of gating can be incorporated into a mould is with either a three-plate mould or a hot runner mould (or possibly an extended hot nozzle). The three-plate mould design would leave a larger cold runner than a two-plate tool and probably a gate witness that may have to be removed as a secondary operation.

A hot runner mould, however, would eliminate the cold runner and the gate witness problem. If a hot runner design were selected, the gate would be positioned directly on the top face of the moulding. In terms of mould cost, the three-plate version would be less expensive than the hot runner design.

Figure 13.4 shows the side gating option. This is the most straightforward option and the simplest in terms of manufacture and therefore cost. This is the classic two-plate design discussed earlier. However, the gate witness may not be acceptable and manual removal of the gate may be necessary. This design also has a cold runner, but it is not as large as in the three-plate tool option.

The last option is shown in **Figure 13.5**. This is the sub (submarine) gate or tunnel gate design. This design would be used in conjunction with a two-plate tool and would be self-gating. Once again, however, there will be a gate witness and possibly a gate vestige at this position that may not be acceptable.

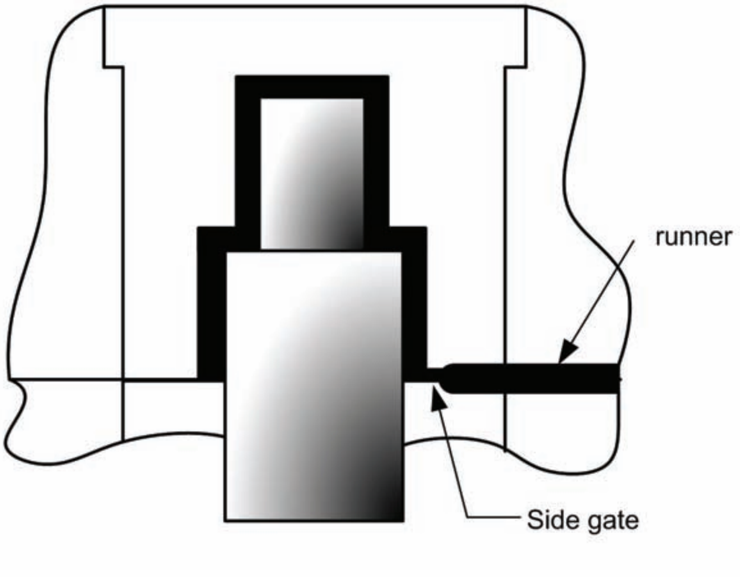


Figure 13.4 Side gating

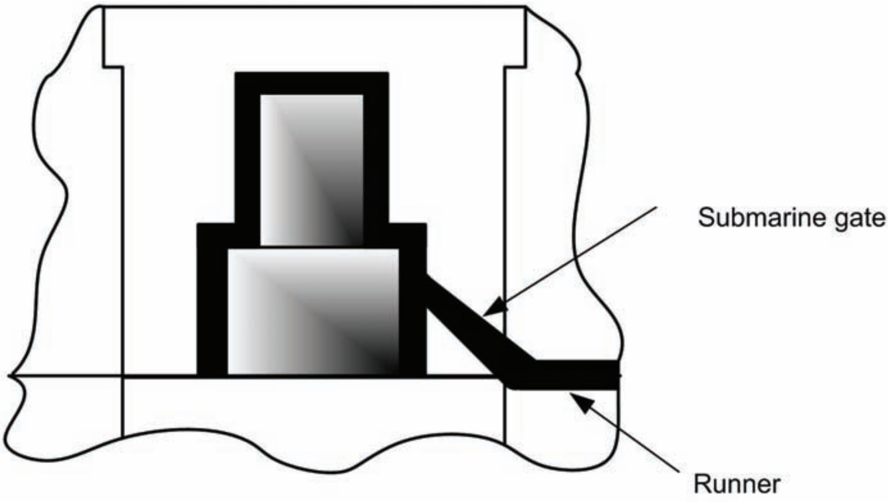


Figure 13.5 Submarine gating

13.1.2.3 Stage 3: Ejection Options

The basic method of ejection now has to be decided. In this case there are three options:

1. Sleeve ejection
2. Stripper plate
3. Ejector pins.

Figure 13.6 shows a typical sleeve ejector design that would be ideally suited to this type of component but it may leave an unacceptable witness mark on the base of the part. This is because there may be a very small vestige (or projection) left at this position that may not be acceptable if, for example, this face was a bearing surface.

The second option is the stripper plate design in which a single plate moves forward during ejection to 'strip' all the mouldings from the tool. The basic elements of this are shown in **Figure 13.7**. This would also leave similar small witness to the ejection sleeve design but this type of mould is more expensive to make.

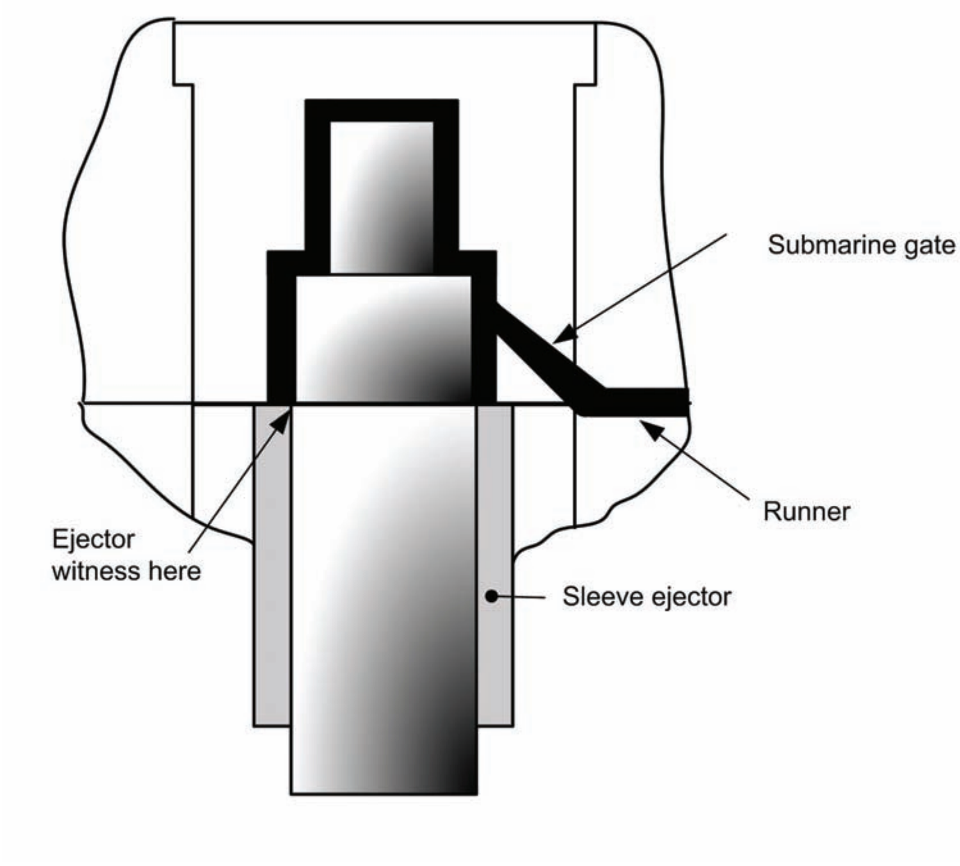


Figure 13.6 Sleeve ejection

Small ejector pins located around the base of the part have been dismissed as an option because of the limited ejection support area available. Another undesirable consequence of this design is the proximity of the pins in relation to the main core. This design is shown in **Figure 13.8**.

13.1.2.4 Stage 4: Resolving Outstanding Queries

Before proceeding any further, the following queries now need to be discussed with the customer.

- the material specification;
- the colour specification;

- the finish required for the part;
- the function of the part;
- whether a gate witness will be acceptable on the body or the top of the part; and
- whether a sleeve ejector witness will be acceptable.

It is important that queries of this nature are discussed with the customer at this stage otherwise a significant amount of time can be wasted in continuing with an estimate based on assumptions with which the customer may not agree.

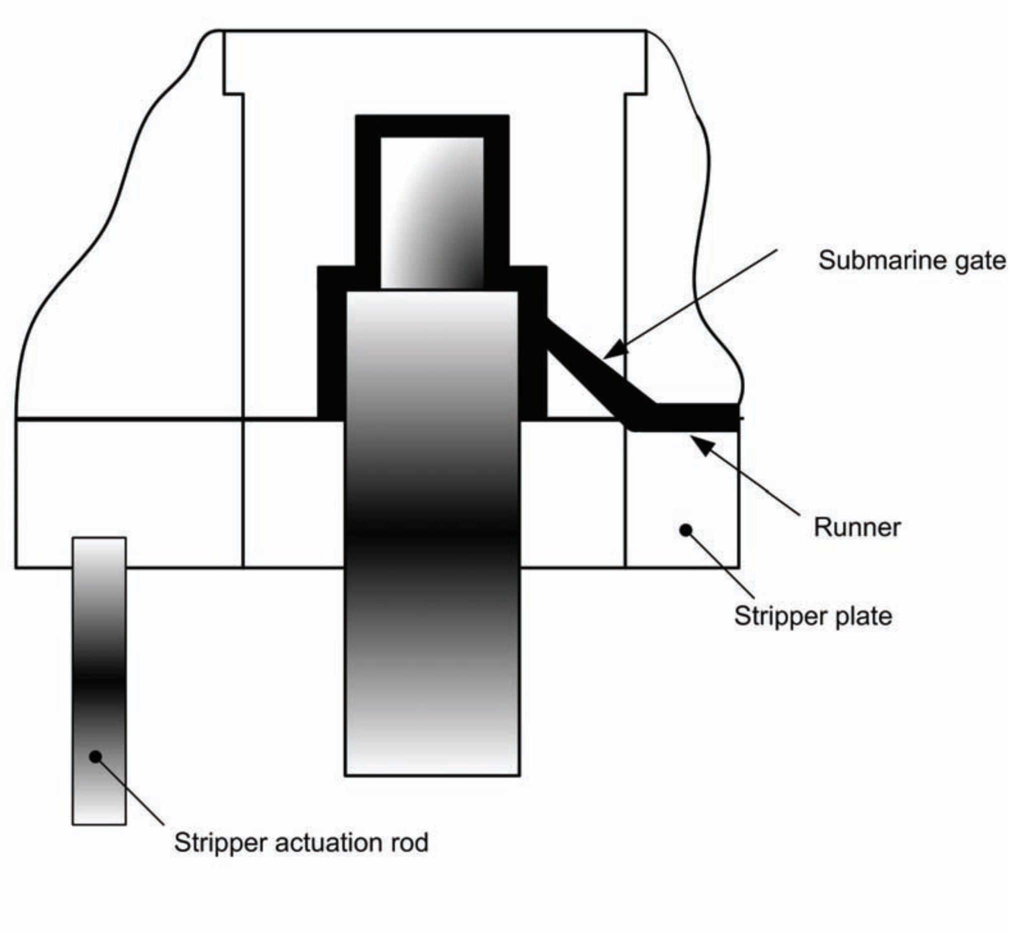


Figure 13.7 Stripper plate design

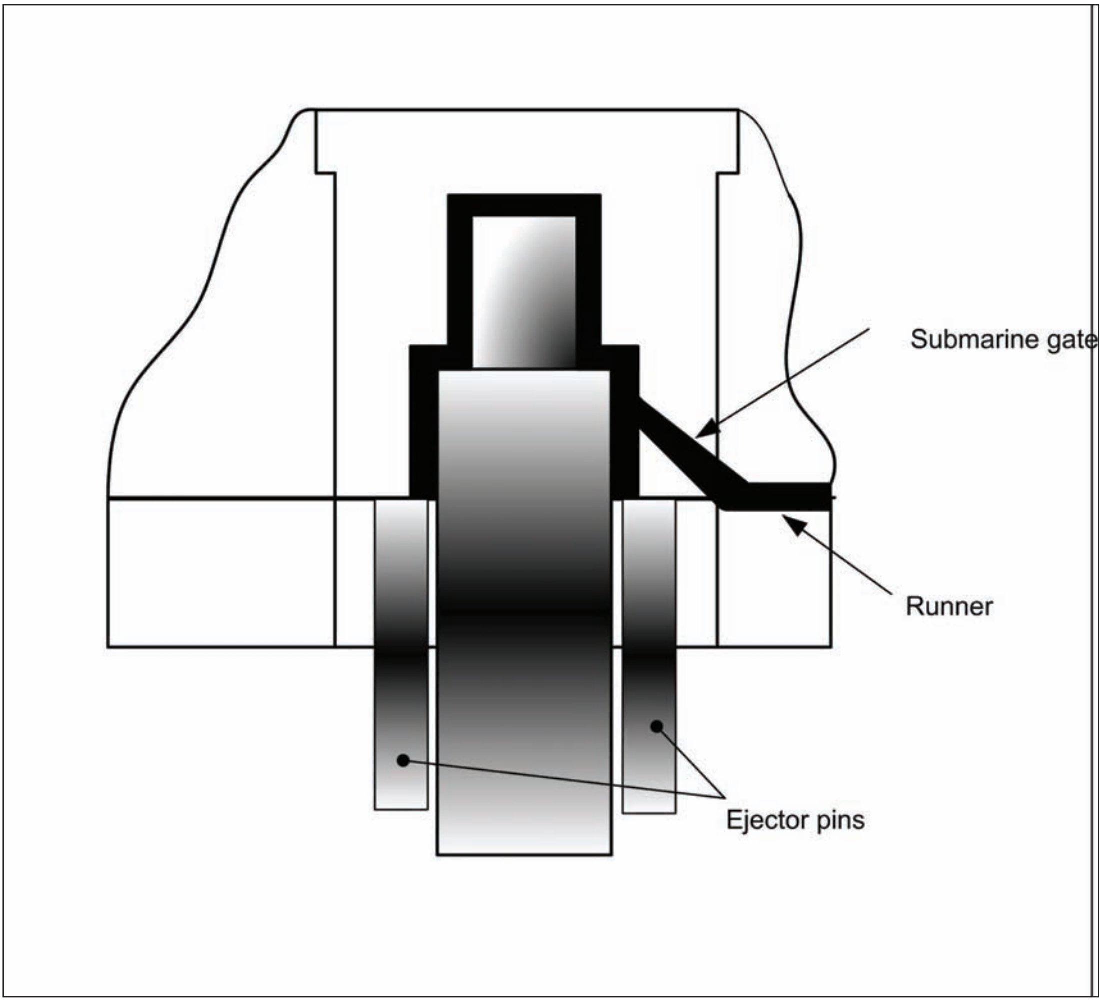


Figure 13.8 Ejector pin design

13.1.2.5 Stage 5: Customer Response

We will now assume that a satisfactory response has been received from the customer and, as a result of this, the tool design will be a two-plate mould tool with a sub gate and sleeve ejection as shown in **Figure 13.6**. The customer has ruled out a full hot runner tool at this stage.

13.1.2.6 Stage 6: Number of Impressions

Now these issues have been resolved, detailed work may be carried out on the estimate. The next parameter to be determined is the number of impressions. Based on the tolerance of the central smaller hole and the size of the parts, it is decided that four impressions would be the maximum number that will consistently guarantee this tolerance in production.

In view of the quantities stated by the customer, it is decided to base the estimate on a two- and four-impression tool as summarised in **Table 13.1**.

13.1.2.7 Stage 7: Mould Layout

The next stage is to produce a scale drawing of the basic layout for the two alternatives (**Figures 13.9** and **13.10**). **Figure 13.9** shows the basic layout for the two-impression tool option. This is necessary to establish the insert diameters and the position of these relative to each other and to the sprue bush. This enables the dimensions of the runner system to be established.

It should be noted that it is preferable to place the cavities and cores inside separate inserts (as shown here) as opposed to machining all the cavities directly into a single larger plate. Using inserts has the following advantages over using a single large plate:

- they are easier for the toolmaker to work with due to their smaller size; and
- if an impression becomes damaged, it is much easier to repair or replace.

Figure 13.10 shows the four-impression option.

Table 13.1 Selection of number of impressions

Volume of parts	Number of impressions
250,000	2
500,000	4
750,000	4

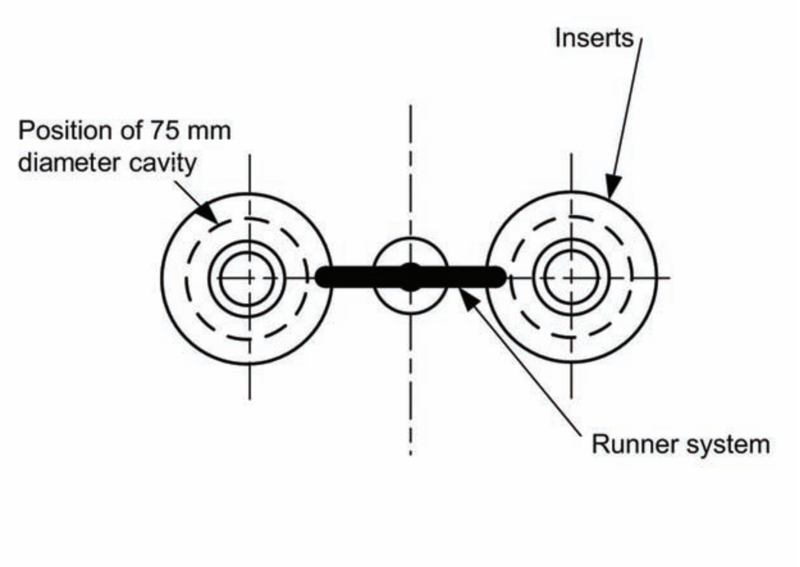


Figure 13.9 Basic two impression mould layout

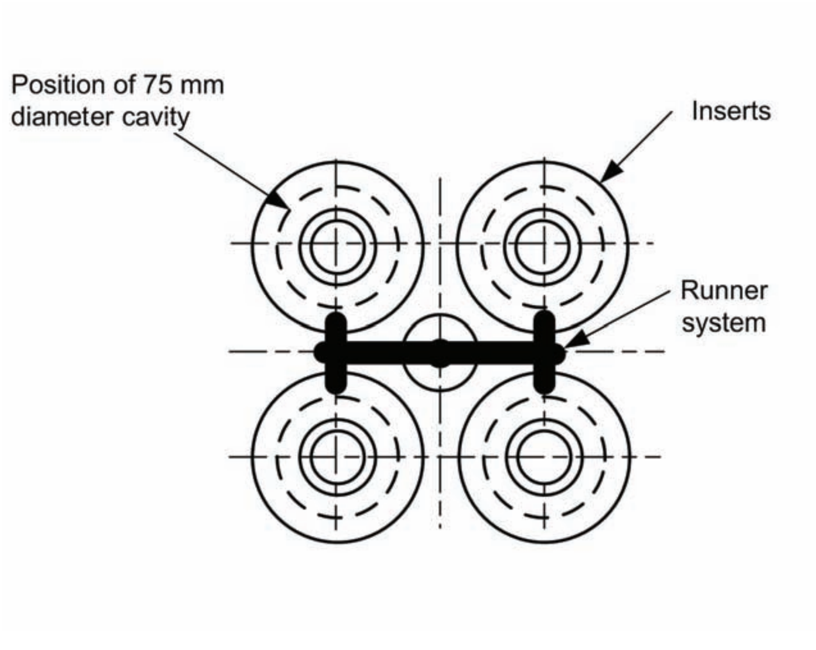


Figure 13.10 Basic four impression mould layout

13.1.2.8 Stage 8: Calculating Material Weights

The next stage is to calculate the weight of the part and the runner and sprue. This can be carried out by hand using a calculator or by using a computer-aided design (CAD) program.

We will first calculate the weight of the part. If CAD is not being used, the part may be split into three pieces to calculate the volume, as shown in **Figure 13.11**. This is a straightforward process:

$$\begin{aligned}
&\frac{\pi}{4}[(50)^2-(45)^2]\times 62.5+\frac{\pi}{4}[(75)^2-(68)^2]\times 50+\frac{\pi}{4}\times(45)^2\times 2\\
&\quad=\frac{\pi}{4}(2{,}500-2{,}025)\times 62.5+\frac{\pi}{4}(5{,}625-4.624)\times 50+\frac{\pi}{4}\times 2{,}025\times 2\\
&\quad=\frac{\pi}{4}(475\times 62.5)+\frac{\pi}{4}(1{,}001\times 50)+\frac{\pi}{4}\times 4.050\\
&\quad=\frac{\pi}{4}(29{,}687.5+50{,}050+4{,}050)\\
&\quad=\frac{\pi}{4}(83{,}787.5)\\
&\quad=65{,}806.5\ \text{mm}^3\\
&\quad\approx 65.81\ \text{cm}^3
\end{aligned}$$

It important to remember that the drawing dimensions are in millimetres, and hence the volume will be in cubic millimetres. It is usually more convenient to convert this result into cubic centimetres at this point. Mistakes are sometimes made by failing to use the correct units in the computation of the part weight.

This volume must now be multiplied by the specific gravity of the material in order to arrive at the final weight. In this case we will take the specific gravity of the polypropylene bring used as 0.92. Hence:

Weight of part = 65.81 × 0.92 = 60.55 g

The weight of the runner and sprue may be determined in a similar way. If N = number of impressions, P = part weight, R = runner + sprue weight and S = shot weight, then:

$$S = N\times P+R$$

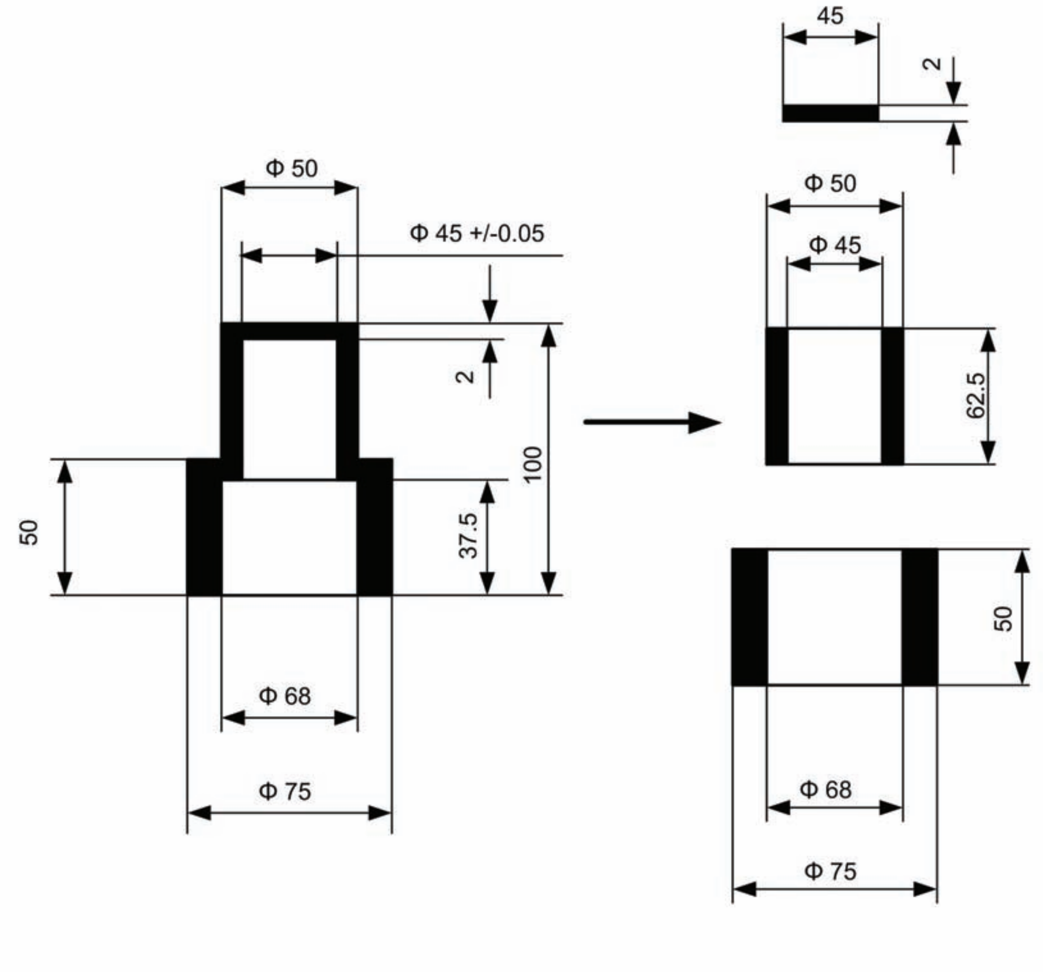


Figure 13.11 Calculating the part weight

For the two options under consideration, the results of the calculations are given in **Table 13.2**.

13.1.2.9 Stage 9: Calculating the Projected Area

The projected area (see glossary) of the mouldings and runners now has to be determined.

Table 13.2 Shot weights

No. of impressions	Part weight (g)	Sprue weight (g)	Runner weight (g)	Shot weight (g)
2	60.55	4	3	128.1
4	60.55	4	5	251.2

The projected area in this case is simply the area of a 75 mm diameter circle when looking in the direction of the arrow as shown in **Figure 13.12**. Therefore, the projected area is:

$$
\begin{aligned}
&\frac{\pi}{4}(75)^2 \\
&\quad = \frac{\pi}{4} \times 5,625 \\
&\quad \approx 4,418 \text{ mm}^2 \\
&\quad \approx 44.2 \text{ cm}^2
\end{aligned}
$$

We also need the projected areas of the runners, which in this case are estimated as 960 mm^2 (approximately 10 cm^2) for the two-impression option and 1,100 mm^2 (11 cm^2) for the four-impression option.

13.1.2.10 Stage 10: Calculating the Locking Force

Knowing the projected areas, we can now calculate the force trying to open the tool during the injection phase of the cycle. In this case, we will assume a minimum clamping pressure (C) of 0.5 tonnes per square centimetre is required for this material. The minimum machine locking force (L) required is given by:

$$L = N \times P$$

where N is the number of impressions and P is the total projected area of the mouldings plus the runner for each option.

For the two-impression option we have:

$$\text{Total projected area} = 2 \times 44.2 + 10 = 98.4 \text{ cm}^2$$

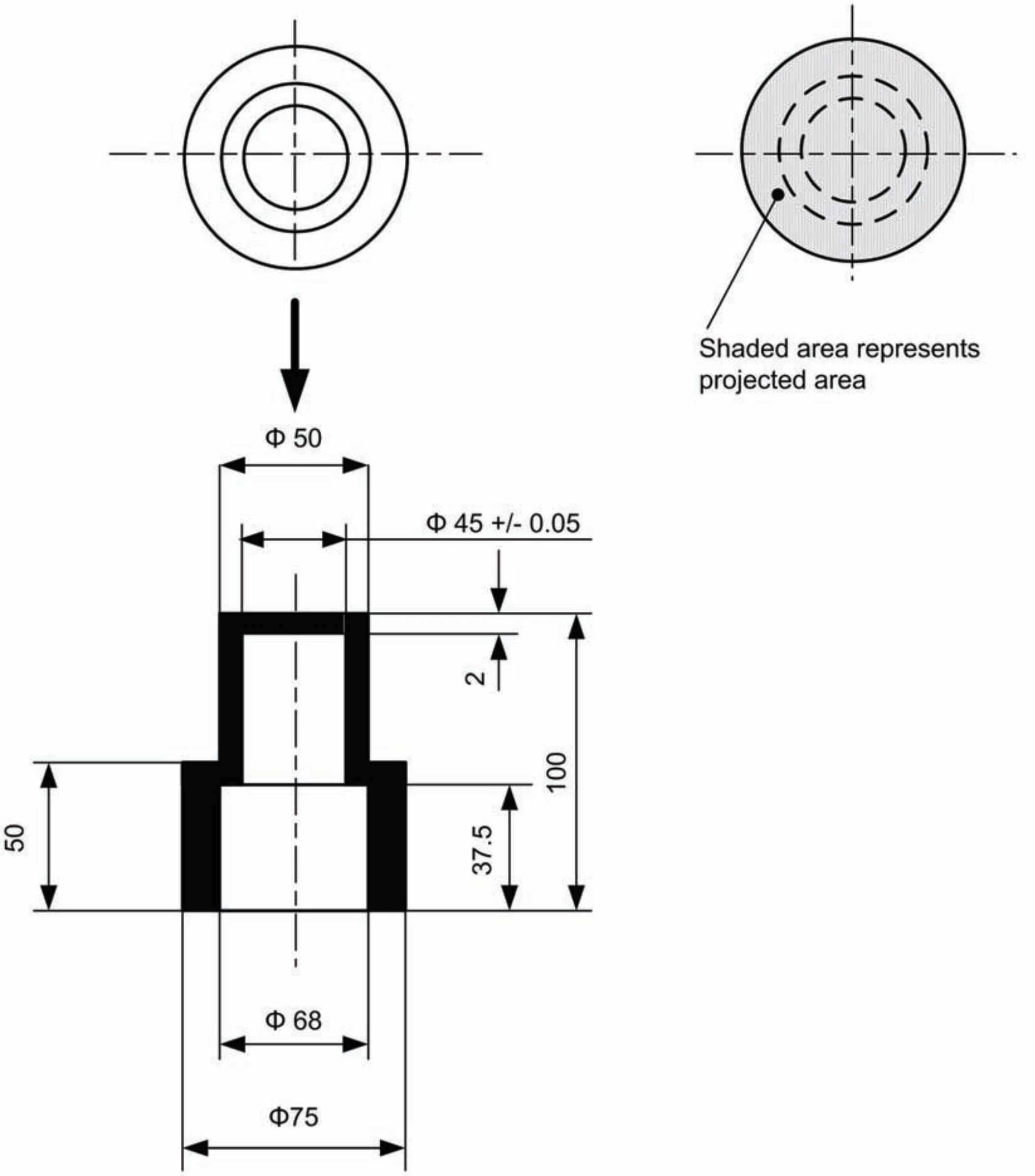


Figure 13.12 Calculating the projected area

Therefore, for this option we need a minimum locking force of:

$$L = 98.4 \times 0.5 = 49.2 \text{ tonnes}$$

For the four-impression option we have:

$$\text{Total projected area} = 4 \times 44.2 + 11 = 187.8 \text{ cm}^2$$

Therefore, for this option we need a minimum locking force of:

$$L = 187.8 \times 0.5 = 93.9 \text{ tonnes}$$

13.1.2.11 Stage 11: Selecting the Machine

It is now time to review all the data we have collected, which are summarised in **Table 13.3**. From these data, suitable machines for running these tools have to be selected.

ABC has three 100 tonne lock machines, with shot weights from 200 to 275 g. Hence the 200 g version is selected for the two-impression option and the 275 g version is selected for the four-impression option.

ABC realises that the four-impression option will be near to the maximum capacity of their 100 tonne 275 g machine but decides to go ahead on this basis anyway as the 250 tonne machine would make the parts considerably more expensive and the company has previously run jobs of this size successfully on the 100 tonne machine. This information is summarised in **Table 13.4**.

13.1.2.12 Stage 12: Cycle Time

The only remaining data needed is the cycle time for each option. It is decided that this should be 30 seconds for the two-impression option and 34 seconds

Table 13.3 Summary of data

No. of impressions	Shot weight (g)	Locking force required (tonnes)
2	128.1	49.2
4	251.2	93.9

Table 13.4 Machine selection details

No. of impressions	Shot weight (g)	Locking force required (tonnes)	Machines selected		
			Locking force (tonnes)	Max. shot weight (g)	MHR (£/hour)
2	128.1	49.2	100	200	48
4	251.2	93.9	100	275	48

for the four-impression option. These figures include a 3% allowance for wasted cycles.

The cycle times have been established by a combination of previous experience of similarly shaped parts in the same material plus an adjustment for the different wall thickness.

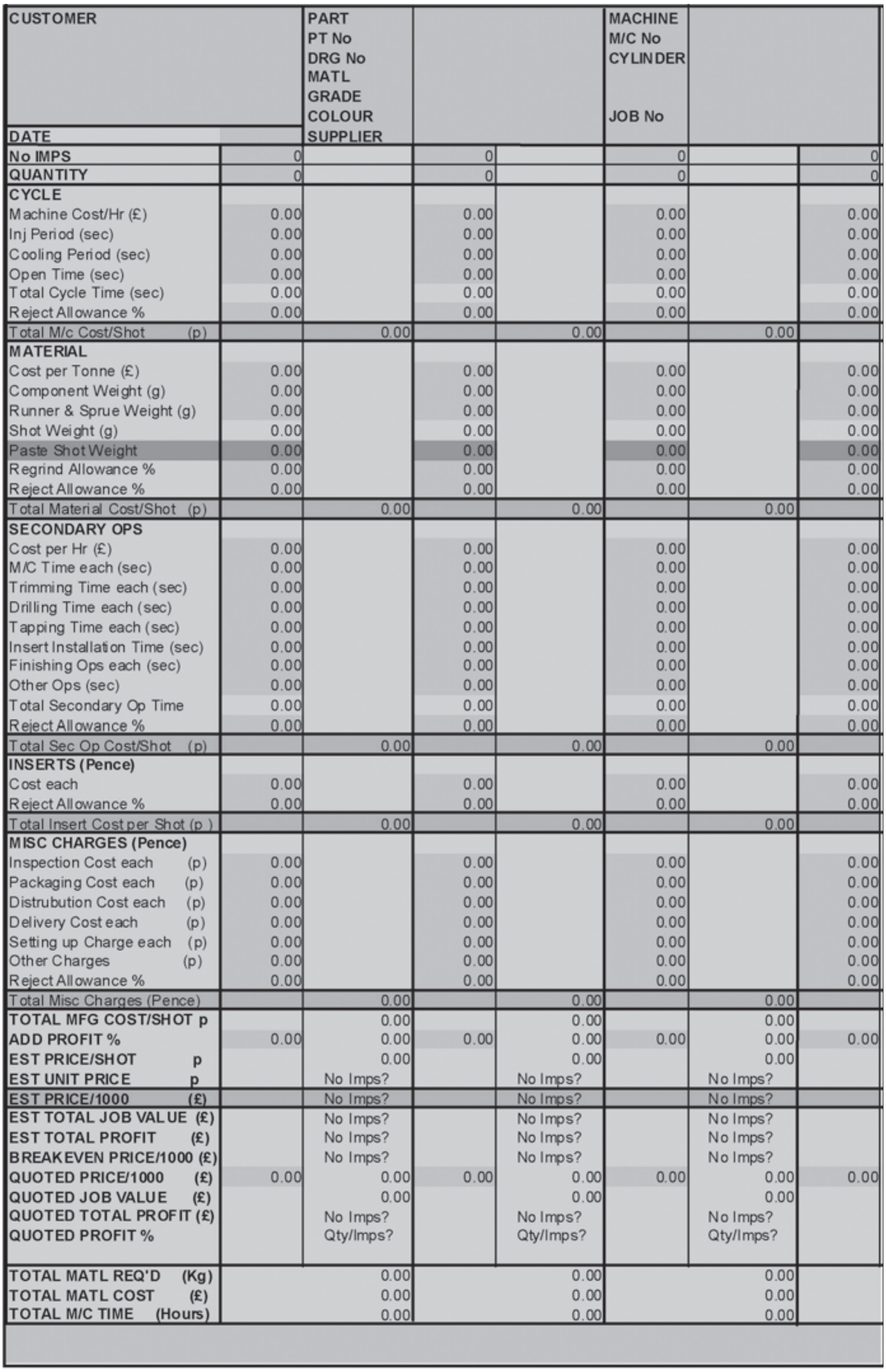
13.1.2.13 Stage 13: Final Costing and Estimate

There is now sufficient information to prepare the estimate. ABC uses a standard estimation sheet which is shown in **Figure 13.13**. This is part of a specially programmed Excel spreadsheet that the author has designed to automate calculation tasks and minimise potential omissions and errors. It also incorporates an 'If what' scenario analysis to allow adjustments to be made after the basic costs have been established.

Many companies will have their own estimating programs that are dedicated to the type of work in which they specialise. The best system is one that is linked to a CAD program. This enables information on projected area and runner and part weights to be integrated directly into the estimation program.

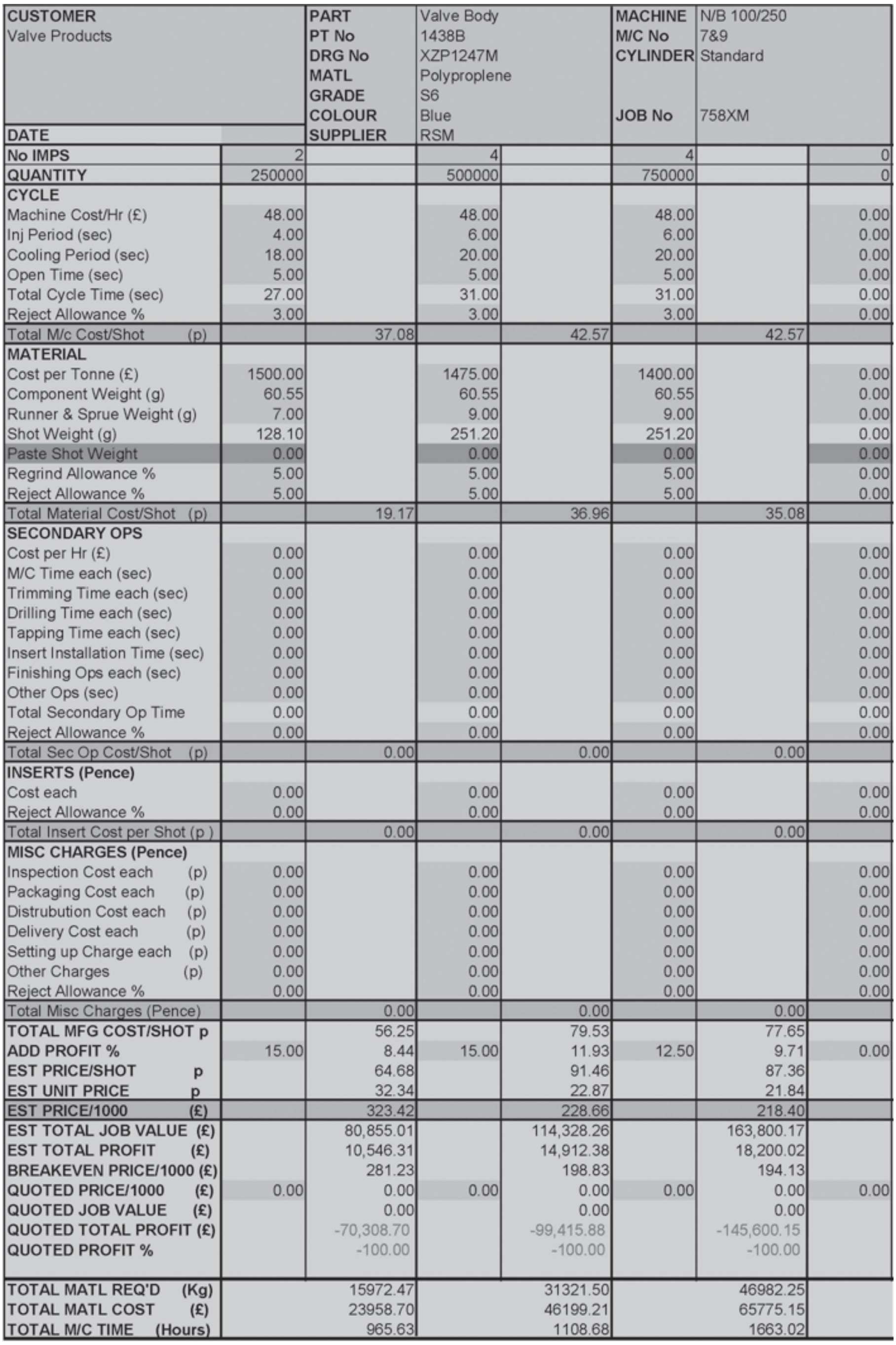
Figure 13.14 shows the completed estimate for this job. These figures are then forwarded to the customer in the form of a quotation. A summary of the ABC estimate is shown in **Table 13.5**.

As a result of the quotation, ABC is contacted by the customer who advises ABC that an order will be placed for the four-impression tool based on the quantity of 750,000 if they can reduce the price slightly to £216 per thousand as opposed to the £218.40 quoted. ABC examines the effect of this by entering this figure in the lower portion of the estimating spreadsheet in **Figure 13.15**. **Figure 13.16** shows the result enlarged and circled for extra clarity.



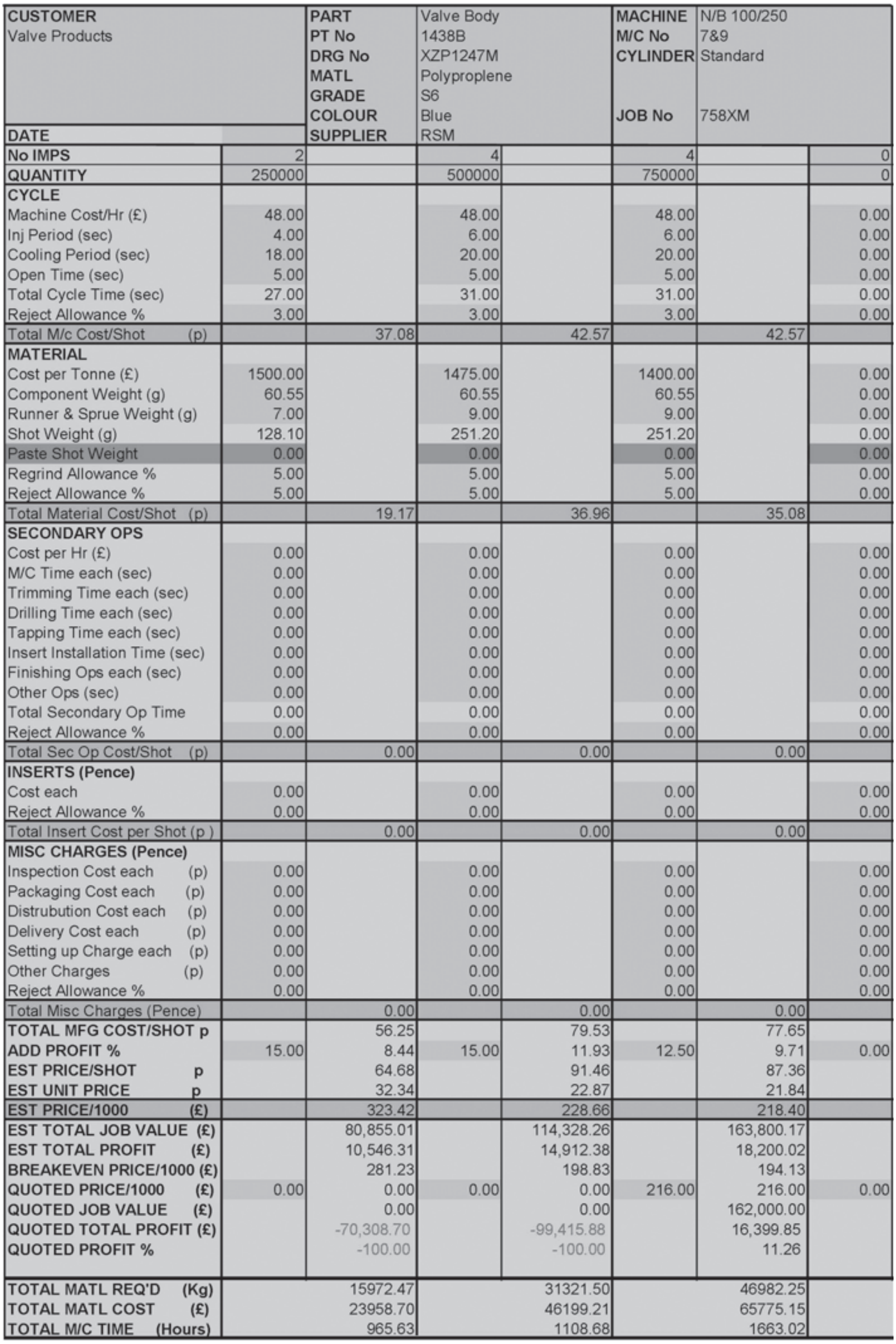
CUSTOMER		PART PT No DRG No MATL GRADE COLOUR SUPPLIER			MACHINE M/C No CYLINDER JOB No		
DATE							
No IMPS	0		0		0		0
QUANTITY	0		0		0		0
CYCLE							
Machine Cost/Hr (£)	0.00		0.00		0.00		0.00
Inj Period (sec)	0.00		0.00		0.00		0.00
Cooling Period (sec)	0.00		0.00		0.00		0.00
Open Time (sec)	0.00		0.00		0.00		0.00
Total Cycle Time (sec)	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total M/c Cost/Shot (p)		0.00		0.00		0.00	
MATERIAL							
Cost per Tonne (£)	0.00		0.00		0.00		0.00
Component Weight (g)	0.00		0.00		0.00		0.00
Runner & Sprue Weight (g)	0.00		0.00		0.00		0.00
Shot Weight (g)	0.00		0.00		0.00		0.00
Paste Shot Weight	0.00		0.00		0.00		0.00
Regrind Allowance %	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total Material Cost/Shot (p)		0.00		0.00		0.00	
SECONDARY OPS							
Cost per Hr (£)	0.00		0.00		0.00		0.00
M/C Time each (sec)	0.00		0.00		0.00		0.00
Trimming Time each (sec)	0.00		0.00		0.00		0.00
Drilling Time each (sec)	0.00		0.00		0.00		0.00
Tapping Time each (sec)	0.00		0.00		0.00		0.00
Insert Installation Time (sec)	0.00		0.00		0.00		0.00
Finishing Ops each (sec)	0.00		0.00		0.00		0.00
Other Ops (sec)	0.00		0.00		0.00		0.00
Total Secondary Op Time	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total Sec Op Cost/Shot (p)		0.00		0.00		0.00	
INSERTS (Pence)							
Cost each	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total Insert Cost per Shot (p)		0.00		0.00		0.00	
MISC CHARGES (Pence)							
Inspection Cost each (p)	0.00		0.00		0.00		0.00
Packaging Cost each (p)	0.00		0.00		0.00		0.00
Distrubution Cost each (p)	0.00		0.00		0.00		0.00
Delivery Cost each (p)	0.00		0.00		0.00		0.00
Setting up Charge each (p)	0.00		0.00		0.00		0.00
Other Charges (p)	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total Misc Charges (Pence)		0.00		0.00		0.00	
TOTAL MFG COST/SHOT p		0.00		0.00		0.00	
ADD PROFIT %	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EST PRICE/SHOT p		0.00		0.00		0.00	
EST UNIT PRICE p		No Imps?		No Imps?		No Imps?	
EST PRICE/1000 (£)		No Imps?		No Imps?		No Imps?	
EST TOTAL JOB VALUE (£)		No Imps?		No Imps?		No Imps?	
EST TOTAL PROFIT (£)		No Imps?		No Imps?		No Imps?	
BREAKEVEN PRICE/1000 (£)		No Imps?		No Imps?		No Imps?	
QUOTED PRICE/1000 (£)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
QUOTED JOB VALUE (£)		0.00		0.00		0.00	
QUOTED TOTAL PROFIT (£)		No Imps?		No Imps?		No Imps?	
QUOTED PROFIT %		Qty/Imps?		Qty/Imps?		Qty/Imps?	
TOTAL MATL REQ'D (Kg)		0.00		0.00		0.00	
TOTAL MATL COST (£)		0.00		0.00		0.00	
TOTAL M/C TIME (Hours)		0.00		0.00		0.00	

Figure 13.13 Estimating Spreadsheet



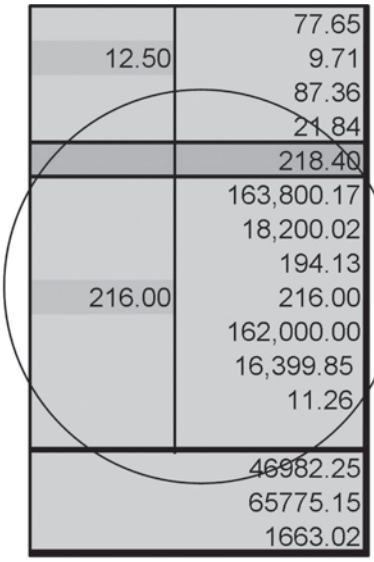
CUSTOMER		**PART**	Valve Body		**MACHINE**	N/B 100/250	
Valve Products		**PT No**	1438B		**M/C No**	7&9	
		DRG No	XZP1247M		**CYLINDER**	Standard	
		MATL	Polyproplene				
		GRADE	S6				
		COLOUR	Blue		**JOB No**	758XM	
DATE		**SUPPLIER**	RSM				
No IMPS	2		4		4		0
QUANTITY	250000		500000		750000		0
CYCLE							
Machine Cost/Hr (£)	48.00		48.00		48.00		0.00
Inj Period (sec)	4.00		6.00		6.00		0.00
Cooling Period (sec)	18.00		20.00		20.00		0.00
Open Time (sec)	5.00		5.00		5.00		0.00
Total Cycle Time (sec)	27.00		31.00		31.00		0.00
Reject Allowance %	3.00		3.00		3.00		0.00
Total M/c Cost/Shot (p)		37.08		42.57		42.57	
MATERIAL							
Cost per Tonne (£)	1500.00		1475.00		1400.00		0.00
Component Weight (g)	60.55		60.55		60.55		0.00
Runner & Sprue Weight (g)	7.00		9.00		9.00		0.00
Shot Weight (g)	128.10		251.20		251.20		0.00
Paste Shot Weight	0.00		0.00		0.00		0.00
Regrind Allowance %	5.00		5.00		5.00		0.00
Reject Allowance %	5.00		5.00		5.00		0.00
Total Material Cost/Shot (p)		19.17		36.96		35.08	
SECONDARY OPS							
Cost per Hr (£)	0.00		0.00		0.00		0.00
M/C Time each (sec)	0.00		0.00		0.00		0.00
Trimming Time each (sec)	0.00		0.00		0.00		0.00
Drilling Time each (sec)	0.00		0.00		0.00		0.00
Tapping Time each (sec)	0.00		0.00		0.00		0.00
Insert Installation Time (sec)	0.00		0.00		0.00		0.00
Finishing Ops each (sec)	0.00		0.00		0.00		0.00
Other Ops (sec)	0.00		0.00		0.00		0.00
Total Secondary Op Time	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total Sec Op Cost/Shot (p)		0.00		0.00		0.00	
INSERTS (Pence)							
Cost each	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total Insert Cost per Shot (p)		0.00		0.00		0.00	
MISC CHARGES (Pence)							
Inspection Cost each (p)	0.00		0.00		0.00		0.00
Packaging Cost each (p)	0.00		0.00		0.00		0.00
Distrubution Cost each (p)	0.00		0.00		0.00		0.00
Delivery Cost each (p)	0.00		0.00		0.00		0.00
Setting up Charge each (p)	0.00		0.00		0.00		0.00
Other Charges (p)	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total Misc Charges (Pence)		0.00		0.00		0.00	
TOTAL MFG COST/SHOT p		56.25		79.53		77.65	
ADD PROFIT %	15.00	8.44	15.00	11.93	12.50	9.71	0.00
EST PRICE/SHOT p		64.68		91.46		87.36	
EST UNIT PRICE p		32.34		22.87		21.84	
EST PRICE/1000 (£)		323.42		228.66		218.40	
EST TOTAL JOB VALUE (£)		80,855.01		114,328.26		163,800.17	
EST TOTAL PROFIT (£)		10,546.31		14,912.38		18,200.02	
BREAKEVEN PRICE/1000 (£)		281.23		198.83		194.13	
QUOTED PRICE/1000 (£)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
QUOTED JOB VALUE (£)		0.00		0.00		0.00	
QUOTED TOTAL PROFIT (£)		-70,308.70		-99,415.88		-145,600.15	
QUOTED PROFIT %		-100.00		-100.00		-100.00	
TOTAL MATL REQ'D (Kg)		15972.47		31321.50		46982.25	
TOTAL MATL COST (£)		23958.70		46199.21		65775.15	
TOTAL M/C TIME (Hours)		965.63		1108.68		1663.02	

Figure 13.14 Completed estimating spreadsheet



CUSTOMER		**PART**	Valve Body		**MACHINE**	N/B 100/250	
Valve Products		**PT No**	1438B		**M/C No**	7&9	
		DRG No	XZP1247M		**CYLINDER**	Standard	
		MATL	Polyproplene				
		GRADE	S6				
		COLOUR	Blue		**JOB No**	758XM	
DATE		**SUPPLIER**	RSM				
No IMPS	2		4		4		0
QUANTITY	250000		500000		750000		0
CYCLE							
Machine Cost/Hr (£)	48.00		48.00		48.00		0.00
Inj Period (sec)	4.00		6.00		6.00		0.00
Cooling Period (sec)	18.00		20.00		20.00		0.00
Open Time (sec)	5.00		5.00		5.00		0.00
Total Cycle Time (sec)	27.00		31.00		31.00		0.00
Reject Allowance %	3.00		3.00		3.00		0.00
Total M/c Cost/Shot (p)		37.08		42.57		42.57	
MATERIAL							
Cost per Tonne (£)	1500.00		1475.00		1400.00		0.00
Component Weight (g)	60.55		60.55		60.55		0.00
Runner & Sprue Weight (g)	7.00		9.00		9.00		0.00
Shot Weight (g)	128.10		251.20		251.20		0.00
Paste Shot Weight	0.00		0.00		0.00		0.00
Regrind Allowance %	5.00		5.00		5.00		0.00
Reject Allowance %	5.00		5.00		5.00		0.00
Total Material Cost/Shot (p)		19.17		36.96		35.08	
SECONDARY OPS							
Cost per Hr (£)	0.00		0.00		0.00		0.00
M/C Time each (sec)	0.00		0.00		0.00		0.00
Trimming Time each (sec)	0.00		0.00		0.00		0.00
Drilling Time each (sec)	0.00		0.00		0.00		0.00
Tapping Time each (sec)	0.00		0.00		0.00		0.00
Insert Installation Time (sec)	0.00		0.00		0.00		0.00
Finishing Ops each (sec)	0.00		0.00		0.00		0.00
Other Ops (sec)	0.00		0.00		0.00		0.00
Total Secondary Op Time	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total Sec Op Cost/Shot (p)		0.00		0.00		0.00	
INSERTS (Pence)							
Cost each	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total Insert Cost per Shot (p)		0.00		0.00		0.00	
MISC CHARGES (Pence)							
Inspection Cost each (p)	0.00		0.00		0.00		0.00
Packaging Cost each (p)	0.00		0.00		0.00		0.00
Distrubution Cost each (p)	0.00		0.00		0.00		0.00
Delivery Cost each (p)	0.00		0.00		0.00		0.00
Setting up Charge each (p)	0.00		0.00		0.00		0.00
Other Charges (p)	0.00		0.00		0.00		0.00
Reject Allowance %	0.00		0.00		0.00		0.00
Total Misc Charges (Pence)		0.00		0.00		0.00	
TOTAL MFG COST/SHOT p		56.25		79.53		77.65	
ADD PROFIT %	15.00	8.44	15.00	11.93	12.50	9.71	0.00
EST PRICE/SHOT p		64.68		91.46		87.36	
EST UNIT PRICE p		32.34		22.87		21.84	
EST PRICE/1000 (£)		323.42		228.66		218.40	
EST TOTAL JOB VALUE (£)		80,855.01		114,328.26		163,800.17	
EST TOTAL PROFIT (£)		10,546.31		14,912.38		18,200.02	
BREAKEVEN PRICE/1000 (£)		281.23		198.83		194.13	
QUOTED PRICE/1000 (£)	0.00	0.00	0.00	0.00	216.00	216.00	0.00
QUOTED JOB VALUE (£)		0.00		0.00		162,000.00	
QUOTED TOTAL PROFIT (£)		-70,308.70		-99,415.88		16,399.85	
QUOTED PROFIT %		-100.00		-100.00		11.26	
TOTAL MATL REQ'D (Kg)		15972.47		31321.50		46982.25	
TOTAL MATL COST (£)		23958.70		46199.21		65775.15	
TOTAL M/C TIME (Hours)		965.63		1108.68		1663.02	

Figure 13.15 Amended estimate spreadsheet



	77.65
12.50	9.71
	87.36
	21.84
	218.40
	163,800.17
	18,200.02
	194.13
216.00	216.00
	162,000.00
	16,399.85
	11.26
	46982.25
	65775.15
	1663.02

Figure 13.16 Enlarged detail of profit analysis

Table 13.5 Prices quoted to customer

No. of impressions	Quantity	Price per 1,000 (£)
2	250,000	323.42
4	500,000	228.66
4	750,000	218.40

Note that in this example the distribution costs and inspection costs are all included in the MHR.

This shows the profit would reduce from 12.5 to 11.26%. After internal consultation, ABC decides it will accept the order for the job at this lower price.

For those who do not have such a program, the one shown here should provide a good basis for custom designing one. Alternatively, although more laborious, printed sheets may be used if preferred.

14

Estimating Mould Tool Costs

14.1 Universal Mould Costing Programs

One of the most highly prized assets in injection moulding would be a program that would allow the user to estimate mould costs that could be used straight from the box without seeking a quotation from a toolmaking company.

Unfortunately, there is no universal piece of software that will accurately predict the price that a toolmaking company will charge for a particular mould tool. This is exemplified by the fact that identical enquiries sent out to different toolmakers can sometimes vary by 100% or more.

The reasons for this are complex and also there are many non-quantifiable variables associated with the way toolmakers determine mould prices that make this virtually impossible. To understand this we have to examine mould making from the toolmaker's point of view.

The main factors that will decide how much a toolmaker quotes for a mould are as follows:

1. The geographical location.
2. Work loading in terms of how busy the toolmaker is.
3. Toolmaking plant available.
4. Payment history of customer.
5. Caution when dealing with new customer.
6. Familiarity with the type of mould design.
7. Degree of difficulty of the mould construction.
8. How many outstanding enquiries the toolmaker has.
9. Special finish requirements.

10. Number of impressions.

11. Size of the mould.

14.1.1 Geographical Location

There are obvious differences in philosophy, work ethic and labour costs depending on where the toolmaker is geographically located. If an overseas toolmaking company manufactures a mould tool, they can often undercut prices substantially and offer unbelievably short deliveries compared with their Western European and North American counterparts. The main factor is, of course, lower labour costs with countries like China having very low costs compared those in Europe and America.

Such low costs are sometimes superficially attractive but there can be hidden costs of which the buyer should be wary. Whilst the moulds may be delivered on time and at the quoted price, there can be problems if the mould is going to be run in countries outside China.

The main problem can occur when the customer samples the mould on its own machines and finds it does not fit the moulding machines in some way or the part dimensions are incorrect or perhaps the mould does not operate as intended.

This can incur extra costs if a moulder then has to arrange for a local toolmaker to rectify these faults, or in extreme circumstances the mould has to be returned to the original toolmaker. In this case, there can be problems with language as well as distance (and cost).

Hence, all these potential costs and lost time should be taken into account when trying to arrive at a future mould tool cost from the same supplier.

The same costs must also be taken into account with moulds made by more local toolmakers. Therefore, the total cost of purchasing a mould is:

Original cost + cost of any subsequent modifications + cost of lost time

14.1.2 Work Loading

Most European and American toolmaking companies are relatively small enterprises employing 10 to 50 toolmakers. There are, of course, some very large companies principally in China with some employing hundreds of toolmakers. However, in both cases, the price and delivery period the toolmaker quotes will depend on how much capacity they have available at the time.

In Europe and to a lesser extent in the USA this often leads to unexpected quotations for mould tools that can be very competitive or very expensive with lengthy delivery periods. This can create confusion with the moulder when, for example, a quote for a mould very similar to a previous one made by the same toolmaker can be significantly more expensive and with a very long delivery.

The reason for this is that the toolmaker has to deal with rapidly changing work loading conditions due to the relatively small size of their business and their usually small customer base.

The problem is that toolmakers cannot predict how much work they will receive, and this leads to two extreme conditions exacerbated by their size.

- having no spare capacity; and
- not having sufficient work to occupy all the toolmakers.

If a toolmaker is already working at full capacity, this will be reflected in the prices and delivery periods it quotes for new tools. In particular, the delivery period may, for example, change from 14 weeks in normal circumstances to, say, 20 to 24 weeks.

If a moulder challenges this, the toolmaker may reduce the delivery period but increase the price for the mould tool by 50% or more on the basis that they will use large amounts of overtime if this work were placed with them.

What they will not normally do is to employ more toolmakers. There are two potential problems that make toolmakers reluctant to do this:

1. The work loading situation may change in the short term leading to having to make the new toolmakers redundant.
2. Employing more toolmakers often means that additional plant and equipment may have to be purchased. If the work load subsequently decreased, the company would also be left in a situation of having to continue to pay off the loan it took out to purchase the new plant without gaining any revenue from it.

14.1.3 Plant Available

In the same way that moulding companies may serve a particular market, a toolmaking company also has to decide which market it is going to serve as follows:

- general trade moulding;
- custom moulding; or
- specialist market.

The market it opts for will determine the plant and equipment that it will need to manufacture the mould tools for the market and be competitive.

All toolmaking companies will have a common core of plant and equipment comprising:

- a variety of lathes of different sizes;
- milling machines;
- a variety of drilling machines;
- surface grinding facilities;
- cylindrical grinding facilities; and
- electro-discharge machining (EDM) equipment.

However, other plant will be acquired depending on the type of market they have chosen, as discussed below.

14.1.3.1 General Trade Moulding Market

Toolmakers in this market have to place the emphasis on producing mould tools for a wide range of industries and, therefore, components. These tools generally tend to be less difficult to make than the other categories but the toolmakers have to be able to make almost any type of tool within this category.

14.1.3.2 Custom Moulding Market

This tends to be a more specialist field supplying industries that require parts that are more technical or parts required to operate in demanding operational conditions. Such parts often include close tolerances, more complex geometries and more difficult-to-mould materials.

In view of this, the toolmakers would have to purchase more specialised, expensive equipment like perhaps wire EDM and maybe more sophisticated CAD and computer aided machining (CAM) facilities.

14.1.3.3 Specialist Moulding Market

These markets would include the medical, pharmaceutical, electronic, aerosol valves and closure fields amongst many others. The toolmakers involved in this type of market would tend to be very highly skilled and experienced in this type of work.

In this market, a toolmaking company normally specialises in one of these fields and may have to invest more heavily in dedicated plant and equipment. This may include more specialist EDM, metrology or finishing equipment. Usually, the mould tools cost very much more to manufacture than moulds in the other categories.

The specialist market also includes the manufacture of very large moulds that are required to produce refrigerators, wheelie bins, etc.

In this case, larger, more expensive toolmaking equipment will be necessary for the machining operations. Special heavy-duty lifting equipment will also be necessary for manoeuvring large pieces of steel into position for machining.

14.1.4 Customer Payment History

Most toolmaking companies do not have large capital reserves and therefore need a constant supply of revenue from sales to stay in business. In many cases, plant and machinery is purchased on deferred payment schemes and the business depends on prompt payment from customers to survive.

Therefore, a toolmaker may refuse to accept work from a new customer with a poor payment record. If an existing customer starts to pay later than it has in the past then, generally speaking, the toolmaker will inflate the prices of new tools to counter this.

A toolmaker may also start to look for other customers to see if it can find new ones that will pay on time with a view to ultimately phasing out its customers with poor payment records.

14.1.5 Caution with New Customers

In keeping with many other manufacturers, toolmakers will err on the cautious side when providing quotations for new clients, as probably will the customer in placing orders with new suppliers.

As toolmakers' usually more fragile financial position is always of paramount importance, they will tend to be very conservative in terms of pricing tools and the delivery period they require. They will spend a longer time in costing the job and estimating the delivery than normal to make sure their quotation is as accurate as it can be.

However, their quotation will be influenced by the current work loading they have. This conservative pricing philosophy may change dramatically if they do not have much work in progress at the time and they may quote very competitively. They will also try to make the best possible impression with the customer to encourage further work.

14.1.6 Unfamiliar Mould Designs

If a toolmaker receives an enquiry for a component that requires a tool with which it is unfamiliar, it will usually inflate the price and delivery in the quotation to cover unforeseen problems. In effect, such work would be treated as a development project.

Sometimes, the work involved on the tool may require the toolmaker to purchase additional equipment. At this stage, the toolmaker will want to ensure that this equipment will be useful for future work from the same or other new customers.

If the toolmaker feels this may not be forthcoming, it may decline to provide a quotation for the work or quote a very high price for the work based on subcontracting certain work or processes to other companies specialising in these areas like specialist EDM, texturing or electro-forming.

14.1.7 Degree of Difficulty

The first thing a toolmaker will do when a new enquiry is received is to carefully examine the geometry of the part and the tolerances required on the part dimensions.

If the geometry is complex or the tolerances very small, these will significantly affect the price to be charged. Clearly, complex parts will require more complex design solutions and construction and small tolerances will require greater levels of accuracy to achieve.

As one would expect, both of these factors would increase the design and manufacturing costs of the mould tool as the degree of difficulty increases.

14.1.8 Time Available to Process Enquiries

In most smaller toolmaking companies, nearly all the employees including the partners or directors are toolmakers. Since a quotation requires considerable experience to prepare, one of the partners or a director would carry this out.

The problem is that the person who prepares the quotations will also be called upon to ‘lend a hand’ with the toolmaking when projects are running late. This leads to enquiries being left without being actioned until customers chase up the quotations for their enquiries. This results in much less time being spent in costing the work and frequently leads to a ‘guesstimate’ that may be considerably different from that prepared under normal circumstances.

14.1.9 Special Finishes

Special finish requirements will increase the cost of a mould and may even necessitate a special, more complex mould design to incorporate. For example, a leather grain finish of the sides of a box-shaped component may lead to a more expensive split tool being employed than a simpler two-plate mould that could otherwise be used.

A finish like this often creates an undercut thus preventing a component from being withdrawn from the mould tool without the surface suffering scuffing or scoring.

Different toolmakers will view the degree of difficulty of making tools for this type of part differently, depending on the plant and equipment that are available.

14.1.10 Number of Impressions

This is a major factor in establishing the price of a tool. Clearly, the greater the number of impressions, the larger the tool will be and the greater the amount of work will be.

This is another area where different toolmakers will adopt different methods of costing. This results in a wide range of prices and deliveries being quoted for the same tool from different toolmakers.

14.1.11 Size of the Mould

The physical size of the mould is also a factor that affects cost, but this is often difficult to quantify. For example, a tool with four impressions manufacturing complex parts may be more expensive than a larger eight-impression tool producing simpler parts.

14.1.12 Conclusion

Many of the topics discussed above illustrate the difficulty of designing a universal program that will predict mould costs for a particular component.

Several areas are unquantifiable, like the different costing methods employed by different toolmakers, the conception of the degree of difficulty, the work loading, the time available for processing enquiries and so on.

Despite the advent of computer-aided systems for estimating machining times, there are too many variables that cannot be included in such programs. The concept of the degree of difficulty and the rate charged per hour are just two of the obstacles.

14.2 Custom-designed Mould Estimating Programs

Although a universal mould costing programs is not possible to create, it is possible for companies to develop their own custom-designed program that increases in accuracy with time.

The system is based on recording information from all previous mould enquiries and logging the information on prices and delivery periods into the program in the appropriate categories.

The program can be developed by using a standard spreadsheet which has been pre-programmed in a template form. The system consists of recording information into the spreadsheet in the chosen categories. This builds up a database of previous mould prices from which mould price estimates can be extrapolated. As the size of the database increases, the accuracy of the predicted mould prices will also increase.

It is suggested that the system is based on five types of mould tool models, although this can be changed to suit individual preferences. The mould categories in this example are based on:

- two-plate mould with form in half of the mould only;
- two-plate mould with form in both halves of the mould;
- side core moulds;

- split moulds; and
- automatic unscrewing moulds for producing screw threads.

Thus with this system, five spreadsheets would be necessary – one for each of the above models.

This categorises the mould prices according to the basic mould construction model. However, to obtain meaningful results, each of these categories must be subdivided into further subcategories:

- the complexity of the component – whether the part is straightforward, like a washer, coffee spoon, basic snap fit closure and similar parts, or more complex, like a gear, cam or other more complex forms that would require considerably more toolmaking time to manufacture; and
- the type of runner system – whether it is a cold runner or a hot runner.

Table 14.1 shows an example of a spreadsheet that includes these basic categories. The top part is where the information is logged, and the lower part allows the user to enter four basic parameters to obtain a tool price estimate based on the information that has been recorded.

In this example, three toolmakers are being used to obtain quotations for mould tool prices and have been allocated the codes A, B and C. This ensures that an estimated mould price can be generated more accurately for each toolmaker, rather than a less accurate average price based globally on prices previously quoted by all toolmakers.

At least three toolmakers should be used and work placed with them regularly so that a good working relationship is established with each of them. This will also result in shorter deliveries and lower mould prices than if a larger number of toolmakers are used less frequently.

An additional parameter has been included in this example spreadsheet to achieve more accuracy. This ‘Volume’ variable needs further explanation. It is simply the volume of the smallest rectangular box of zero thickness that will fit snugly over the component as shown in **Figure 14.1**. This will have the effect of establishing the overall size of the mould which is an important factor in the estimating the final price of the mould.

Whist a simple spreadsheet system can be used quite successfully, a dedicated program may be more efficient when larger numbers of mould quotations are required.

Table 14.1 Example spreadsheet for estimating mould cost

Two plate tool - form in one half only

				Degree of compexity			**Runner type**				
Tool Ref	**Toolmaker**	**Date**	**No impressions**	**Regular**	**Complex**	**Volume cm^3**	**Cold**	**Hot**	**Price (£)**	**Delivery (weeks)**	**Comments**
1001	A		4		x	5	x		25,000	14	Query on finish
1001	B		4		x	5	x		18,500	12	
1002	B		8	x		4		x	21,000	14	Drawing query
1002	C		8	x		4		x	18,750	16	Drawing query
1003	B		16		x	6.5		x	27,000	16	
1003	A		16		x	6.5		x	35,000	14	
1004	A		12	x		3.7	x		25,000	12	
1004	B		12	x		3.7	x		28,000	14	
1005	C		12	x		3.7	x		22,000	12	
1006	A		8	x		4.5	x		28,000	14	
1006	B		8	x		4.5	x		25,000	16	
1006	C		8	x		4.5	x		18,500	16	
Mould Price Estimator											
			Toolmaker	A		Estimated Price		28000			
			No Imps	12		Estimated delivery		16			
			Complexity	C							
			Runner	C							
			Volume cm^3	6							

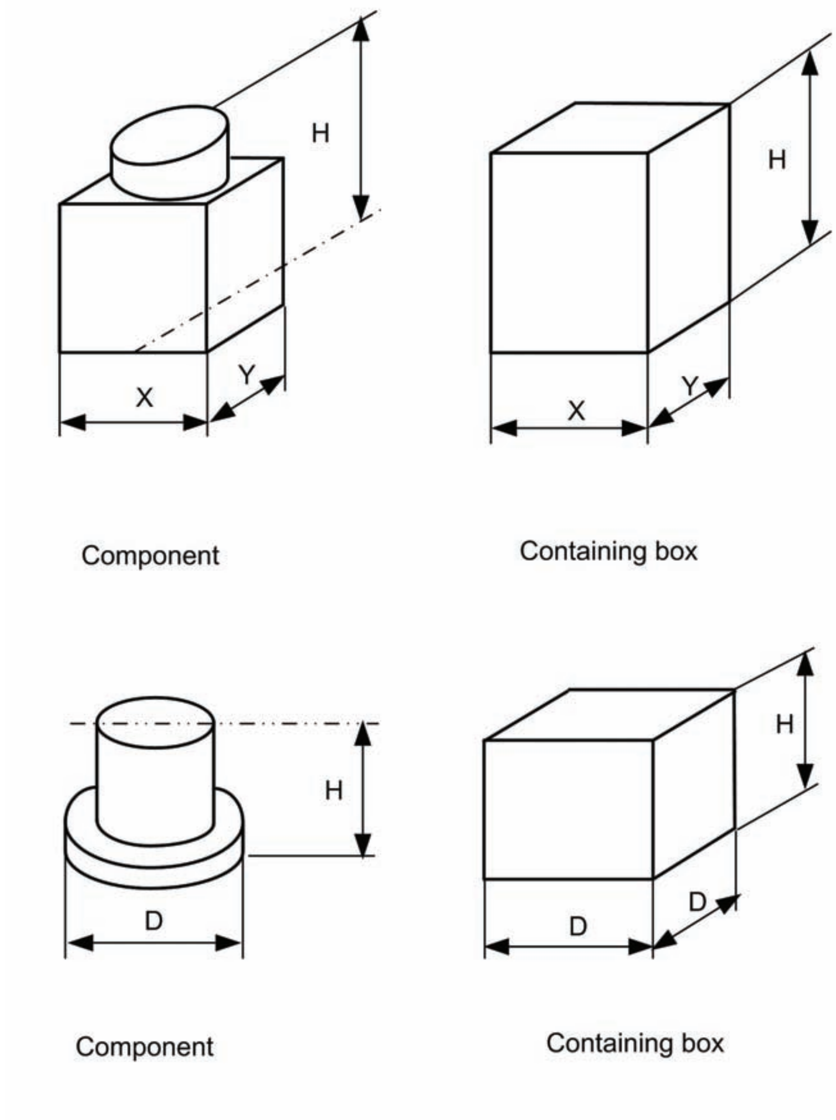


Figure 14.1 Containing box for volume calculation

Figure 14.2 shows a program designed and used by the author using Visual Basic and a database. It uses a more mathematical basis to give a little more accuracy in the results. It is also quicker to use since entries may be clicked instead of characters having to be input in the spreadsheet version, but it is still based on the five basic mould type models.

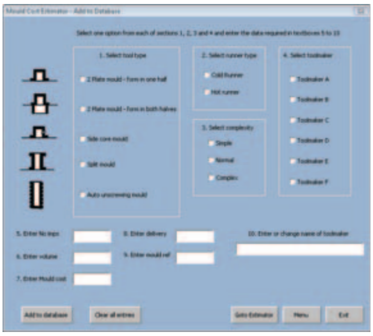


Figure 14.2 Entering data into the database

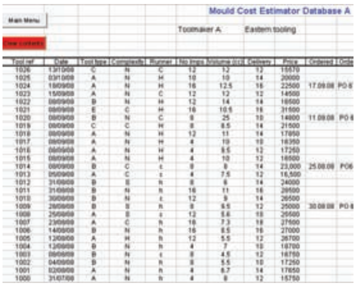


Figure 14.3 Database for toolmaker A

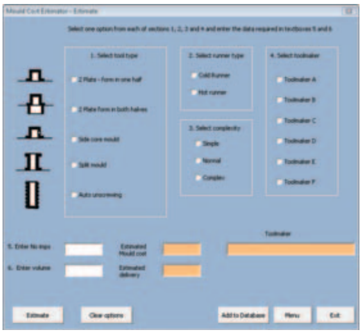


Figure 14.4 Estimating a mould cost

The advantage of designing custom programs like this is that they can be tailored to suit individual company requirements. They can also be modified on a continuing basis to achieve increasingly accurate results.

With this program, clicking the appropriate options displays a database or opens the estimating window. Each of these is dedicated to a particular toolmaker, mould type, runner type and complexity of form where the remaining details can be entered.

After clicking on the options, if the 'Add to database' button is clicked all the data are transferred to an Excel spreadsheet shown in **Figure 14.3**. When an estimate is required, the estimating window opens (**Figure 14.4**). All that is necessary is to enter the number of impressions and the volume (in cm^3), as described in **Figure 14.1**, and then to click on the 'Estimate' button for the estimated mould cost and delivery to be displayed.

This program is designed to be as simple as possible to use; hence, the number of variables that have to be entered are kept to a minimum. Note that the moulding material is not required in this program as generally this is not a major factor that is used by toolmakers in pricing a mould – unless it is one that is likely to significantly affect the mould in any way. For example, materials like certain grades of PVC may corrode the steel necessitating the use of a stainless steel mould. Such instances are usually infrequent and should be regarded as special cases.

There is no reason why a custom-designed program should not include the material or other variables (like the gate position and type) if preferred. However, it should be noted that the more complex the program becomes, the longer it will take to keep the databases up to date and it may not increase the accuracy by any useful amount.

15

Profit and Loss Accounts

15.1 Running Profit and Loss Account

Reference has been made to the value of profit and loss accounts several times in this book. A suitable profit and loss account is a statutory requirement for all companies, and is used as one of the instruments in determining how much tax a company has to pay.

This type of profit and loss account, however, is prepared some time after the end of a particular trading year. Hence it is inevitably finished well after the end of the financial year to which it is related. Whilst this tells us retrospectively how the company has performed, it is of little use in helping to monitor the current performance and take action on a day-to-day basis.

Many companies prepare profit and loss accounts (statutory or otherwise) only following the end of their financial year and therefore only know the actual trading results well after the events have taken place. Clearly this is undesirable as no preventative action can be taken to improve a poor position so that the eventual year-end results can be improved.

Although we can check the costing on individual jobs on a day-to-day basis, inevitably there is a mixture of profitable and not so profitable work. Also, in order to see what the overall trading position is we really need to add up all the costs and invoiced sales to date to find out. We also need to take account of certain other related information. One of the best ways to do this is to use a running profit and loss (P&L) account.

As well as the statutory P&L account for taxation purposes, another type of statutory P&L account may have to be prepared for inspection by the general public. Since most companies do not want to disclose any information that could assist competitors, this type of account displays very little information – usually the minimum required by law.

This shows only the most basic information and the overall position with regard to the company's performance. It only gives global generalised information that would be of little value to competitors or to anyone in another company wishing to know, for example, the cost of electricity for the period, machine repair costs, moulding material costs and so on.

15.1.1 Statutory Profit and Loss Statement

The example in **Table 15.1** shows a typical statutory P&L account available for public inspection. This account shows the final profit for the year, including adjustments made for tax, investments, dividends, loan interest, etc. It does not, however, give the reader much information.

What we need to analyse is the ***trading profit*** of the company. To do this we need much more detailed information on all the costs. In particular we want to know if the actual costs exceeded or fell short of the budgeted costs, and if so, why.

It is only by having this information that we are able to make value judgements about the efficiency of the various aspects of the trading performance. If there were any significant variations from budget, these would have to be investigated to ascertain the cause.

15.1.2 Trading Profit and Loss Statement

Table 15.2 is the same result as the previous example, but presented with more information as a ***trading profit and loss statement***. This clearly shows very much more detailed information. All the costs are categorised in the same format as the budget for easy comparison.

In order to compare the budget with the actual P&L and past years' results it is convenient to present these in a combined format so that the information may be more easily assimilated. This is discussed next.

15.1.3 Profit and Loss Statement with Budgeted and Actual Results

Table 15.3 shows the budget, the actual result and the two previous years' results, which are shown side by side.

This time the invoiced sales for the mouldings and the mould tools have been shown separately – and this has revealed something very significant. Notice that that the first thing that stands out is that the actual profit is less than that budgeted. In fact it is £19,000 lower. Whilst this in itself would not cause undue alarm, it would mean questions would be asked regarding this shortfall.

Table 15.1 Statutory profit and loss statement for year ended 2007

	£	£
Invoiced sales		**10,000,000**
Less		
Opening stocks	1,500,000	
Manufacturing costs	1,500,000	
Materials purchased	2,500,000	
Production labour costs	750,000	
Manufacturing expenses	1,250,000	
	7,500,000	2,500,000
Add		
Closing stocks	1,575,000	**4,075,000**
Gross profit		**4,075,000**
Less		
Administration costs	850,000	
Selling and distribution costs	750,000	
Depreciation	1,250,000	
		2,850,000
Trading profit		**1,225,000**
Add		
Income from investments		500,000
Less		
Interest on long-term loan		150,000
Profit before tax		**1,575,000**
Less		
Taxation		400,000
Profit after tax		**1,175,000**
Less		
Dividends paid		250,000
Retained profits (transferred to reserves)		**925,000**

Table 15.2 Trading profit and loss statement for year ended 2007		
	£	£
Invoiced sales		10,000,000
Less		
Opening costs	1,500,000	
Material (polymer) costs	2,225,000	
Mould tools purchased	1,210,000	
Direct labour costs	750,000	
Works salaries	345,000	
Subcontract work	350,000	
Works expenses	125,000	
Electricity	150,000	
Water charges	50,000	
Repairs to mould tools	150,000	
Repairs to plant	170,000	
Packaging and distribution	400,000	
Maintenance to services	75,000	
	7,500,000	2,500,000
Add		
Closing stocks	1,575,000	4,075,000
Gross profit		**4,075,000**
Less		
Salaries	810,000	
Pensions	125,000	
Office costs	25,000	
Rates	50,000	
Rent	250,000	
Insurance	125,000	
Repairs to premises	65,000	
Sales costs	150,000	
Depreciation	1,250,000	
	2,850,000	**2,850,000**
Trading profit		**1,225,000**

Table 15.3 Profit and loss statement for the year ended 2007 and comparison with years ended 2005 and 2006

	Budget 07	Actual 07	Actual 06	Actual 05
Invoiced sales				
Moulding sales	8,580,000	8,795,000	8,125,000	7,400,000
Mould Tool sales	1,100,000	1,205,000	875,000	850,000
Total sales	**9,680,000**	**10,000,000**	**9,000,000**	**8,250,000**
Less				
Opening stocks	1,250,000	1,500,000	1,000,000	900,000
Material purchased	2,000,000	2,225,000	1,950,000	1,850,000
Mould tools purchased	1,000,000	1,210,000	850,000	750,000
Direct labour costs	725,000	750,000	650,000	600,000
Works salaries	350,000	345,000	325,000	300,000
Sub contract work	325,000	350,000	300,000	250,000
Works expenses	150,000	125,000	135,000	115,000
Electricity	160,000	150,000	140,000	135,000
Water charges	55,000	50,000	45,000	40,000
Repairs to mould tools	155,000	150,000	140,000	120,000
Repairs to plant	170,000	170,000	150,000	145,000
Packaging and distribution	425,000	400,000	410,000	395,000
Maintenance to services	70,000	75,000	73,000	70,000
	6,835,000	**7,500,000**	**6,168,000**	**5,670,000**
Add				
Closing stocks	1,250,000	1,575,000	975,000	950,000
Gross profit	**4,095,000**	**4,075,000**	**3,807,000**	**3,530,000**
Less				
Salaries	825,000	810,000	760,000	740,000
Pensions	125,000	125,000	115,000	110,000
Office costs	26,000	25,000	18,000	16,000
Rates	50,000	50,000	48,000	46,000
Rent	250,000	250,000	250,000	225,000
Insurance	125,000	125,000	120,000	116,000
Repairs to premises	55,000	65,000	10,000	10,000
Sales costs	145,000	150,000	120,000	120,000
Depreciation	1,250,000	1,250,000	1,200,000	1,175,000
	2,851,000	2,850,000	2,641,000	2,558,000
Trading profit	**1,244,000**	**1,225,000**	**1,166,000**	**972,000**

Looking at the figures we can soon identify where the shortfall has occurred. The gross profit is £20,000 less than budget. The main culprits are the material usage, which is about 11% too high, and the sales of mould tools, which have been sold at a loss of £5,000.

In addition to this, several direct costs are also slightly over budget while only a few others are slightly less. The cumulative effect of these factors has also contributed to the shortfall.

As mentioned previously, once the actual end of year results have been established, it is too late to change anything. This is why the running P&L account is so important – action can be taken *well before* the year end to rectify significant deviations from budget.

The company accountant should be able to provide this information to the management quite easily, providing the costs have been accurately assigned to the appropriate cost centres throughout the year.

With the advent of computerised accounting the drudgery of logging this type of information has been made very much easier. In fact, because of the ease with which information can be recorded and analysed on a computer, more information may be recorded and examined.

If the figures are posted into their appropriate categories on a monthly basis, this forms the ideal platform for developing a monthly running P&L and permits fast, accurate feedback of all costs (and sales). It gives maximum information at the soonest possible moment, allowing changes to be made where necessary. The best systems have accounts available within seven to fourteen days after the end of the month.

Most company boards insist on at least half-yearly accounts and many require quarterly accounts as well. Half-yearly accounts should be the *absolute minimum* that any company should have. However, these again are often considerably retrospective.

15.1.4 Running Profit and Loss Account: April 2007

If we now take a look at a running P&L account we can see the value of this system. In this case we will assume it is the end of April 2007 – the end of the first quarter. The results are given in Table 15.4.

The information presented in this type of P&L account is invaluable for highlighting problems and drawing attention to areas that need attention. It can be seen that

Table 15.4 Running profit and loss account: April 2007

	Budget April	Budget cumulative	Actual April	Actual cumulative
Invoiced sales				
Mouldings sales	715,000	2,860,000	710,000	2,830,000
Mould tool sales	91,667	366,667	93,000	372,000
Total	**806,667**	**3,226,667**	**803,000**	**3,202,000**
Less				
Opening stocks	104,166	416,667	126,000	380,000
Materials	166,667	666,667	175,000	710,000
Mould tools purchased	83,333	333,333	95,000	345,000
Direct labour costs	60,417	241,667	60,700	259,000
Works salaries	29,167	116,667	29,000	115,000
Subcontract work	27,083	108,333	29,000	116,000
Works expenses	12,500	50,000	12,100	48,300
Electricity	13,333	53,333	12,500	52,350
Water charges	4,583	18,333	4,500	18,100
Repairs to mould tools	12,917	51,666	13,000	49,850
Repairs to plant	14,167	56,667	13,950	55,500
Packaging and distribution	35,417	141,667	34,250	139,000
Maintenance to services	5,833	23,333	6,200	23,750
Total	569,583	2,278,333	611,200	2,311,850
Add				
Closing stocks	104,167	416,667	110,250	430,750
Gross profit	**341,251**	**1,365,001**	**302,050**	**1,320,900**
Less				
Salaries	68,750	275,000	67,500	270,000
Pensions	10,417	41,668	10,417	41,668
Office costs	2,167	8,667	2,100	8,450
Rates	4,167	16,667	4,167	16,667
Rent	20,883	83,333	20,833	83,333
Insurance	10,417	41,667	10,417	41,667
Repairs to premises	4,583	18,333	5,417	23,000
Sales costs	12,083	48,333	12,500	49,000
Depreciation	104,167	416,667	104,667	416,667
Total	**237,634**	**950,335**	**238,018**	**950,452**
Profit	**103,617**	**414,666**	**64,032**	**370,448**

the profit for the month of April is considerable down on budget – in fact almost 40% down!

The total sales for the month are almost on budget, so this was not the cause of the problem. If we look at the gross profit we can see that the problem is an *above the line* one. The gross profit is £39,201 down on budget. The *below the line* results show that the *overhead costs* are reasonably on target.

As a result we now concentrate on the gross profit to establish what has gone wrong. It soon becomes apparent that the direct costs are well above budget. The mould tool sales are £2,000 less than it cost to purchase them even though they are above budget.

Mouldings sales are also £5,000 down on budget and this fact together with the loss on mould tool sales is a serious matter with obvious consequences for the trading position at the end of the year if no action is taken.

Even worse, we can see that the material usage figure is way off course. It is in excess of £8,333 over budget. This is made worse by the moulding sales being £5,000 down. This is extremely serious and immediate action is required to prevent a very dramatic drop in profit or even a loss at the end of the year.

Thus the running P&L account has highlighted for us the fact that all is not well. More than this, it has identified and quantified the amounts and areas that need attention and the information has been provided shortly after the event.

In practice, it is much more common for problems to occur in the invoiced sales and the direct costs giving a shortfall in gross profit. The overhead costs are usually much easier to predict, establish and control. For example, the rent, rates, insurance, salaries, pensions and depreciation are pretty well known in advance and are unlikely to provide any unpleasant surprises. There are, of course, exceptions to this but it is usually policy driven when this occurs – for example, expanding the sales or other staff. This would normally occur through increased production or profits. In such circumstances, the board would normally sanction such changes and a new budget would be prepared.

In our theoretical example, the running P&L account has highlighted several areas of concern and allowed action to be taken well in advance of the year end – December in this case.

15.2 Observations

- The value of a running P&L account or similar control system is inestimable. As mentioned previously, working without one is like driving a car without a fuel gauge.
- Companies that use a running P&L account or similar system are usually more profitable than those that do not.

15.3 Summary

- A monthly running P&L account gives maximum control over costs.
- It identifies and quantifies costs above and below budget.
- It allows action to be taken at the earliest opportunity, including, for example, adjustmnet of the MH.
- Using a computer program to log and process information allows fast input and calculation of results. This should allow an account to be prepared not more than seven to fourteen days after the end of the month to which it refers.

Glossary of Moulding Terminology

Time Elements in the Moulding Cycle

Cooling time This is normally considered to be the time in seconds from the moment injection time (including injection hold time) ends until the moment the mould starts to open. In reality, however, the cooling time is usually the same as the cycle time, since the coolant flows through the mould continuously, regardless of whether the mould is moving, or stopped open or closed. However, the statement is true if any form of pulsed cooling is used.

Cycle time The time in seconds from the start of one shot to the start of the next shot including the mould open time. This is usually measured with a stopwatch at the point when the mould reaches the mould closed position.

Dry cycle (time) This is the time in seconds from the moment the mould starts closing from its fully open position to the point it arrives again in the fully open position after having closed completely. The times for injection, hold and cooling periods are not included.

The dry cycle includes the mould closing time, the time to clamp and unclamp the mould and the mould opening time.

The dry cycle is an important measure of the clamping performance of a moulding machine. The shorter the dry cycle, the less time is wasted. This is of particular importance in fast cycling applications when moulding packaging products.

The dry cycle time depends significantly on the distance the moving platen has to move. The shorter the stroke, the shorter is the dry cycle.

Ejection time This is the time in seconds required to eject all the mouldings from the mould after the mould starts opening. It includes the time to clear the mould of all mouldings and runners, multi-stroke ejection times and the use of any robots.

The ejection time is part of the overall cycle time. Long ejection times can affect the cycle time seriously because they may require a slow opening speed of the clamp (the dry cycle), or it may require additional mould open time, or the lengthening of any mould open time already in the cycle to accommodate special ejection designs.

Ideally, the ejection time should take place during the mould opening time, and be completed by the time the mould starts closing again, without requiring any mould open time or pause time.

Occasionally, the ejection phase extends into the mould closing time (during the mould closing phase); providing all obstructions are cleared before the mould closes.

Injection hold time The time in seconds from the moment the first stage (high) injection pressure ends to the end of all subsequent secondary (lower) injection pressure phases. These lower pressure phases are necessary to compensate for the volumetric shrinkage of the material as it cools in the mould cavities. In very thin-walled parts the ‘hold time’ is frequently not used.

Injection time The time in seconds during which material is injected into the mould during the first high-pressure phase but not including second stage or holding pressure phases.

Mould closed time The time in seconds from the moment the mould is fully clamped up to the moment when it starts opening.

Mould open time The time in seconds from the moment the mould arrives in the fully open position to the moment when it starts closing for the next cycle. Ideally, a mould should run without any open time but it is often necessary to ensure the mould is clear of all mouldings, runners or robotic removal devices.

Passive cycle In certain hydro-mechanical machines (using shutters) this occurs at the point the machine is ready to open. After the cooling cycle ends, the clamp force is first relaxed, which takes a fraction of a second followed by the shutters being withdrawn, which takes another fraction of a second. The total of these time elements, before the mould actually starts opening, is called the passive cycle.

The mould will remain closed until this moment and the actual set cooling time includes the time for the passive cycle. This has to be taken into account when setting the cooling period.

However on fully hydraulic machines, and on toggle machines, there is no passive cycle. As soon as the cooling time is ended, the mould starts to open.

Profiled injection With modern machines controlled by microprocessors, injection and hold pressures can be programmed to change relative to the injection time or/

and stroke. The injection pressures or speeds can be increased or decreased in steps, or at a variable rate, to 'profile' the injection rate depending on the machine.

With older machines, injection and hold times are distinct times, which are individually set for each individual pressure and time.

Mould and Processing Terminology

Amorphous Having no pattern or structure; molecular chains are oriented at random. Amorphous materials have low shrinkage values compared to crystalline materials.

Barrel This has the same meaning as the term 'Cylinder' (see page 235).

Bolster A tool usually consists of a set of impressions containing the form to produce the mouldings and a set of plates screwed together into which they are located. This set of containing plates is termed a bolster.

Burned When the melt is injected into a tool, the advancing front of material has to displace the air from the cavities in order to fill them and for the melt to solidify into the moulding. If the air gets trapped and cannot escape, the incoming melt compresses it causing the air temperature to rise. This temperature can reach a value that degrades or decomposes the material giving the moulding a characteristic black sooty appearance.

Cartridge heater A cylindrical heating element available in different diameters, lengths and wattage ratings. Most often used for heating hot runner manifolds.

Cavity That portion of the tool containing most of the female form of the moulding. A four-cavity mould means four mouldings are produced each cycle, a six-cavity, six mouldings and so on. The term 'impression' is also used in this context, i.e. a six-impression mould would produce six mouldings per cycle.

Clamping force The force that holds the mould together from mould closing to the start of mould opening so that the injection pressure of the material inside the cavity space cannot force the mould open and cause it to flash at the split line. The required clamping force can be determined by multiplying the total projected area of all cavities (plus any additional area due to cold runners) by the injection pressure. The term 'locking force' has the same meaning.

Clamping force is measured in kN (kilo Newtons) or MN (mega Newtons). See 'Newton' on page 238.

The clamping force should only be sufficient to ensure the mould will not open while the material is being injected. If excessively high clamping forces are used, the stress on the split line surfaces of the mould may be high enough to damage them. It is also undesirable to mount a small mould on a relatively large machine due to potential damage to the machine platens through the tendency of the mould to 'hob' into them.

Clamping force, tie bar stretch and preload To ensure that the mould will not open during the injection phase, it must be held closed with a force, or 'preload', greater than the minimum clamping force required to just hold the mould closed. This preload is generated by the clamping mechanism of the moulding machine.

As the mould closes, the two mould halves meet at the parting line. At this moment, there is no force on either of the mould halves, and the tie bars remain in their original, unstretched length.

As the clamping mechanism starts to exert its full force, the mould halves start to become compressed together. As the locking force increases, the fixed platen is forced away from the clamping mechanism until the full clamp is achieved. Counteracting this force are the tie bars, which connect the stationary platen to the machine clamping mechanism. The tie bars stretch to provide the necessary clamping force to keep the mould closed during injection.

Clamping pressure The clamping force divided by the total projected area of the tool.

Closed loop This is a control system that monitors and adjusts melt temperatures, pressures and other moulding parameters automatically through feedback obtained via transducers in the mould.

Cold runner A cold runner tool produces a solidified runner and sprue as well as the mouldings each cycle. The runner and sprue are usually reprocessed and reused.

Crystalline Having a regular or ordered structure termed crystals.

Cushion When adjusting the length of the injection stroke of a machine, the stroke should be about 10 mm more than the actual shot volume required to fill the mould. This means that when the mould is filled after the end of the injection stroke, there will be still a small amount of plastic left in the cylinder to provide a 'cushion', of material at the front of the machine screw.

With amorphous plastics (acrylics, polkycarbonate, styrene-acrylonitrile and polystyrene) there is less or no need for a cushion since their shrinkage is quite small compared to crystalline materials.

The cushion provides a reservoir of material for the holding pressure, to make up for shrinkage. It also overcomes the difficulty of stopping the screw in precisely the right position every time as it retracts (screws back) during plasticising when preparing the shot for the next injection cycle.

A cushion also ensures that in the case of some plastic leaking back through the check valve at the tip of the screw during injection, there will always be sufficient material to fill the mould.

When moulding crystalline materials and/or thick-walled products a cushion is essential to provide a reserve of material for adequate filling during the holding pressure phase. However with fast cycling thin-walled products there is often no cushion required.

Cylinder The tubular container that holds the rotating screw and material. It has heater bands on the outside to help melt the plastic material.

Down time A term used to describe the time a machine does not have a mould tool on it. This is frequently due to a mould suffering damage and having to be removed from the machine for immediate repair.

Ejected A part has been ejected when it has been forced out of the mould by an ejector.

Ejector A device for forcing the moulding components out of the mould tool after the mouldings have solidified and the mould opened (or during mould opening). These are available as pins, blades or may be specially shaped.

End user The company that markets the moulding either direct or as part of some other piece of equipment.

Feed Another term used for ‘gate’ (see page 236).

Flash This is surplus material (usually in the form of a thin film), which is attached to the moulding resulting in the moulding being rejected. There may be several causes of flash occurring:

- Material being forced into the cavities at too high a pressure resulting in material penetrating areas of the cavity construction it is not supposed to – for example, down the sides of ejectors.
- As the tool wears, gaps in mating sliding parts become larger making flash more likely.

- As the result of the locking force of the machine being insufficient to keep the tool closed against the incoming injection pressure. This causes the tool to open slightly allowing the material to spread across the faces of the split line of the tool.

- Using low-viscosity materials that tend and flash more easily than high-viscosity materials.

Force See 'Newton'.

Freeze, frozen A term used to describe the condition when the melt has solidified.

Gate A feature machined into the cavity to connect the runner to the moulding. It is smaller than the runner so that it may be detached easily from the moulding. The gate also performs other functions to control the way in which the melt enters the cavity.

A variety of different gates are used which vary in shape, size and form depending on the size of the moulding and the material being used. A gate is also called a feed – they mean the same thing.

Guard A safety device preventing access to a mould tool or dangerous parts of a machine. Opening the guard door of a machine renders the machine (and hence the tool) inoperable and stops all functions.

Guide pillar Circular steel shafts fixed in one side of a tool and located into a bush (guide bush) on the other half of the tool. The purpose is to make sure that both halves of the tool align together properly as the tool closes.

'Heavy-wall' and 'thin-wall' mouldings These are subjective descriptions but one common method uses the length to thickness (L:T) ratio, which applies mainly to containers with a more or less uniform wall thickness. Depending on the ratio, a part is deemed either thin walled or thick walled.

Hobbing A process where one piece of steel (A) is forced into another (B), thereby leaving a female impression of it in B. This is sometimes used in cavity construction.

Holding pressure The reduced pressure exerted by the screw after the main injection pressure phase to compensate for volumetric shrinkage. See also 'injection hold time' above.

Hopper The container into which the raw material is poured to feed the material into the cylinder for processing.

Hot runner A hot runner mould tool is one in which the runner remains at melt temperature. Only the mouldings are produced thus saving wastage or reprocessing costs.

Impression This is a term used to describe all the parts of the tool required for forming the moulding usually (but not always) in separate insert sets.

Injection pressure The first-stage pressure exerted by the screw on the molten material to inject the material into the mould tool. See also ‘injection time’ above.

Injection stroke The distance the screw moves forward to displace the melt into the mould tool. The longer the stroke, the more the material is forced into the mould tool.

Injection unit The complete injection assembly comprising the cylinder, the screw, heater bands, hopper, metering devices, limit switches and the hydraulic cylinders and motors necessary to actuate injection.

Insert A separate unit located in the mould tool distinct from the plates.

Lock or locking force This has the same meaning as ‘clamping force’.

Manifold Used in hot runner tools. It consists of a block of steel into which a runner system is machined. It contains cartridge heaters and thermocouples to maintain the temperature required to keep the material at melt temperature. It is insulated from the rest of the mould tool to prevent loss of heat.

Mass The *inertia* of a body can be described as its reluctance to start moving, or to stop moving once it has started. A body of large mass requires a large force to change its speed or direction by a noticeable amount, i.e. the body has a large inertia. Thus the mass of a body is a measure of its inertia. Mass is measured in grams (g) or kilograms (kg).

Material The term used to describe the raw material or ‘plastic’. Polymer is also used in the same context.

Melt A term used to describe a material in its molten form at its melt temperature.

Melt flow index (MFI) A measure of how easily a molten material will flow. The lower the MFI, the more difficult it is to inject the material.

Micron 0.001 millimetres.

Mould The total mechanical assembly that provides the means by which mouldings are produced. The terms ‘tool’ and ‘mould tool’ have the same meaning.

Mould designer The person responsible for designing the mould tool to a standard whereby satisfactory production and quality is achieved.

Moulder A commonly used term to describe an injection moulding company or department carrying out a moulding operation.

Newton The force required to give a mass of 1 kilogram an acceleration of 1 metre per second every second. Prefixes are used by international agreement (SI) to describe quantity. For example:

- kN (kilo Newtons) = 1,000 Newtons; and
- MN (mega Newtons) = 1, 000,000 Newtons.

There are many other prefixes but these (kN and MN) are most frequently used in the injection moulding industry.

Very roughly 10,000 N (or10 kN) = 1 tonne = 1000 kg force. Machine locking or clamping forces are usually expressed in kN. Hence a 400 kN machine has a locking or clamping force of 40 tonnes (force).

Force is also sometimes expressed as 10 kgf, 100 gf, etc., to distinguish it from mass.

Open loop A method of moulding where no automatic adjustments are made to the processing conditions during moulding as opposed to a closed loop system (see page 234).

Operating window A term used to describe the range of operating settings or conditions of a moulding machine and mould, such as melt temperatures, cooling periods, pressures and other cycle times within which mouldings of satisfactory quality can be produced.

The operating window is heavily dependent on the mould design and mould quality, and in particular the gate size and location and satisfactory ejection. The larger the operating window, the easier it is for the moulder to achieve satisfactory mouldings. By contrast, narrow operating windows require frequent ‘fiddling’ of the moulding conditions incurring higher reject and production costs.

In effect, the wider the operating window, the easier it is for the moulder to produce mouldings of the required quality with low rejections levels.

Plasticised A material is plasticised when it reaches the melt temperature.

Platen The part of a machine on which a mould tool is mounted. The fixed platen is at the injection end of the machine and does not move. The moving platen is moved by the machine locking system via toggles or links and opens and closes the mould.

Plates The basic structure of a mould tool is made up of steel (sometimes aluminium) plates. They may be circular solids or rectangular solids that are available in various diameters, widths, lengths and thicknesses.

The plates have to be machined to accept the cavities or impressions and all other operating mechanisms required by the design. Plates are supplied in different grades of steel or aluminium depending on where they used in the tool construction.

Polymer The material used for the moulding operation. The terms ‘material’ and ‘plastic’ are also used.

Projected area The total area of mouldings seen in the direction of the clamping force. In cold runner moulds the area of the runners must also be included. In hot runner moulds, only the projected area of the cavities need be considered.

The forces due to the projected area are the product of the projected area and the injection pressure being used. This force is resisted by the clamping force to ensure the mould is kept closed during the injection phase.

Reprocessed material Material that is reclaimed by a process in which redundant material like cold runners and rejects, generated during production, may be reused. A granulator is used to chop up the material into small pieces which may be recycled in a controlled proportion with the ‘virgin’ material.

Runner A channel machined into the mould tool to direct the flow of the melt to the gates and into the cavities.

Screw A bar of steel machined with continuous spiral channels in the form of a helix. It is similar to an Archimedean screw. The flights of the screw get progressively shallower towards the tip of the screw. The purpose of the screw is to transport the material to the front of the cylinder ready for injection and to provide frictional heat.

Seized, seizing, seized up When two sliding components start to abrade each other, their surfaces become damaged and ultimately ‘weld’ or ‘lock’ themselves together.

Shear heat Frictional heat developed in the material by the ‘shearing’ action of the rotating screw on the material and by the material passing through the gates.

Short or shorts A term used to describe an incomplete moulding.

Shot The total number of items ejected from the mould tool each time it opens. That is, all the mouldings and associated runner and sprue (if present).

Shot capacity Used for defining the maximum amount of plastic that can be injected by a machine. This depends on the screw and cylinder diameter and the stroke of the screw. Shot capacity is usually specified as the maximum mass in grams that the machine can inject in polystyrene having a specific gravity of 1.05. When moulding other materials, with a different specific gravity, this mass must then be divided by 1.05 to get the corresponding shot volume, and then be multiplied by the value of the specific gravity for the material to obtain its shot mass.

Shot weight The weight of the total mass of all components moulded during one complete moulding cycle. The shot weight includes all the mouldings and the runner and sprue in cold runner moulds. To maintain adequate control the shot weight should not be less than 25% and not more than 80% of the rated shot capacity of the machine on which the mould is going to be run.

Shrinkage All materials undergo a volumetric reduction when injected into a cavity. The final size of the moulding is less than that of the cavity in which it is formed. It is necessary to make the cavities large enough so that after shrinkage has taken place the moulding will be the correct size. Crystalline materials have a higher shrinkage than amorphous ones.

Snatch, snatches, snatch pin A feature designed to ensure that runners are held on the correct half of the tool so that they may be successfully ejected.

Split line All mould tools have to separate into two parts (sometimes more) to allow parts to be ejected from them. The plane where these two halves meet is called the split line.

Split line moulding Most moulding operations are carried out on a horizontal machine. That is, all the movements of the machine and the tool take place in a horizontal plane. In split line moulding, the injection takes place along the split line of the tool. The tool movements are horizontal and the machine injection carriage vertical.

Sprue A cylindrical tapered part of the runner system leading from the sprue bush to the runner and thus to the cavities.

Sprue bush A shaped circular piece of steel that contains the sprue. It is hardened to resist the impact from the nozzle of the cylinder.

Starve feeding A method of adjusting the injection system so that the injected volume of material is exactly the same as the volume of the cavity space (plus any runners). This method is usually used for moulding thin-wall components where there is no need for holding pressure. This is because the material enters the cavity so quickly that it almost immediately fills it, with the result that the moulding instantly freezes along with the gate.

Until the time the cavity is filled, the material exerts relatively little pressure on the mould walls. However, in this case, by the time the mould is full, no more material is being injected due to the lack of cushion and hold pressure. Hence there is only a relatively small force trying to open the mould against the clamping force.

The advantage of this method is that a thin-walled moulding with a large projected area can be moulded in a smaller machine with a lower locking force. Another advantage is that moulds with long, slender cores can be filled with minimal core deflection since the pressures inside the cavity are significantly less than with general moulding techniques.

Sticking back a term used to describe a moulding staying in the wrong side of the tool (usually the fixed half) as opposed to the ejection side of the tool. Parts that have stuck back cannot be ejected from the tool and frequently have to be removed manually.

Stripper plate Either a full plate or insert that supports the periphery of the moulding whilst ejecting it from the mould.

Temperature controller A piece of equipment used to control the temperature of a mould coolant at a given value. A temperature controller is also used to control the temperature of hot runner manifolds.

Thermal degradation If a material is subjected to elevated temperatures for prolonged periods of time, it can decompose. This can take the form of burned particles being produced or, in more serious cases, decomposition into completely carbonised material accompanied by gases.

Thermocouple A sensor that sends information to a temperature controller enabling the temperature to be controlled within preset limits.

Thermoplastic A material that can be melted, allowed to solidify and then re-melted again.

Thermosetting A material that may be melted but once solidified cannot be re-melted.

Tie bar The high-strength steel bars along which a moving platen slides. The tie bars of a machine are stretched to provide the clamping force necessary to keep the mould tool closed during the moulding process. There are usually four tie bars on a machine.

Tie bar stretch The tie bar stretch is proportional to the clamping force. Knowing the tie bar stretch and the tie bar diameter and length, the actual clamp force can be easily calculated. The tie bar diameter determines the maximum possible clamp force of a machine. Machine manufacturers ensure that the maximum tie bar stretch is not greater than 10% of the yield stress of the tie bar material to maximise their operating fatigue life.

Tool See 'Mould'.

Toolmaker This can either mean an individual that works on the manufacture of a mould tool or a company that manufactures mould tools.

Twin barrel A machine having two cylinders or barrels used for increasing the nominal capacity of the shot weight of the machine. It is also used for moulding in two colours on the same moulding.

Virgin Describes material that has not previously been used. It is in the original untouched state as supplied by the material manufacturer.

Viscosity The degree of fluidity of a melted polymer. The lower the viscosity the easier it flows and *vice versa*. Low-viscosity materials are more like water while high-viscosity materials are more 'treacle-like'.

Weight This is defined as the force acting on a mass due the local gravitational attraction of the Earth, or: $W = mg$. It is a consequence of Newton's second law of motion (force = mass × acceleration). In the UK the value of g is usually taken as 9.81 metres per second per second. For less critical calculations a more approximate value of 10 metres per second per second is used.

Appendix

A.1 Machine Power Consumption

A.1.1 Power Factor

All electrical machinery will have a power factor which is a measure of how efficiently the electrical power supply is being used. The lower the power factor, the more expensive the plant will be to run and vice versa. The power factor (PF) ranges from 0 to 1, with 1 being the most efficient.

Most electrical loads fall into one of three categories:

- inductive;
- resistive; and
- capacitive.

In injection moulding, the most common load is inductive, consisting of transformers, fluorescent lighting and electrical AC motors. All inductive loads require two types of power to function:

- active power (kW); and
- reactive power (kVAr).

The operating power from the power distribution system is composed of both active (working) and reactive (non-working) components. The consumer has to pay for both.

The graph shown in **Figure A.1** illustrates how the power consumption becomes less efficient as the PF falls. For example, if the PF drops from 1 to 0.9, the efficiency drops by 10%. With a drop in PF from 1 to 0.5, the current required is approximately twice that to service the same load.

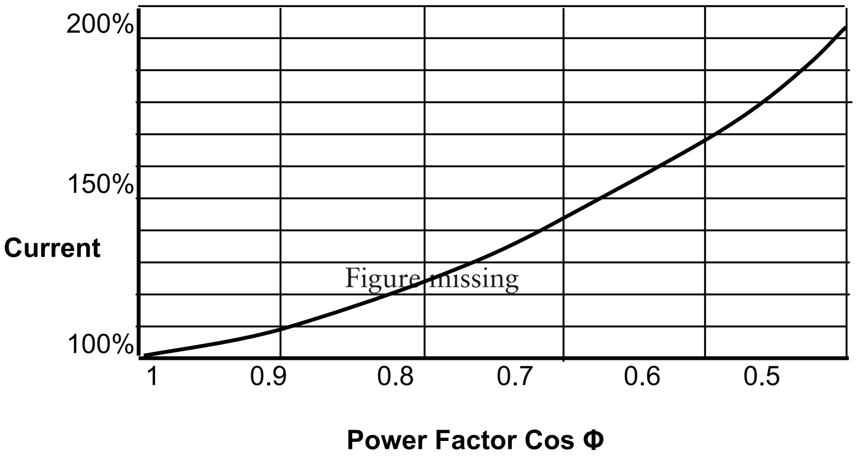


Figure A1 Power factor graph

AC electric motors consume both active and reactive power, but since they are only about 75% efficient they operate at a lower PF because of the 25% reactive power they consume. This equates to poor energy and cost efficiency because energy companies charge penalty rates for a poor PF.

A.1.2 kVA (kilovolt amperes) and kW (kilowatts)

Kilovolt amperes (or amps) are simply:

$$\frac{\text{Volts}\times\text{amps}}{1{,}000} \quad \text{or} \quad \frac{V\times A}{1{,}000}$$

where V and A are the root mean square values of the voltage and amperage, respectively. Kilowatts (kW) = kVA × PF.

A.1.3 Reducing the Cost of Electricity

Reducing the power consumption and hence the cost is dependent on achieving an efficient PF. This can easily be achieved by installing power factor correction equipment, which can result in lower electricity bills.

Many companies could reduce their electricity bills by 20% or more by having PF equipment installed. Therefore, it is well worthwhile having the PF checked by a specialist company and if necessary installing the appropriate power factor correction equipment.

There are also other advantages from installing PF correction equipment as follows:

- reduction of heat loss from transformers and other equipment;
- stabilised voltage;
- increased (electrical) capacity for existing plant;
- longer machine life; and
- increased profitability.

A.2 Summary of Formulae

A.2.1 Chapter 1: Terms and Definitions

Let

A = the original asset value

p = the reducing balance percentage rate

B_r = the reducing balance at end of year n

n = the depreciation period in years.

Then,

at the end of year 1:

$$B_r = \left(A - A \times \frac{p}{100}\right) = A\left(1 - \frac{p}{100}\right)$$

at the end of year 2:

$$B_r = A\left(1 - \frac{p}{100}\right)\left(1 - \frac{p}{100}\right) = A\left(1 - \frac{p}{100}\right)^2$$

at the end of year 3:

$$B_r = A\left(1 - \frac{p}{100}\right)\left(1 - \frac{p}{100}\right)\left(1 - \frac{p}{100}\right) = A\left(1 - \frac{p}{100}\right)^3$$

and so on. Hence,

at the end of year n:

$$B_r = A\left(1 - \frac{p}{100}\right)^n \tag{1.1}$$

$$p = 100\left(1 - \sqrt[n]{\frac{B_r}{A}}\right) \tag{1.2}$$

$$n = \frac{\log\left(\frac{B_r}{A}\right)}{\log\left(1 - \frac{p}{100}\right)} \tag{1.3}$$

$$\text{Utilisation} = \frac{\text{Utilisation}}{168} \times 100\% \tag{1.4}$$

$$\text{Efficiency factor} = \frac{\text{No. of production hours}}{\text{Utilisation}} \times 100\% \tag{1.5}$$

$$\text{Return on investment} = \frac{\text{Monies received} - \text{capital invested}}{\text{Capital invested}} \times 100\% \tag{1.6}$$

A.2.2 Chapter 3: Methods of Costing

A.2.2.1 Marginal costing

The parameters are as follows: S = sales value; V = variable costs; F = fixed costs; N = number of items sold; B = number of items required to be sold to break even; P = profit; N_v = number of items chosen for analysis; C = contribution = $S - V$.

$$\frac{S \times B}{N} = \frac{V \times B}{N} + F \tag{3.1}$$

$$B = \frac{N \times F}{S - V} \tag{3.2}$$

$$P = \frac{S \times N_v}{N} - \left(\frac{V \times N_v}{N} - F\right) \tag{3.3}$$

$$P = \frac{(S - V)N_v}{N} - F \tag{3.4}$$

$$P = \frac{C \times N_v}{N} - F \tag{3.5}$$

A.2.3 Chapter 5: Overlooked Costs

The parameters are as follows: A = original MHR cost per 100 items; B = energy cost expressed a percentage of normal MHR; C = normal material cost for job per 100 items; D = material premium percentage; E = modified material cost per 100 items; F = modified MHR per 100 items (based on total annual energy costs only); G = modified item costs per 100 items; J = original item cost per 100 items. Then:

$$E = C\left(1 + \frac{D}{100}\right) \tag{5.1}$$

$$F = \frac{B \times A}{100} \tag{5.2}$$

$$G = E + F \tag{5.3}$$

If G is greater than J there will be direct loss of $G - J$; if J is greater than G there will be a net contribution of $J - G$.

A.2.4 Chapter 7: Reducing the Costs of Production

A.2.4.1 Required to Achieve Original Profit Level

$$\text{Let } A = \text{material cost per 1,000} = \frac{\text{Shot weight} \times \text{material cost per tonne}}{\text{No. imps} \times 1{,}000}$$

$$\begin{aligned}\text{Let } B = \text{machine cost per 1,000} &= \frac{\text{Cycle time (s)} \times \text{MHR} \times 1{,}000}{3{,}600 \times \text{no. imps}} \\ &= \frac{C \times \text{MHR}}{3.6 \times N}\end{aligned}$$

Let P = total original cost (MHR + material cost)

Then $B = P - A$

Hence,

$$\frac{C \times \text{MHR}}{3.6 \times N} = P - A \tag{7.1}$$

Transposing this expression in terms of C we get:

$$C = \frac{(P - A) \times (3.6 \times N)}{\text{MHR}} \tag{7.2}$$

A.2.4.2 Cycle Required to Break Even

We require: selling price (SP) = $A + B$. Hence B = SP – A. That is:

$$\frac{C \times \text{MHR}}{3.6 \times N} = \text{SP} - A$$

Transposing this expression in terms of C, we obtain

$$C = \frac{(\text{SP} - A) \times (3.6 \times N)}{\text{MHR}} \tag{7.3}$$

A.2.5 Chapter 9: Cooling Cycle and Its Effect on Cost

Calculation of water channel diameter:

$$d = \sqrt{\frac{4V_\text{f}}{L_\text{f} \times \pi}} \tag{9.1}$$

where V_f = volumetric flow in kg /s, L_f = linear flow in m /s and d = diameter of round water channel in mm.

Abbreviations

A	Amorphous
A/C	Account
AMC	Actual material content
AMUF	Actual material usage factor
BMUF	Budgeted material usage factor
CAD	Computor aided design
CAM	Computor aided machining
DVD	Digital video disk
EDM	Electro-discharge machining
EF	Efficiency factor
EMC	Estimated material content
GA	General arrangement drawing
JIT	Just-in-time stock control
KVAr	Kilovolt-Ampere-reactance
m/c	Machine(s)
MFI	Melt flow index
MHR	Machine hour rate(s)
MMC	Maximum metal conditions
NOW	Narrow operating window
OW	Operating window

PC	Polycarbonate
PF	Powers factor
PVC	Polyvinylchloride
P&L	Profit and loss
RCE	Return on capital employed
ROI	Return on investment
SC	Semi-crystalline
SP	Selling price
SPC	Statistical procewss control
UF	Utilisation factor
UV	Ultraviolet
WOW	Wide operation window(s)

Index

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The topics of budgeting, costing and estimating for injection moulding are the source of much confusion in the plastics industry and from the research carried out by the author, there does not appear to be any kind of authoritative published work that addresses these topics. This book addresses them head-on to explain in detail all the stages involved from budgeting to the final estimate.

This book discusses and defines the different methods of budgeting, costing and estimating that are normally used within the injection moulding industry. In order to establish the costing system, the operating costs first have to be identified and quantified by means of a budget. Based on the budget, a costing system can then be developed that can be applied to determine the manufacturing cost of each product a company manufactures.

The underlying theme of this book is the maximisation of profits through the control of costs. Hence, emphasis is placed on ensuring the understanding of costing and estimating models through discussion and examples.

This book will be of considerable value to managers of injection moulding companies, to accountants who work in these companies and users of the equipment who may have involvement in the costing and budgeting of new projects.

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