MACHINING -LEVEL II

Based on Version 2 February 2017

Occupational Standard (OS)

Training Module –Learning Guide 21-23

Unit of Competence: **Perform Tool Grinding Operations**

Module Title: **Performing Tool Grinding Operations**

TTLM Code: **IND MAC2 TTLM 1019v1**

October 2019

Module Title: Performing Tool Grinding Operations

TTLM Code: IND MAC2 TTLM07 1019v1

This module includes the following Learning Guides

LG 21: Determine job requirements

LG Code: IND MAC2 M07 LO1-LG-21

LG 22:-Perform grinding operation
LG Code: IND MAC2 M07 LO2-LG-22

LG 23:-Check conformance with specification
LG Code: IND MAC2 M07 LO3-LG-23

INSTRUCTION SHEET	LEARNING GUIDE #21

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Interpreting drawings and determining sequence of operations.
- Selecting tool and cutter grinding wheels.
- Selecting accessories and holding devices.
- Observing safety procedures.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, **upon completion of this Learning Guide, you will be able to**:

- Interpreting drawings and determining sequence of operations based on standard.
- Selecting tool and cutter grinding wheels based on knowledge of discs and grinding agents.
- Selecting accessories and holding devices.
- Observing safety procedures.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the “Self-checks” which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to “Operation sheets
7. Perform “the Learning activity performance test” which is placed following “Operation sheets” ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

Information sheet-1	Interpreting drawings and determining sequence of operations

1.1 Drawing interpretation

Drawing interpretation means reading and understanding the information given by the drawing about the component to be manufactured. The information includes the shape, surface condition, dimension, number of parts (work piece) and the type of material to be used. It provides the following advantages.

- Easily inspect and select the rough size of the work stock black.
- Recognized the surface finish expected.
- For plan the machining sequence operation technically.

Drawing Views

Multi-View Projection -The Glass Box

- ✓ A view of an object is know technically as a projection
- ✓ A projection is a view conceived to be drawn or projected on to a plane, known as the plane of projection
- ✓ Multi view or orthographic projection is a system of views of an object formed by projectors from the object perpendicular to the desired plane of projection**.**

The projection of an object.

- ✓ Perpendicular lines or projectors are drawn from all points on the edges or contours of the object to the plane of projection. •Shown below is the projection of an object onto the frontal plane

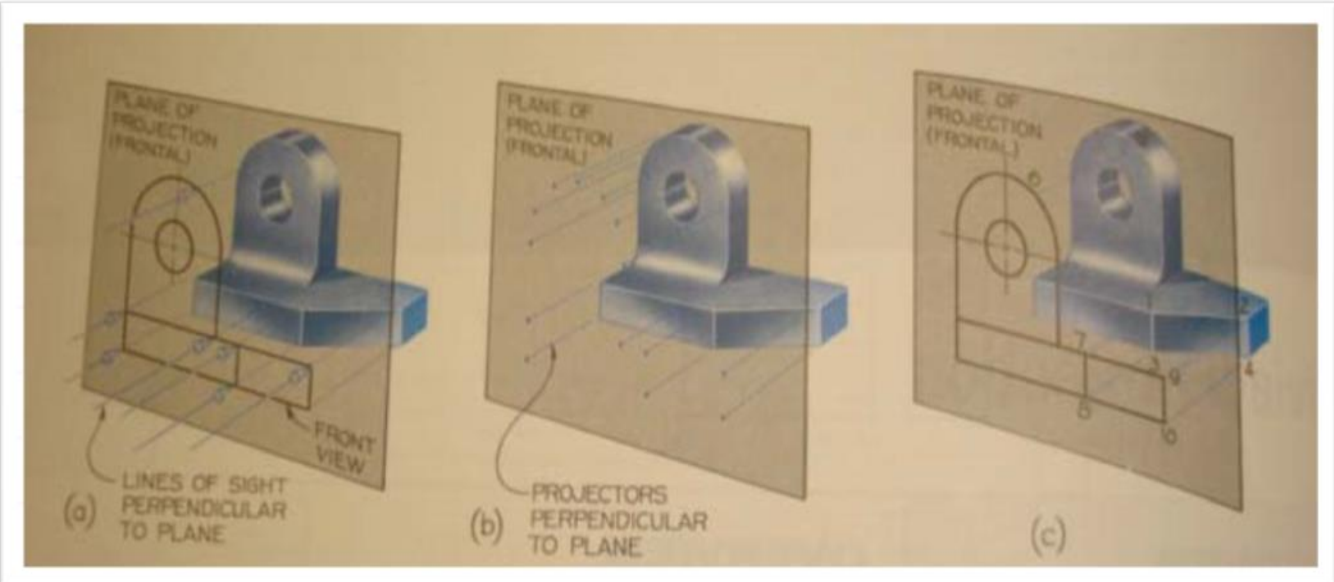


Fig. 1. projection of an object using front view

- **Drawing Views –Planes of projection**

- ✓ the top view is projected onto the horizontal plane
- ✓ he side view is projected onto the profile plane

- ✓ Multi view Projection –Proper number of Views

By unfolding the box six views of the object are possible

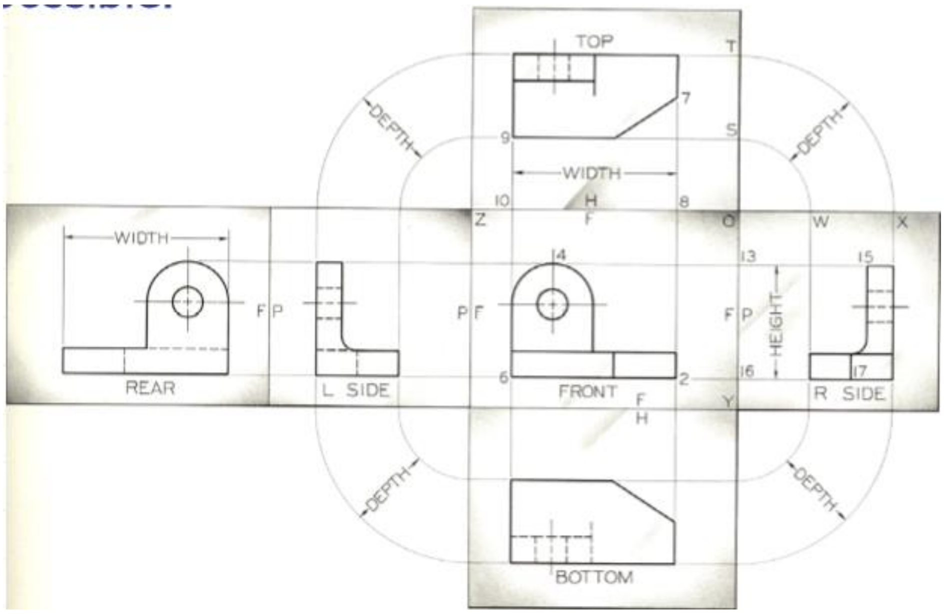


Fig 2 shows the six views of an object Drawing Views –Third Angle Projection

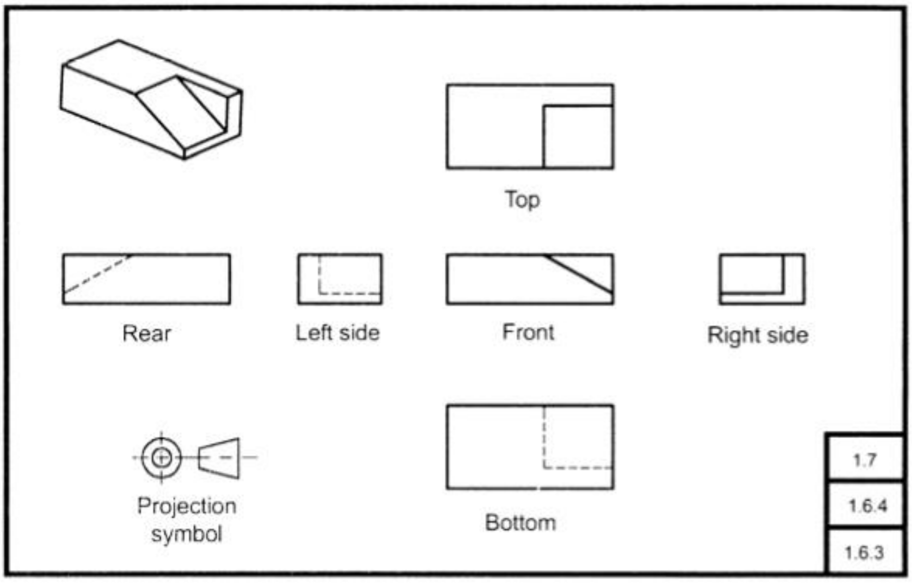


Fig 3 shows the six views of an object using 3rd angle projection

SELF-CHECK -1	WRITTEN TEST

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Use the figure for the Question 1-2 given below

1. How many views are necessary to completely describe this plate(1 point)
   a) 1   b) 2   c)3   D) 4
2. All total views of the above figure will be. (1 point)
   a) 6   b) 2   c)8   D) 4
3. a system of views of an object formed by projectors from the object perpendicular to the desired plane of projection**.** (1 point)
   a) Multi view   b) orthographic projection   c) Isometric drawing   D A & B

Note: **Satisfactory rating – 1.5 points   Unsatisfactory - below 1.5 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________
Rating: _____________

Name: ___________________________   Date: ________________

Short Answer Questions

1.
2.
3.

2.1 Grinding wheels: The wheel shapes most frequently employed for tool and cutter grinding are the flaring cup wheel and the **straight cup wheel** (disc wheel).

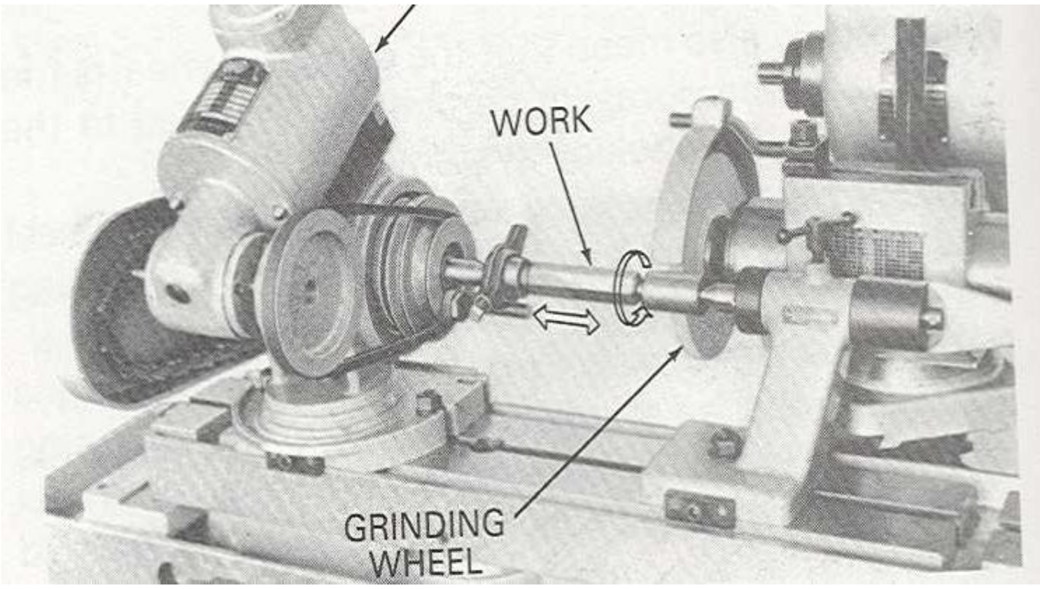


Figure 4.Tooth rest is being used to position teeth of cutter

Grinding wheel construction

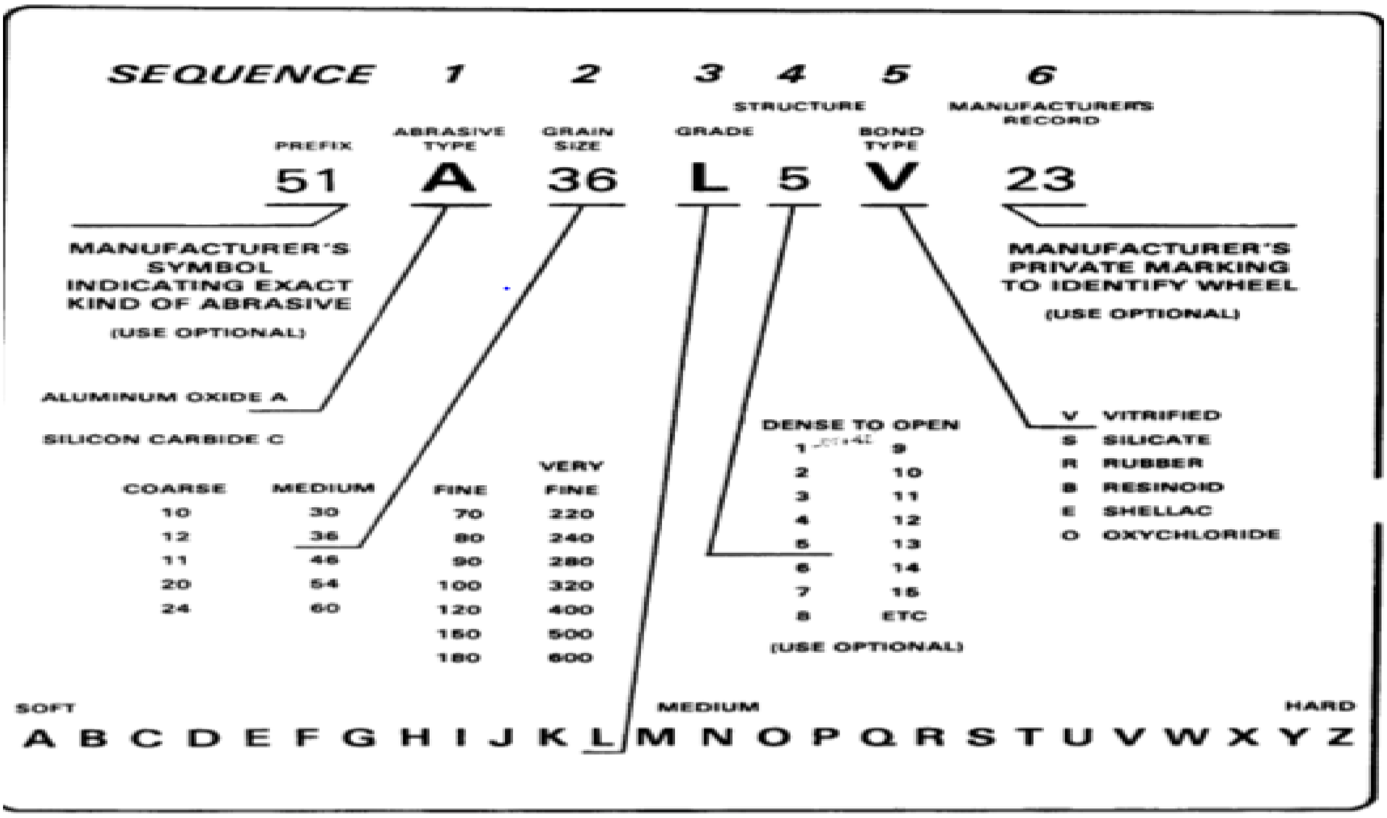
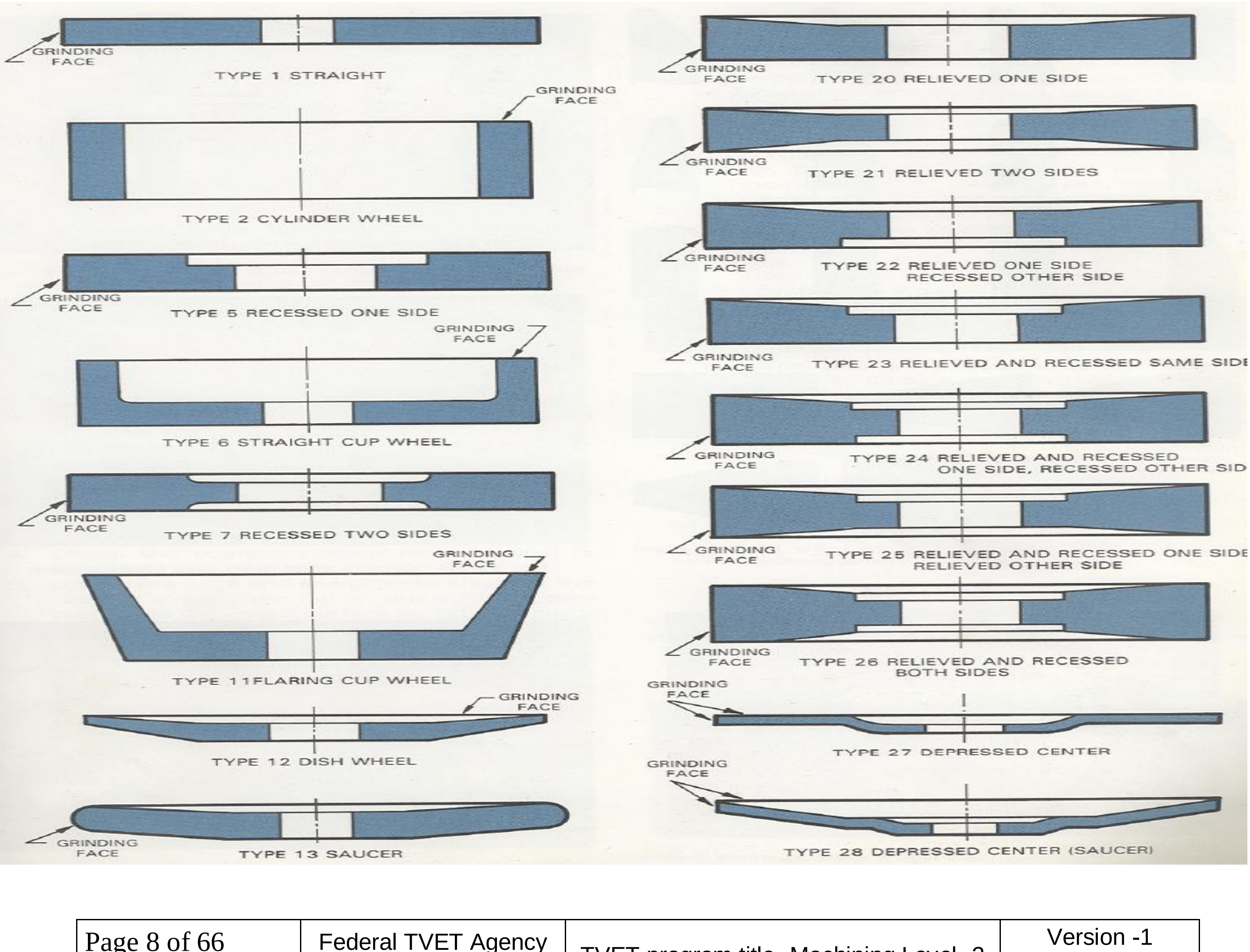


Figure 5.grinding wheel construction

2.2 STANDARD TYPES OF GRINDING WHEELS

Grinding wheels come in many different sizes, shapes, and abrasives (Figure 6). Some of the various types are listed below.

- **Straight:** Straight wheels**,** numbers 1, 5, and 7, are commonly applied to internal, cylindrical, horizontal spindle, surface, tool, and offhand grinding and snagging. The recesses in type numbers.5 and 7 accommodate mounting flanges. Type number 1 wheels from 0.006-inch to l/8-inch thick are used for cutting off stock and slotting.
- **Cylinder:** Cylinder wheels, type number 2, may be arranged for grinding on either the periphery or side of the wheel.
- **Tapered:** Tapered wheels, type number 4, take tapered safety flanges to keep pieces from flying if the wheel is broken while snagging.
- **Straight Cup:** The straight cup wheel, type number 6, is used primarily for surface grinding, but can also be used for offhand grinding of flat surfaces. Plain or beveled faces are available.
- **Flaring Cup:** The flaring cup wheel, type number 11, is commonly used for tool grinding. With a resinoid bond, it is useful for snagging. Its face may be plain or beveled.
- **Dish:** The chief use of the dish wheel, type number 12, is in tool work. Its thin edge can be inserted into narrow places, and it is convenient for grinding the faces of form-relieved milling cutters and broaches.
- **Saucer:** The saucer wheel, type number 13, is also known as a saw gummer because



it is used for sharpening saws.

Figure 6.Shape of grinding wheel

2.3 ABRASIVES

Most grinding wheels are made of silicon carbide or aluminum oxide, both of which are artificial (manufactured) abrasives. Silicon carbide is extremely hard but brittle. Aluminum oxide is slightly softer but is tougher than silicon carbide. It dulls more quickly, but it does not fracture easily therefore it is better suited for grinding materials of relatively high tensile strength.

2.4 KINDS OF ABRASIVES: Abrasive type classifies the abrasive material in the grinding wheel. Grinding wheels are made of abrasive particles bonded together by means of some suitable bond. An abrasive is a hard material which can be used to cut or wear away other materials. It is extremely hard and tough, and when fractured, it forms sharp cutting edges and corners. Abrasive particles used for grinding wheels are of two type's (a) **natural abrasives** and (b) **artificial abrasives**. Generally for most of the purposes, natural abrasives are not used due to certain advantages of artificial (manufactured) abrasives.

- **Natural abrasives:** These are produced by uncontrolled forces of nature. The following are the generally found and used natural abrasives:
  - ✓ Sand stone or solid quartz
  - ✓ Emery (50 - 60% crystalline MO, + Iron oxide)
  - ✓ Corundum (75 — 90% crystalline AlO, + Iron oxide)
  - ✓ Diamonds
  - ✓ Garnet

- **Artificial or manufactured** The quality and composition of these particles can be easily controlled and their efficiency is far better than that of natural abrasives. Most commonly used manufactured abrasives are:
  - ✓ **Silicon Carbide (SiC):** It is available in variety of colors. A special variety of bluish green is very suitable for grinding tip tools. The trade names of it are 'Carborandum', Crystolon'. 'Electron' etc.
  - ✓ **Aluminiwn Oxide (AlO):** The trade names for fused aluminum oxide are 'Aloxite'; 'Alundum' and 'Borolon'. Its special form is white MO which when pure, looks like brilliant white crystal. It is most suitable for tool steels where heat generation due to grinding is low.
  - ✓ **Boron Carbide**
  - ✓ **Boron Nitride (CBiV):** CBN grinding wheels are used to grind hardened and difficult to grind steels. These have long life and high grinding ratios. Temperature encountered in grinding is much less and hence much better finish and quality of surface.

2.5 EFFICIENCY OF ABRASIVE PARTICLES

The efficiency of abrasive particles depends upon

- **Purity**
- **Uniformity in composition**.

- **Hardness**: Common rule about it is that hardness of abrasive should be more that of Work material.
- **Toughness:** If wheel is not tough, then abrasive particles will fracture readily and wheel wear will be excessive.
- **Sharpness of fracture:** The better cutting action is obtained by sharp edged abrasives.

2.6 Classification of grain Sizes, Grade, Structure and Bond.

- ✓ **Grain size** is indicated by a number, usually from 8 (coarse) to 600 (very fine).
- ✓ **Grade** is the strength of the bond holding the wheel together ranging from a (soft) to Z (hard).
- ✓ **Structure** refers to grain spacing or the manner in which the abrasive grains are distributed throughout the wheel. It is numbered 1 to 16—the higher the number the "more open" the structure (wider grain spacing). The use of this number is optional.
- ✓ **Bond** indicates the type of material that holds the abrasive grains (wheel) together. Eight types are used:
  B = Resinoid
  BF = Resinoid reinforced
  E = Shellac
  0 = Oxy-chloride
  R = Rubber
  RF = Rubber reinforced
  S = Silicate
  V = Vitrified
  An additional number or letter(s) is sometimes used as the manufacturer's private marking to identify the grinding wheel.

- **ABRASIVE GRAIN SIZE:** Abrasive grains are selected according to the mesh of a sieve through which they are sorted. For example, grain number 40 indicates that the abrasive grain passes through a sieve having approximately 40 meshes to the linear inch. A grinding wheel is designated coarse, medium, or fine according to the size of the individual abrasive grains making up the wheel.

- **BONDING MATERIAL**

  - ✓ **Bond:** The abrasive particles in a grinding wheel are held in place by the bonding agent. The percentage of bond in the wheel determines, to a great extent, the "hardness" or "grade" of the wheel. The greater the percentage and strength of the bond, the harder the grinding wheel will be. "Hard" wheels retain the cutting grains longer, while "soft" wheels release the grains quickly. If a grinding wheel is "too hard" for the job, it will glaze because the bond prevents dulled abrasive particles from being released so new grains can be exposed for cutting. Besides controlling hardness and holding the abrasive, the bond also provides the proper safety factor at running speed. It holds the wheel together while centrifugal force is trying to tear it apart. The most common bonds used in grinding wheels are vitrified, silicate, shellac, resinoid, and rubber.

- ✓ **Vitrified:** A vast majority of grinding wheels have a vitrified bond. Vitrified bonded wheels are unaffected by heat or cold and are made in a greater range of hardness than any other bond. They adapt to practically all types of grinding with one notable exception: if the wheel is not thick enough, it does not withstand side pressure as in the case of thin cutoff wheels.
- ✓ **Silicate:** Silicate bond releases the abrasive grains more readily than vitrified bond. Silicate bonded wheels are well suited for grinding where heat must be kept to a minimum, such as grinding edged cutting tools. It is not suited for heavy-duty grinding. Thin cutoff wheels are sometimes made with a shellac bond because it provides fast cool cutting.
- ✓ **Resinoid:** Resinoid bond is strong and flexible. It is widely used in snagging wheels (for grinding irregularities from rough castings), which operate at 9,500 SFPM. It is also used in cutoff wheels.
- ✓ **Rubber:** In rubber-bonded wheels, pure rubber is mixed with sulfur. It is extremely flexible at operating speeds and permits the manufacture of grinding wheels as thin as 0.006 inch for slitting nibs. Most abrasive cutoff machine wheels have a rubber bond.

2.7 GRADES OF HARDNESS

The grade of a grinding wheel designates the hardness of the bonded material. Listed below are examples of those grades:

A soft wheel is one on which the cutting particles break away rapidly while a hard wheel is one on which the bond successfully opposes this breaking away of the abrasive grain.

Most wheels are graded according to hardness by a letter system. Most manufacturers of grinding abrasive wheels use a letter code ranging from A (very soft) to Z (very hard). Vitrified and silicate bonds usually range from very soft to very hard, shellac and resinoid bonds usually range from very soft to hard, and rubber bonds are limited to the medium to hard range. The grade of hardness should be selected as carefully as Figure 4 illustrates sections of three grinding abrasive the grain size. A grinding abrasive wheel that is too soft wheels with different spacing of grains. If the grain and bond will wear away too rapidly, the abrasive grain will be materials in each of these are alike in size and hardness, the discarded from the wheel before its useful life is wheel with the wider spacing will be softer than the wheel realized. On the other hand, if the wheel is too hard for with the closer grain spacing. Thus, the actual hardness of the job, the abrasive particles will become dull because the grinding wheel is equally dependent on grade of hardness the bond will not release the abrasive grain, and the and spacing of the grains or structure. Wheel's efficiency will be impaired.

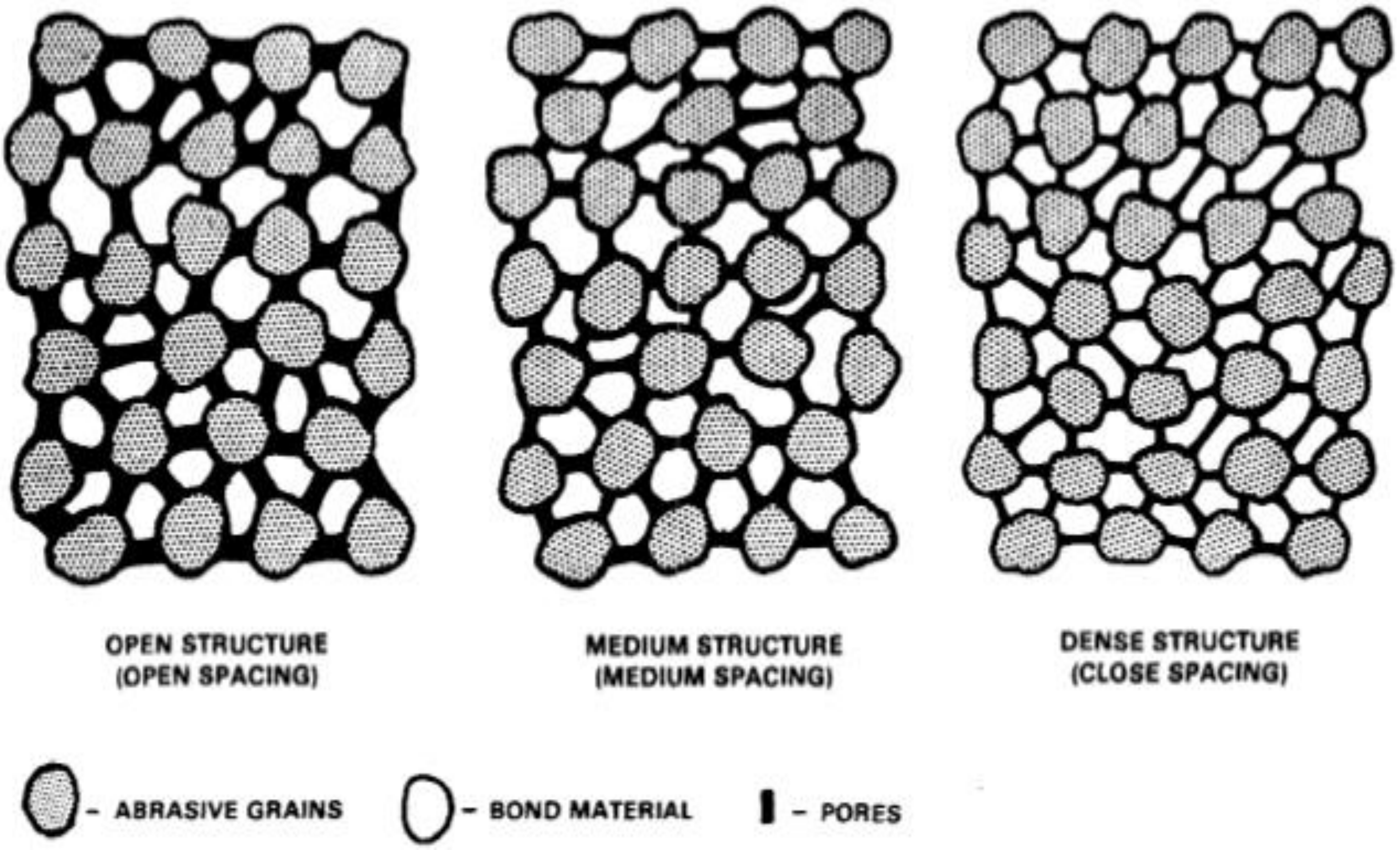


Figure7. Grinding wheel abrasive

2.8 WHEEL DRESSERS

Grinding wheels wear unevenly under most general grinding operations due to uneven pressure applied to the face of the wheel when it cuts. Also, when the proper wheel has not been used for certain operations, the wheel may become charged with metal particles, or the abrasive grain may become dull before it is broken loose from the wheel bond. In these cases, it is necessary that the wheel be dressed or trued to restore its efficiency and accuracy.

- **Dressing:** is cutting the face of a grinding wheel to restore its original cutting qualities. Truing is restoring the wheel's concentricity or reforming its cutting face to a desired shape. Both operations are performed with a tool called an abrasive wheel dresser (Figure 5).
  - ✓ **Mechanical Dresser:** The hand-held mechanical dresser has alternate pointed and solid discs which are loosely mounted on a pin. This dresser is used to dress coarse-grit wheels and wheels used in hand grinding operations.
  - ✓ **Abrasive Stick Dresser:** The abrasive stick dresser comes in two shapes: square for hand use, and round for mechanical use. It is often used instead of the more expensive diamond dresser for dressing shaped and form wheels. It is also used for general grinding wheel dressing.
  - ✓ **Abrasive Wheel Dresser:** The abrasive wheel dresser is a bonded silicon carbide wheel that is fastened to the machine table at a slight angle to the grinding wheel and driven by contact with the wheel. This dresser produces a smooth, clean-cutting face that leaves no dressing marks on the work.

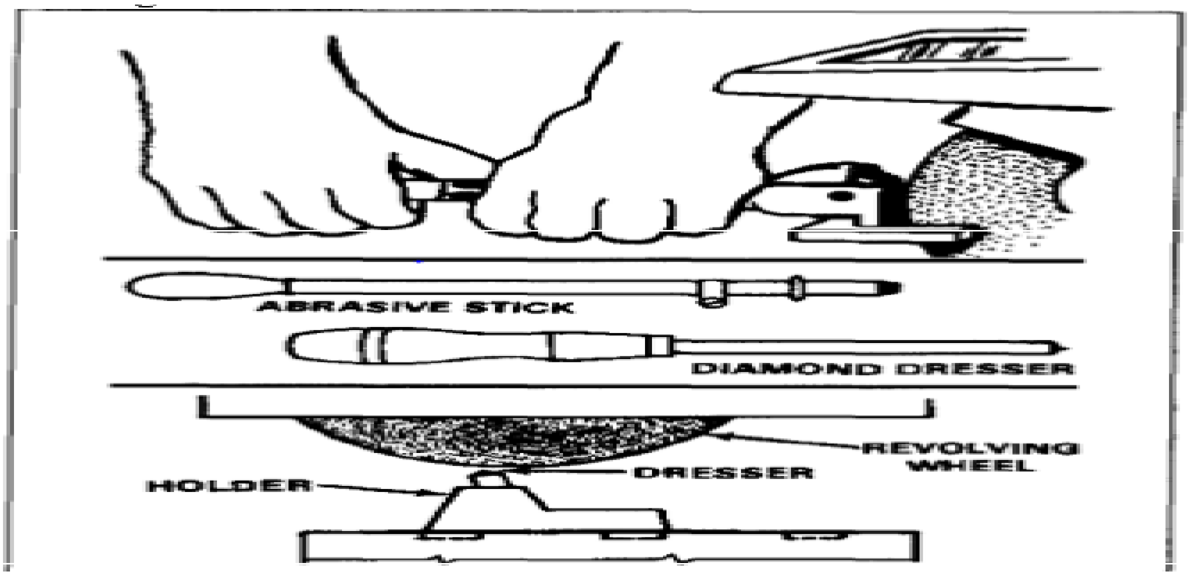


Figure 8.Dressing tools

- ✓ **Diamond Dresser:** The diamond dresser is the most efficient for truing wheels for precision grinding, where accuracy and high finish are required. A dresser may have a single diamond or multiple diamonds mounted in the end of a round steel shank. Inspect the diamond point frequently for wear. It is the only usable part of the diamond, and is worn away it cannot dress the wheel properly. Slant the diamond 3° to 15° in the direction of rotation and 30° to the plane of the wheel as shown in Figure 6 to prevent chatter and gouging. Rotate the diamond slightly in its holder between dressing operations to keep it sharp. A dull diamond will force the abrasive grains into the bond pores and load the face of the wheel, reducing the wheel's cutting ability.

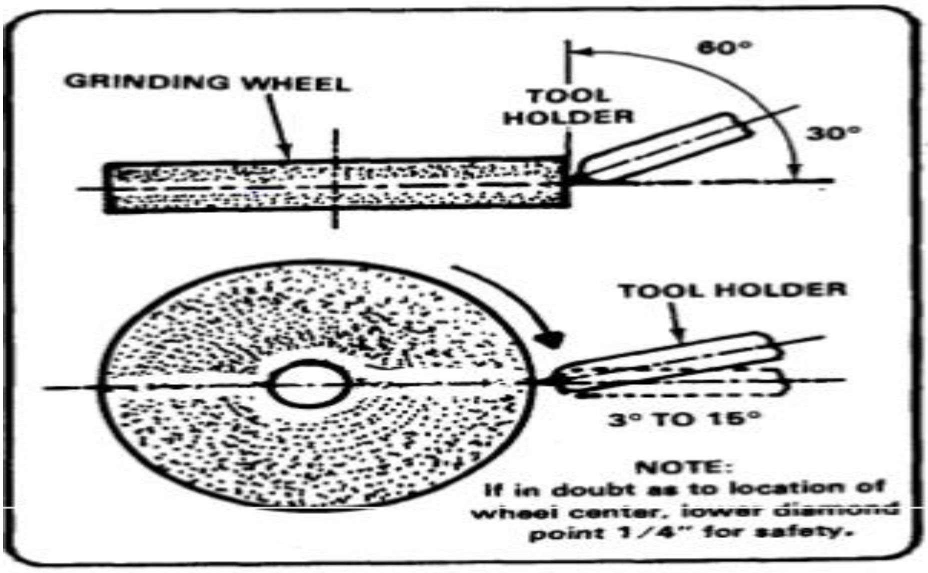


Figure 5-14. Position of diamond dresser.

Figure 9.Position of diamond dresser

When using a diamond dresser to dress or true a grinding wheel, the wheel should be turning at, or slightly less than, normal operating speed never at the higher speed. For wet grinding, flood the wheel with coolant when you dress or true it. For dry grinding, the wheel should be dressed dry. The whole dressing operation should simulate the grinding operation as much as possible. Whenever possible, hold the dresser by some mechanical device. It is a good idea to round off wheel edges with a hand stone after dressing to prevent chipping. This is especially true of a fine finishing wheel. Do not round off the edges if the work requires sharp corners. The grinding wheel usually wears more on the edges, leaving a high spot towards the center. When starting the dressing or truing operation, be certain that the point of the dressing tool touches the highest spot of the wheel first, to prevent the point from digging in.

Feed the dresser tool point progressively, 0.001 inch at a time, into the wheel until the sound indicates that the wheel is perfectly true. The rate at which you move the point across the face of the wheel depends upon the grain and the grade of the wheel and the desired finish. A slow feed gives the wheel a fine finish, but if the feed is too slow, the wheel may glaze. A fast feed makes the wheel free cutting, but if the feed is too fast, the dresser will leave tool marks on the wheel. The correct feed can only be found by trial, but a uniform rate of feed should be maintained during any one pass.

2.9 SETTING UP TOOL AND CUTTER GRINDER

- **Wheel balancing:** the grinding wheel must be balanced in order to prevent the strains caused by equal centrifugal forces that can occur if the wheel is out of balance. Large grinding wheels must be balanced more precisely. The wheel is mounted on the arbor and the wheel together is mounted on a balancing spindle. The balancing spindles is then placed on special parallel ways or balancing discs. The heavy side of the wheel tends to come to rest in the lower position. The flanges of the large arbors will have two, three or four adjustable balance weights which are adjusted until the wheel and arbor are in true balance.

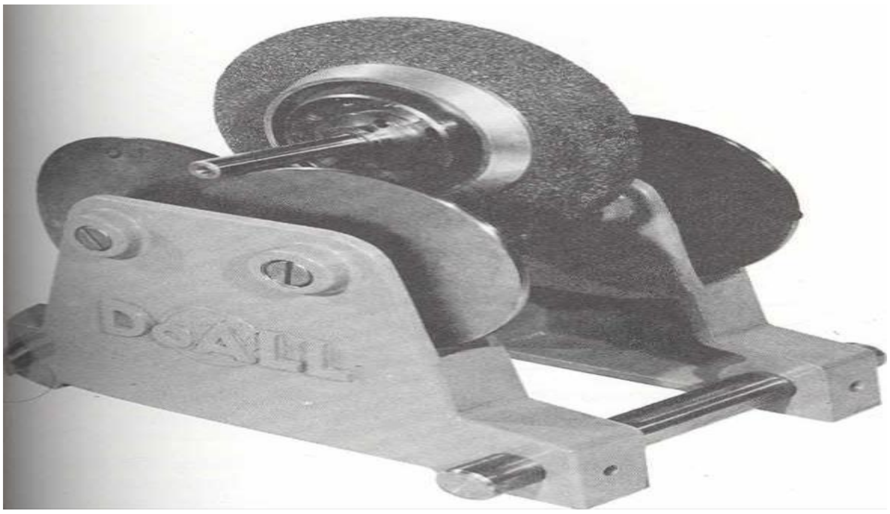


Figure10.A grinding wheel balancing stand

- **Mounting grinding wheel:** Before any grinding wheel is mounted on the spindle of a grinding machine it should be carefully checked to be sure that it is not fractured or cracked.

The inner flange should be keyed or otherwise fastened to the wheel spindle and the face of this flange must run true without any endwise eccentricity. A blotter is placed between the wheel and the flange and the wheel is pushed snugly against the flange. Finally, the nut is placed on the spindle and tightened enough to hold the wheel firmly in place.

The following four items are methods and procedures for mounting grinding wheels:

- ✓ Note that the wheel is mounted between two flanges which are relieved on their inner surfaces so that they support the wheel only at their outer edges. This holds the wheel more securely with less pressure and with less danger of breaking. For good support, the range diameter should be about one-third of the wheel diameter.
- ✓ The spindle hole in the wheel should be no more than 0.002 inch larger than the diameter of the spindle, since a loose fit will result in difficulty in centering the wheel. If the spindle hole is oversize, select another wheel of the proper size. If no others are available, fit a suitable bushing over the spindle to adapt the spindle to the hole.
- ✓ Paper blotters of the proper size usually come with the grinding wheel. If the proper blotters are missing, cut them from heavy blotter paper (no more than 0.025-inch thick :) and place them between the grinding wheel and each flange. The blotters must be large enough to cover the whole area of contact between the flanges and the wheel. These blotters serve as cushions to minimize wheel breakage.
- ✓ When installing the grinding wheel on the wheel spindle, tighten the spindle nut firmly, but not so. tight that undue strain will be put on the wheel.

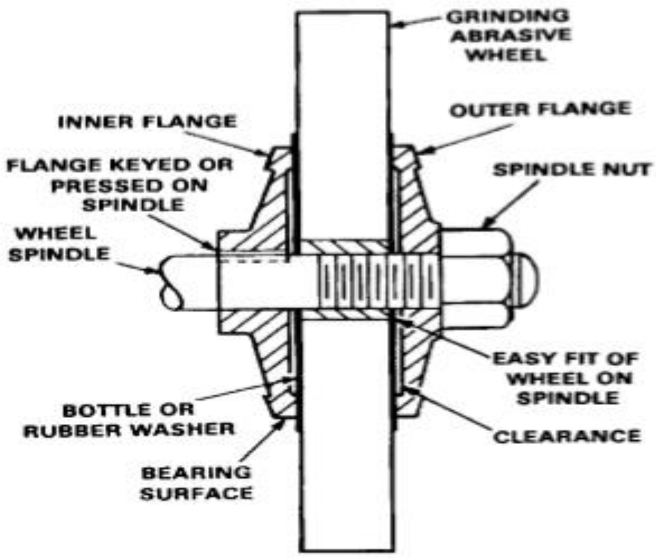


Figure 11.Mounting of grinding Wheel

SELF-CHECK -2	WRITTEN TEST

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false (each 1 point)

1. The grade of a grinding wheel designates the hardness of the bonded material.
2. Before any grinding wheel is mounted on the spindle of a grinding machine it should be carefully checked to be sure that it is not fractured or cracked
3. Grinding wheels should not come in many different sizes, shapes, and abrasives.
4. The greater the percentage and strength of the bond, the harder the grinding wheel will be

II. Choose the best answer (each 1 point)

5. Which one of the following belongs to standard types of grinding wheels
   A. Straight. B. Cylinder. C. Tapered D. All
6. The most common bonds used in grinding wheels are
   A. Vitrified B. shellac C Mild steel D. rubber.

7. Which one is not Natural abrasives:
   a) Sand stone or solid quartz
   b) Emery (50 - 60% crystalline MO, + Iron oxide)
   c) Corundum (75 — 90% crystalline AlO, + Iron oxide)
   d) Calcium carbide E .Diamonds
8. Artificial or manufactured include
   A.Silicon Carbide (SiC B. Aluminiwn Oxide (AlO)
   C.Boron Carbide D. Boron Nitride (CBiV) E. All

Note: **Satisfactory rating –above 4 points Unsatisfactory - below 4 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

1.
2.
3.
4.
5.
6.
7.
8.

3.1 ACCESSORIES, ATTACHMENTS AND WHEELS USED IN TOOL AND CUTTER GRINDING MACHINE OPERATION

- **ATTACHMENTS:** A great variety of additional attachments either extend the range of the work that can be some on the tool and cutter grinding machine or facilitate the performance of the more common operations. Following are some of the attachments used in tool and cutter grinding operation.
  - ✓ **Right and left hand tail stocks**: are mounted in T-slot of the upper table and support the work. They are used for grinding most arbor mounted milling cutters.
  - ✓ **Large face-milling attachment**: used for large face mills.
  - ✓ **Cylindrical grinding attachment**: used to perform cylindrical grinding operation.
  - ✓ **Internal grinding spindle**: which can be attached to the wheel head and used to carry out internal grinding with combination of cylindrical grinding attachment?
  - ✓ **Radius grinding attachment**: provides a means of grinding an accurate radius in the corner of milling cutters if desired.
  - ✓ **Universal vise:** can be used to hold the work piece to perform surface grinding operation and to grind the angles on a single point cutting tools.
- **Accessories:**
  - ✓ **Arbors:** are accessories used to mount milling cutters during grinding.
  - ✓ **Nuts and collars:** are used to hold the cutter firmly in place.
  - ✓ **Tooth rest:** an accessory used to position teeth of cutter. There are several types.

3.2 WORK HOLDING DEVICES

Much work done on a surface grinder is held in position by a magnetic chuck, Fig. 9. This holds the work by exerting a magnetic force. Non- magnetic materials (aluminum, brass, etc.) can be ground by bracing with steel blocks or parallels to prevent movement.

- **A magnetic chuck** makes use of a permanent magnet.This eliminates cords needed for electromagnets and the danger of electrical connection being broken accidentally permitting work to fly off the chuck.
- 

Figure 12.magnetic chuck is being used to hold multiple pieces for surface grinding (Brown & Sharpe Mfg.co.)

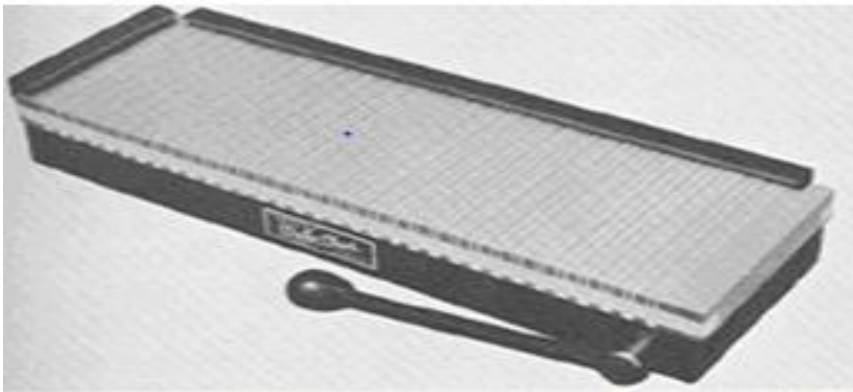


Figure 13.magnetic chuck with a permanent type magnet.(o.s.walker co.inc)

Figure 14.Demagnetizer can be used to neutralize part after being clamped in magnetic chuck.

An electromagnetic chuck utilizes an electric current to create the magnetic field. Frequently, work mounted on a magnetic chuck comes magnetized and must be demagnetized before it can be used. A demagnetizer may be employed to neutralize the piece, Fig.11.

- **The Three-Jaw Universal, Chuck:** It is used to hold round and hexagonal work.

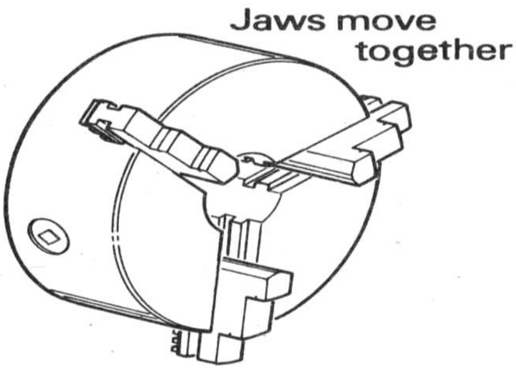


Figure 15.Three-Jaw Self Centering Chuck

* **The Four-Jaw Independent Chuck:** It has four jaws each of which can be adjusted independently by a chuck wrench. They are used to hold Round Square, hexagonal, and irregular - shaped work pieces. The jaws can be reversed to hold work by the inside diameter.

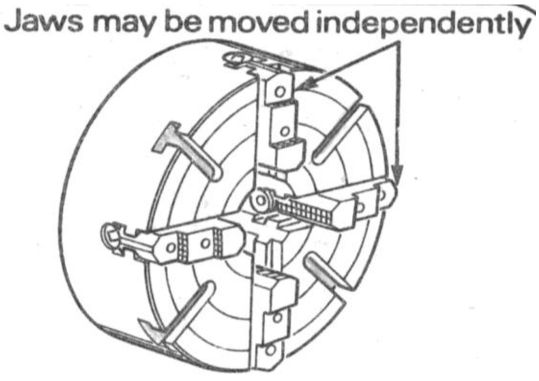


Figure 16.Four-Jaw Self Independent Chuck

* **Face plates:** These are used to hold work that is too large or of such a shape that it cannot be held in a chuck or between centers.

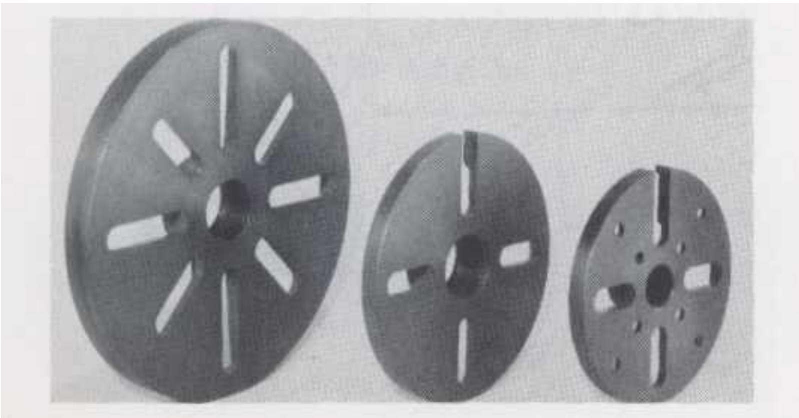


Figure17. Face plates

* **The Collect Chuck:** It is the most accurate chuck, used for high-precision work.
* **Universal vise:** is constructed to allow it to be set at any angle, either horizontally or vertically, to the axis of the tool grinding machine spindle. Due to the flexibility of this vise, it is not adaptable for heavy grinding.

When using a universal vise, the degrees of tilt may be set by reading off the angle on the graduated quadrant, or using a protractor.

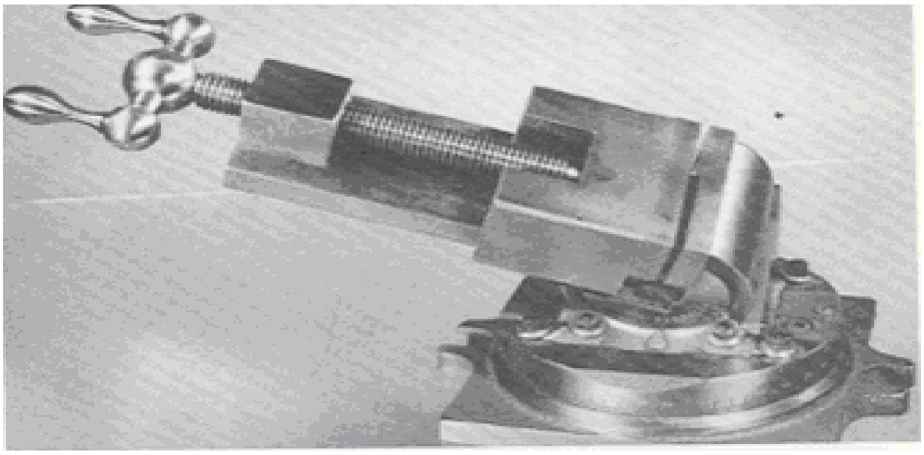


Figure18. Universal vise

- **Vice clamps**: are made of copper, tin plate, lead or fiber, and are fitted to the jaws to prevent the serrations from leaving marks on the work.

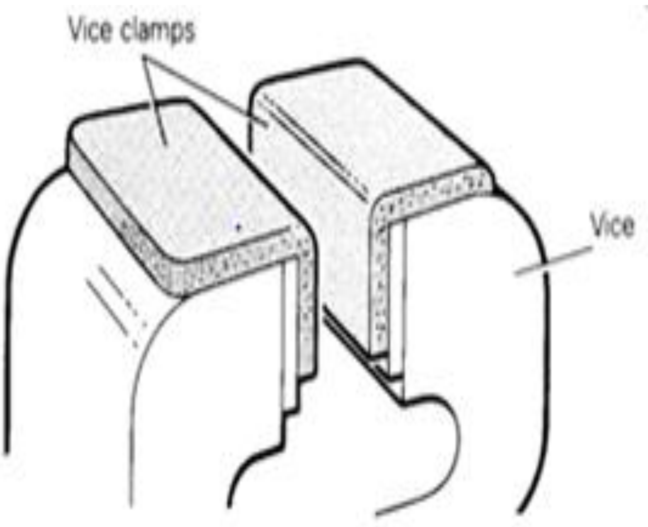


Figure19. Vice clamps

SELF-CHECK -3	WRITTEN TEST

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Matching ITEM (each 1 point)

Column ``A``	Column ``B``
1. Arbors	A. an accessory used to position teeth of cutter
2. Nuts and collars	B. used to hold the work piece.
3. Universal vise	C. are accessories used to mount milling cutters during grinding.
4. Tooth rest	D. are used to hold the cutter firmly in place.
5.4 Jaw chuck	E used to hold Round Square, hexagonal, and irregular - shaped work pieces.
6. Face plates	F. These are used to hold work that is too large or of such a shape that it
	G. is used to hold the long, thin cutting off blade

Note: **Satisfactory rating –above 3 points** **Unsatisfactory - below 3 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: ____________

Name: ___________________________ Date: ________________

1.
2.
3.
4.
5.
6.

INFORMATION SHEET-4	OBSERVING SAFETY PROCEDURES

4.1 SAFETY RULES AND PROCEDURES IN TOOL AND CUTTER GRINDING OPERATION

- **PERSONAL SAFETY:**
  - ✓ Always wear approved type eye protection.
  - ✓ Do not attempt to use unless all guards and safety devices are in place and securely attached.
  - ✓ Stop machine before making measurements or work adjustment.
  - ✓ Remove your watch, rings etc before using the machine.

- **MACHINE SAFETY:**
  - ✓ Never attempt to operate a grinder until you have been instructed properly.
  - ✓ Never place a wheel on a grinder before checking it for soundness.
  - ✓ Use light cuts to prevent drawing the cutter in to the wheel
  - ✓ Keep the grinding wheel clean and sharp by frequent dressing with a diamond tool.
  - ✓ Start the machine and feed the cutter into the wheel
  - ✓ Grinding wheels should not be operated at speed higher than specified.
  - ✓ clean the machine after grinding

- **WORKPLACE SAFETY**
  - ✓ Keep all tools clear of a work table.
  - ✓ Change coolant fluid before it becomes contaminated.
  - ✓ Wipe up all spilled coolants from the floor around the machine right away.

4.2 SAFETY IN GRINDING

Any unsafe practices in grinding can be hazardous for operation and deserve careful attention. Various important aspects are on :-

- **Mounting of grinding wheels:** The wheel should be correctly mounted in the spindle and enclosed by a guard. Wheel bore should not be a tight fit on the sleeve.
- **Wheel speed:** The maximum wheel speed is determined by the Ultimate bursting strength of the wheel and it depends on the abrasive used, grit size, bond, structure, grade, shape and size of the wheel. Its value is specified by the manufacturers which should never be exceeded.
- **Wheel inspection:** Wheels before mounting should be checked for damage in transit, cracks and other defects. Ringing test is good enough for vitrified bond. Sound wheels, when tapped lightly at 45 from the vertical line with a plastic hammer sound like a clear metallic ring but the cracked wheel will not ring. /balancing/ Wheels, when not in use should be stored in a dry place and placed on their edges in racks.

- **Wheel guards:** These should always be used during grinding, and periodically adjusted to compensate for wheel wear.

- **Dust collection and health precaution:** When grinding dry, provision for extracting grinding dust should be made. Protective covers of machine should never be removed while machine is in use. Operator should wear safety devices to protect his eyes and body from flying abrasive particles and dust.
- **Wheel operation:** Adequate power is essential in grinding machines. If power is not adequate then wheels will slow down and develop flat spots, making the wheel to run out-of-balance. During wet grinding, the wheel should not be partly immersed, as this would seriously throw the wheel out of balance.

SELF-CHECK -4	WRITTEN TEST

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I.TRUE OR FALSE ITEM (each 1 point)

1. Any unsafe practices in grinding can be hazardous for operation

2. The wheel should be correctly mounted in the spindle and enclosed by a guard

II.Matching ITEM(each 1 point)

Column ``A``	**Column ``B``**
3. machine safety	A. Remove your watch, rings etc before using the machine
4. personal safety	B. clean the machine after grinding
5. workplace safety	C. Keep all tools clear of a work table.
	D. be obtained in diamond and straight line patterns.

Note: **Satisfactory rating –above 2.5 points** **Unsatisfactory - below 2.5points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: ________________

1.
2.
3.
4.
5.

INSTRUCTION SHEET	LEARNING GUIDE #22

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Operating tool grinding machines.
- Internal and/or external grinding.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, **upon completion of this Learning Guide, you will be able to**:

- Operating tool grinding machines and shape the full range of tools and cutters due to requirements
- performing Internal and/or external grinding.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the “Self-checks” which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to “Operation sheets
7. Perform “the Learning activity performance test” which is placed following “Operation sheets” ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

INFORMATION SHEET-1	OPERATING TOOL GRINDING MACHINES

1.1. GRINDING MACHINE

Grinding is the process of removing metal by the application of abrasives which are bonded to form a rotating wheel. When the moving abrasive particles contact the work piece, they act as tiny cutting tools, each particle cutting a tiny chip from the work piece. It is a common error to believe that grinding abrasive wheels remove material by a rubbing action; actually, the process is as much a cutting action as drilling, milling, and lathe turning. The grinding machine supports and rotates the grinding abrasive wheel and often supports and positions the work piece in proper relation to the wheel. The grinding machine is used for roughing and finishing flat, cylindrical, and conical surfaces; finishing internal cylinders or bores; forming and sharpening cutting tools; snagging or removing rough projections from castings and stampings; and cleaning, polishing, and buffing surfaces. Once strictly a finishing machine, modem production grinding machines is used for complete roughing and finishing of certain classes of work.

1.2. TYPES OF GRINDING MACHINES

- **UTILITY GRINDING MACHINES:** The utility grinding machine is intended for offhand grinding where the work piece is supported in the hand and brought to bear against the rotating grinding abrasive wheel. The accuracy of this type of grinding machine depends on the operator's dexterity. Skill and knowledge of the machine's capabilities and the nature of the work. The utility grinding machine consists of a horizontally mounted motor with a grinding abrasive wheel attached to each end of the motor shaft. The electric-motor-driven machine is simple and common. It may be bench-mounted or floor-mounted. Generally, the condition and design of the shaft bearings as well as the motor rating determine the wheel size capacity of the machine. Suitable wheel guards and tool rests are provided for safety and ease of operation.

- **FLOOR MOUNTED UTILITY GRINDING MACHINE:** The typical floor-mounted utility grinding machine stands waist-high and is secured to the floor by bolts. The floor mounted utility grinding machine shown in Figure 17 mounts two 12-inch-diameter by 2-inch-wide grinding abrasive wheels. The two wheel arrangement permits installing a coarse grain wheel for roughing purposes on one end of the shaft and a fine grain wheel for finishing purposes on the other end this saves the time that would be otherwise consumed in changing wheels. Each grinding abrasive wheel is covered by a wheel guard to increase the safety of the machine. Transparent eye shields. Spark arresters. And adjustable tool rests are provided for each grinding wheel. A tool tray and a water pan are mounted on the side of the base or pedestal. The water pan is used for quenching carbon steel cutting took as they are being ground. Using the 12-inch wheel, the machine provides a maximum cutting speed of approximately 5.500

SFPM. The 2-HP electric motor driving this machine has a maximum speed of 1.750 RPM.

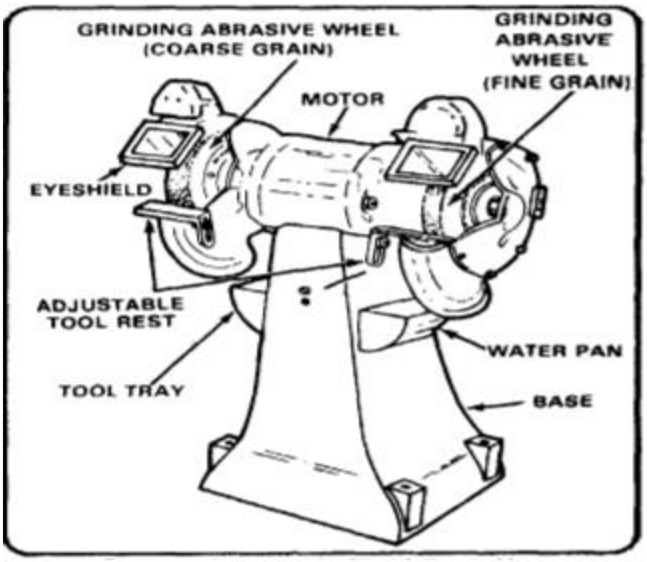


Figure20. Floor-mounted utility grinding machine

- **BENCH TYPE UTILITY GRINDING MACHINE:** Like the floor mounted utility grinding machine, one coarse grinding wheel and one fine grinding wheel are usually mounted on the machine for convenience of operation. Each wheel is provided with an adjustable table tool rest and an eye shield for protection. On this machine, the motor is equipped with a thermal over-load switch to stop the motor if excessive wheel pressure is applied thus preventing the burning out of the motor. The motor revolve at 3.450 RPM maximum to provide a maximum cutting speed for the 7 inch grinding wheels of about 6,300 surface feet per minute (SFPM).

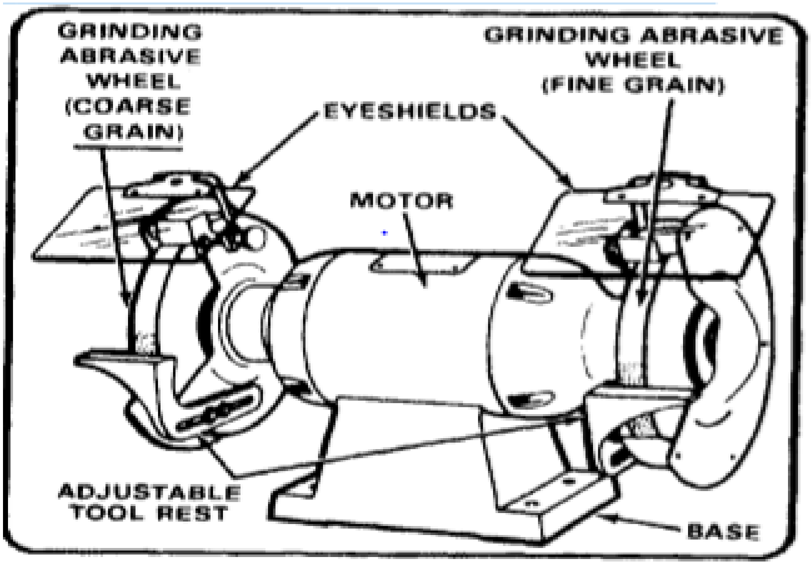


Figure21. Bench type utility grinding machine

- **BENCH-TYPE UTILITY GRINDING AND BUFFING MACHINE:** The bench-type utility grinding and buffing machine is more suitable for miscellaneous grinding, cleaning, and buffing It is not recommended for tool grinding since it contains no tool rests, eye shields, or wheel guards. This machine normally mounts a 4 inch-diameter wire wheel on one end. The wire wheel is used for cleaning and the abrasive wheel is used for general grinding. One of the two wheels can be removed and a buffing wheel mounted in its place for buffing and polishing. The 1/4-HP electric motor revolves at a maximum of 3,450 RPM. The maximum cutting speed of the 4-inch-diameter wheel is approximately 3,600 SFPM.

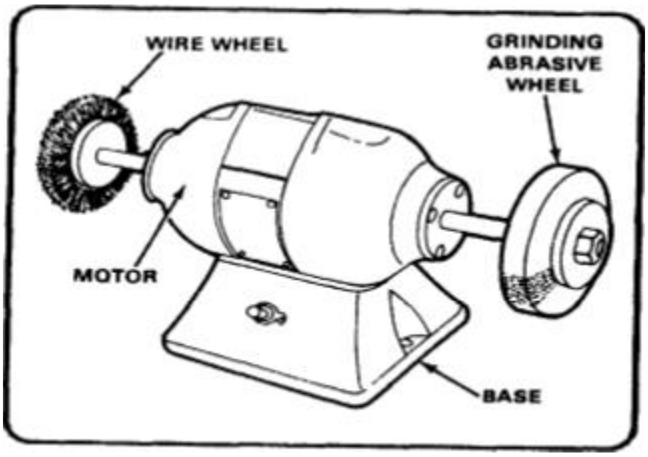


Figure22. Bench-type utility grinding and buffing machine

- **BENCH-TYPE TOOL AND CUTTER GRINDER:** The bench-type tool and cutter grinder, see Figure 20, was designed primarily to grind end mills. It can also grind a large variety of small wood and steel cutters as well as slitting saw cutters up to 12 inches in diameter using the saw grinding attachment. Capacity grinder is as follows: of the typical bench-type tool and cutter
    - ✓ Grinding wheel travel - 7 l/2-inch vertical.
    - ✓ Grinding wheel travel - 5 1/2-inch horizontal.
    - ✓ Table travel - 6 inches.
    - ✓ Slitting saws with attachment - 12-inch diameter.
    - ✓ Distance between centers - 14 inches.
    - ✓ Swing on centers (diameter) - 4 l/2-inch diameter.
    - ✓ Swing in work head (diameter) - 4 l/2-inch diameter.

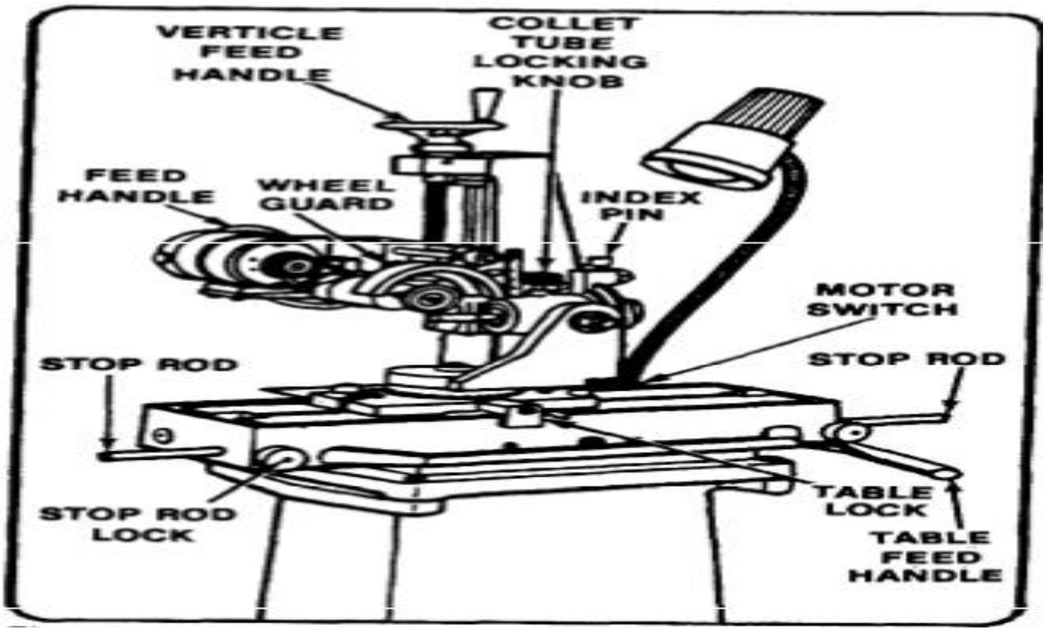


Figure23. The bench-type tool and cutter grinder

- **TOOL POST GRINDING MACHINE:** The tool post grinding machine, see Figure 21, is a machine tool attachment designed to mount to the tool post of engine lathes. It is used for internal and external grinding of cylindrical workplaces. Refer to Chapter 7 for a description of this machine.

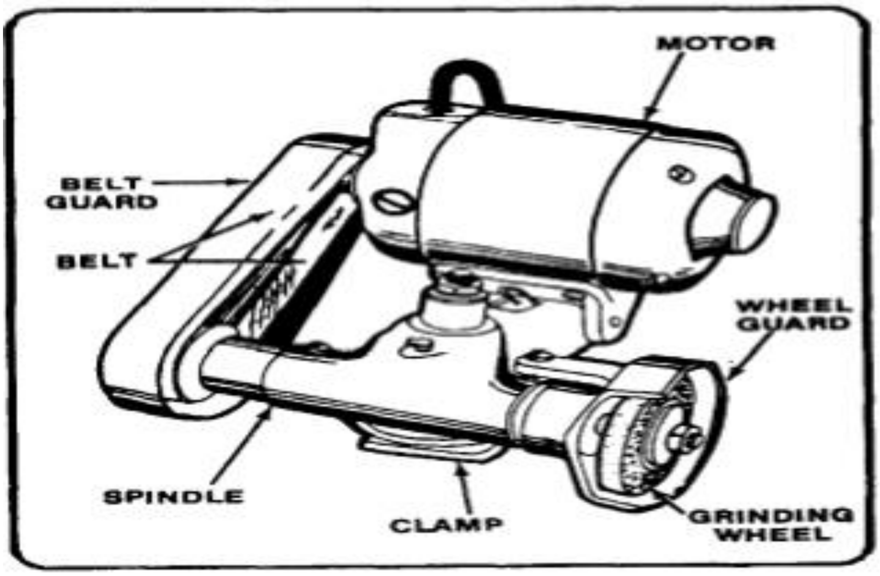


Figure24. Tool post grinding machine

1.3 TYPES OF TOOL AND CUTTER GRINDERS

Generally there are two types of tool and cutter grinding machines. These are:

a. Plain tool and cutter grinder and
b. universal tool and cutter grinder

Both of the machines are similar in construction and function. But, in the case of universal tool and cutter grinder, in addition to swiveling, the wheel head of the machine can also be tilted up or down about a horizontal axis which is not built in the case of plain tool and cutter type.

1.4 FUNCTIONS OF TOOL AND CUTTER GRINDERS

The tool and cutter grinding machine is specialty designed to sharpen a wide variety of cutting tools. It is particularly a supplement to the milling machine because it is the most efficient machine for sharpened on this machine. In addition, it is capable of performing a variety of other light grinding operations including cylindrical grinding, internal grinding, and surface grinding.

1.5 PARTS OF TOOL AND CUTTER GRINDER

In construction the tool and cutter grinder is somewhat similar to the cylindrical grinding machine, though there are some basic differences**.** The main parts are stated as follow:-

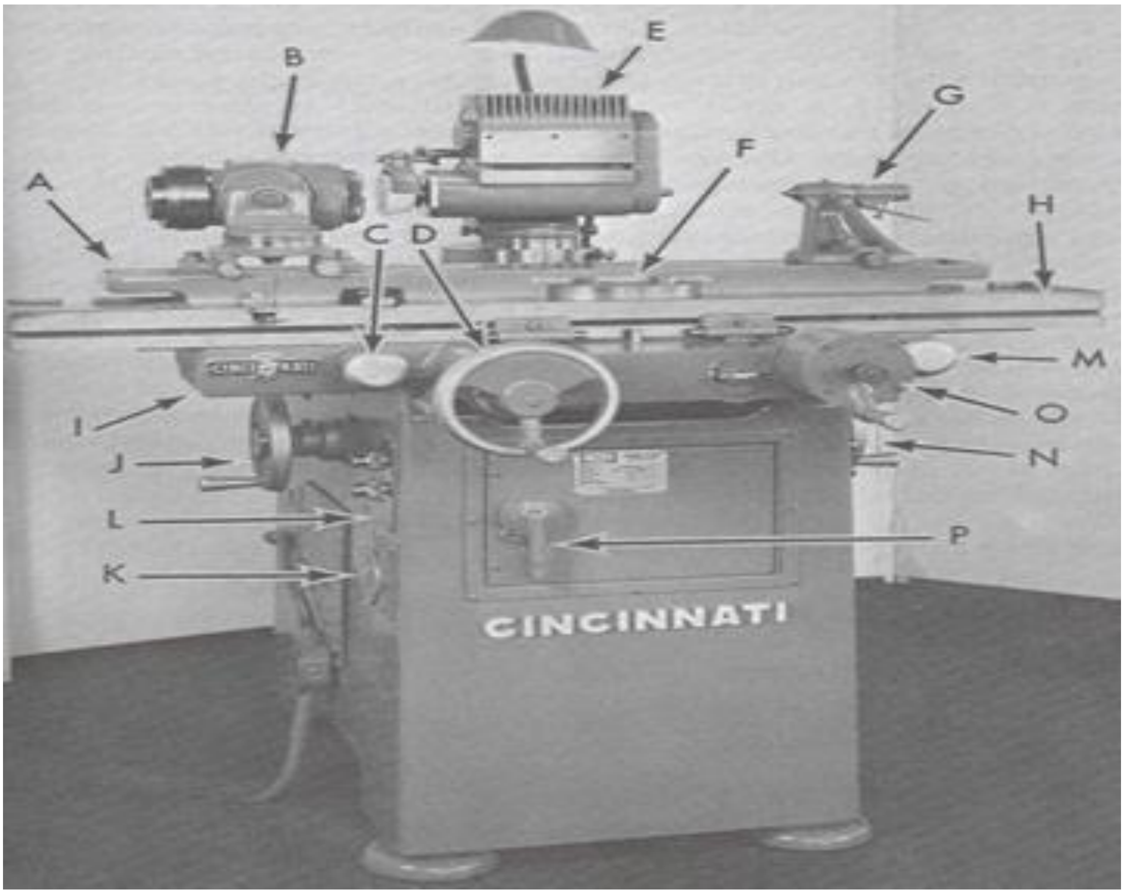


Figure25. Parts of tool and cutter grinder

- **(A) swivel table**: allows the sliding table to be set in angular position
- **(B) swivel head**: front table hand control can be raised and lowered but it is not built to traverse toward the work piece like in case of cylindrical grinding machine
- **(C) front table hand control**
- **(D) front cross slide hand wheel**:
- **(E) tilting wheel head**: permits the wheel head to be tilted up or down about a horizontal axis

- **(F) table swivel scale**:
- **(G) Right and left tail stock**: used to grind between centers.
- **(H) Sliding table**: positioned on the top of the cross slide which traverses longitudinally.
- **(I) Cross slide**: provides a movement of the work toward and away from the wheel.
- **(J) Wheel head vertical control hand wheel**:
- **(K) Attachment power receptacle :**
- **(L) Main electrical control panel:**
- **(M) Front table hand wheel:**
- **(N) Wheel head vertical control hand wheel:**
- **(O) Differential travel traverse control:**
- **(P) Main disconnect switch:**

1.6 MOUNTING WORKPIECE FOR TOOL AND CUTTER GRINDING

Listed below are methods for mounting workplaces when using the tool and cutter grinder:

- A work piece for tool and cutter grinding is usually held between centers or on a fixture clamped to the table.
- The work piece is mounted in the same manner as for cylindrical grinding, except the lathe dog if not used.
- When a fixture is used, the work piece is placed in the fixture and the fixture is clamped to the table.

1.7 TOOL AND CUTTER GRINDING OPERATION

- **Tool and Cutter Grinding:** Tool and cutter grinding is the generally complex operation of forming and re-sharpening the cutting edges of tool and cutter bits, gages, milling cutters, reamers, and so forth. The grinding wheel for any grinding operation should be carefully chosen and the work piece set up properly in the grinding machine. Grinding speeds and feeds should be selected for the particular job. Whenever practical, a coolant should be applied to the point of contact of the wheel and the work piece to keep the wheel and work piece cool, to wash away the loose abrasive, and to produce a better finish.

Even though the tool and cutter grinder is mostly intended to sharpen milling cutters, there are several operations which can be performed.

- sharpening cutting tools
- cylindrical grinding and
- internal grinding

1.7.1 Sharpening cutting tools: Almost all milling cutters including straight and helical teeth are able to be reconditioned using tool and cutter grinding machine.

- **Procedures for grinding a plain milling cutter:**

✓ Select the correct wheel for the job. True it with a diamond tool.

- ✓ Mount the cutter on a suitable arbor and place the unit between centers.
- ✓ Mount the tooth rest to the wheel head. Position the edge about 6 mm above the center line of the grinding wheel**.** This will produce a 5 to 6 degree clearance angle on the cutting edge of a 1.5 mm diameter cutter. Adjust to suit the cutter being ground.
- ✓ The setup should permit the wheel to grind away from the tooth cutting edge while requiring more machining care than grinding into a cutting edge of the tooth there is less chance of drawing the temper. Also, no burr is formed that must be oil stoned off to secure a sharp edge.
- ✓ Flaring cup wheels are also used for cutter and tool grinding. Since there is a greater area of contact when using flare cup wheels, **lighter cuts** should be taken than with straight grinding wheels.
- ✓ Start the machine and feed the cutter into the wheel. Take a light cut. A bit of thinned layout bluing should be applied to the back of the tooth. This will allow a visual check of how the grinding operation is progressing and whether the setup is producing the proper clearance angle.
- ✓ When satisfied with the setup, bring the next tooth into position on the tooth rest and grind that tooth.
- ✓ Repeat the operation until all of the teeth are sharpened. Make necessary adjustment to assure tooth concentricity (cutting surfaces of all teeth are some distance from arbor hole center line.) After a cutter has been sharpened several times, the clearance angle **flat** (land) will become too wide. Then, it becomes necessary to grind in a secondary clearance. If it becomes apparent that more material is being removed from some teeth than others, a quick check must be made to determine the cause:
- ✓ The grinding wheel may be too soft and wear down too rapidly. As the wheel wears, less material is removed from the cutter tooth.
- ✓ The tooth rest may NOT be mounted solidly and moves during the grinding operation.
- ✓ The arbor may NOT be running true on the centers. Test arbor run out with an indicator as it is rotated. When the trouble has been **pin pointed,** make the necessary corrections and continue the operation.

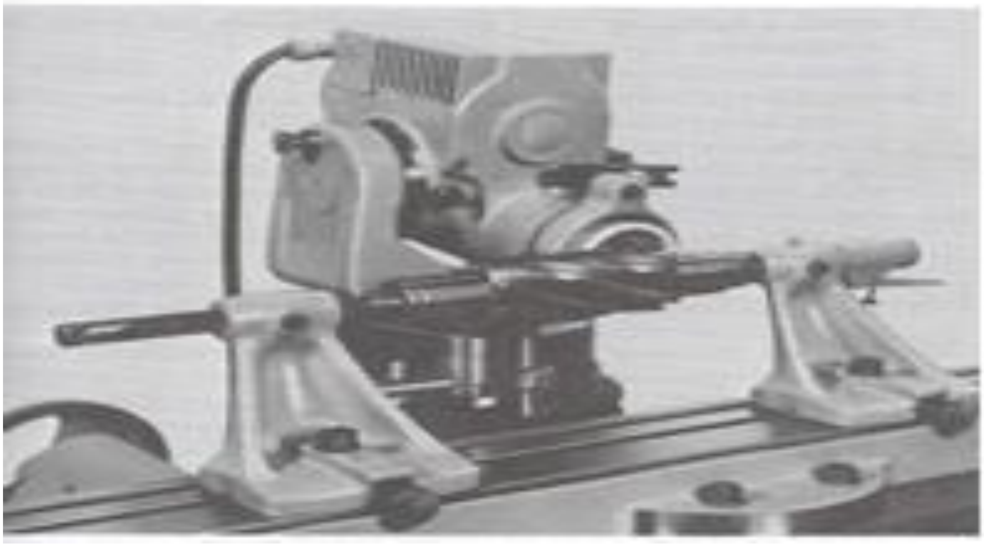


Figure26. Grinding a plain milling cutter

- **Grinding helical teeth cutters:** Slabing cutters and other cutters having helical teeth are sharpened in much the same manner all plain milling cutter However, these cutters must be held against the tooth rest as the table is traversed. This will impart a twisting motion to keep the tooth correctly located against the grinding wheel.

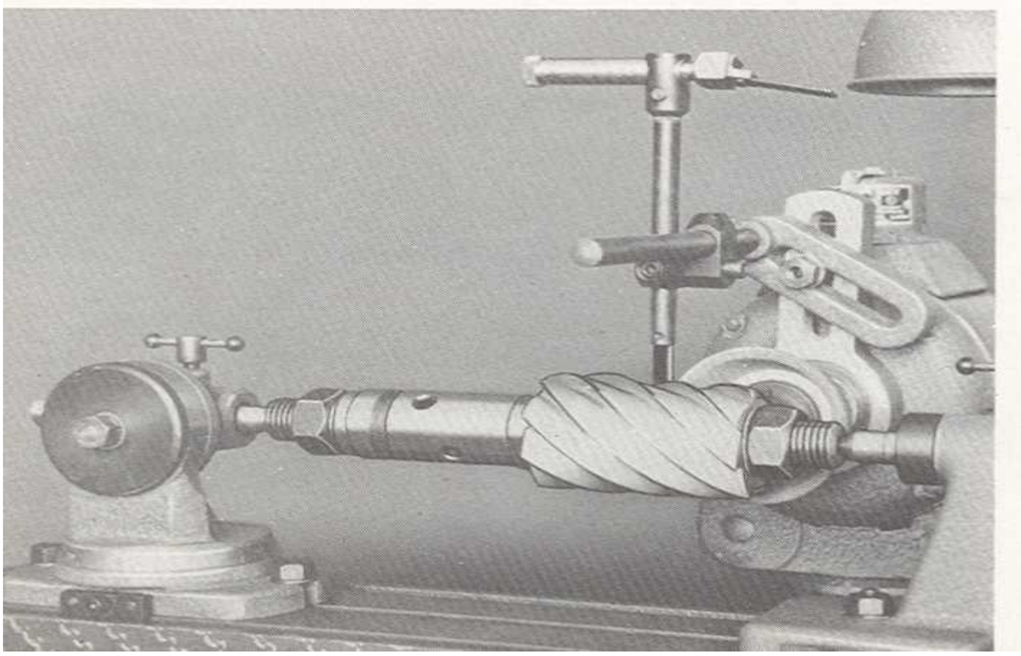


Figure27. Setup & grinding helical teeth cutters

- **Grinding end mills:** End mills are sharpened in much the same way as helical teeth cutters with the end mill mounted in a work head rather than between centers. The end teeth are sharpened with the same technique used to sharpen the side teeth on a side milling cutter.

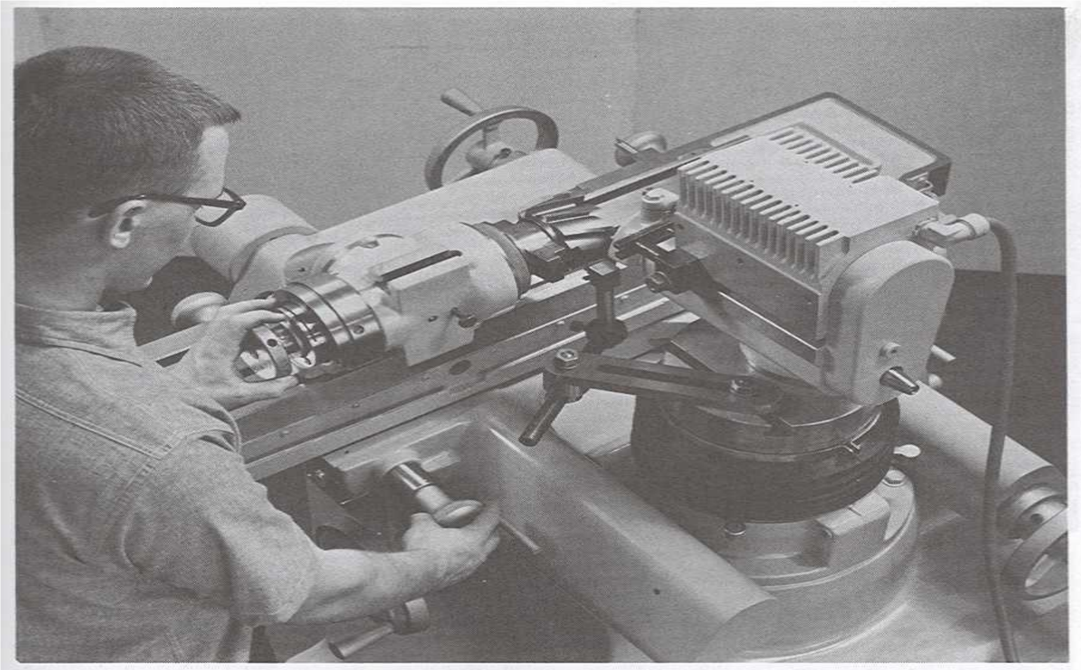


Figure28. Grinding end mills

- **Grinding form cutters:** Form tooth cutters must be ground radially to preserve the tooth shape An index disc may be employed or a special form cutter grinder may be utilized.

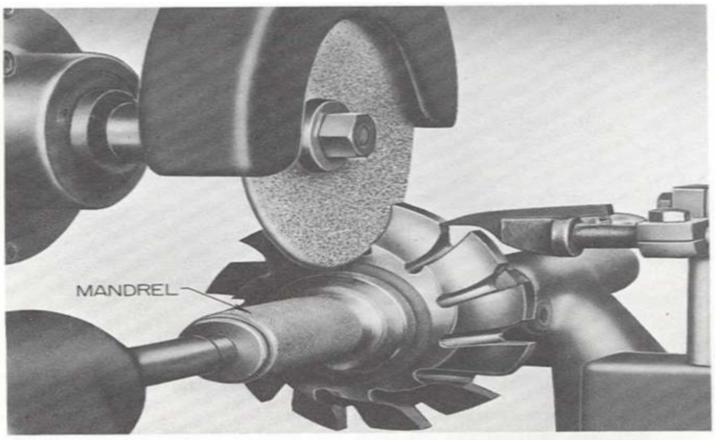


Figure29. Grinding form cutters

- **Grinding Taps:** A universal tool and cutter grinder may also be used to re sharpen taps. Normally a tap becomes dull when the leading edges of the starting chamfer become worn. The chamfer can be reground by mounting the tap in a work head**.** Flutes are reground with a straight wheel with an edge that has been shaped to fit the flutes**.**

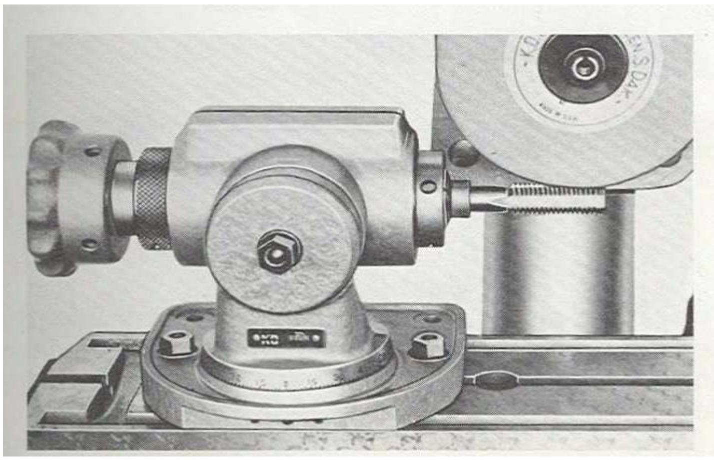
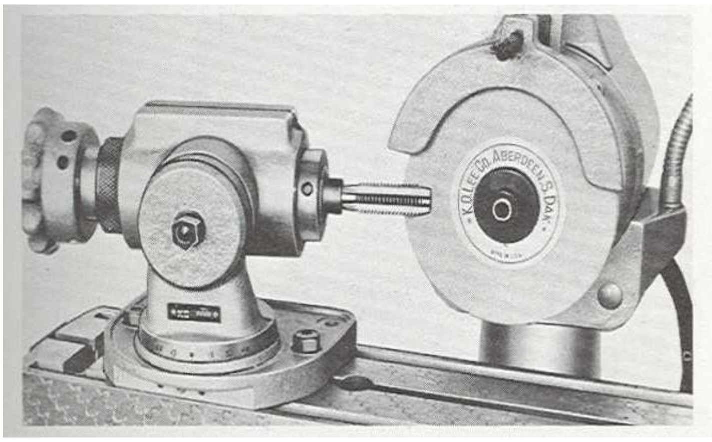
 

Figure30. Grinding Taps

- **Grinding Reamers:** The cutting action of a machine reamer takes place at the front end of the teeth**.** The worktable is pivoted at a 45 deg. angle. Using a cup wheel, adjust the tooth rest and/or grinding head to give the correct clearance. Sharpen the reamer in the same manner employed to sharpen a face milling cutter.

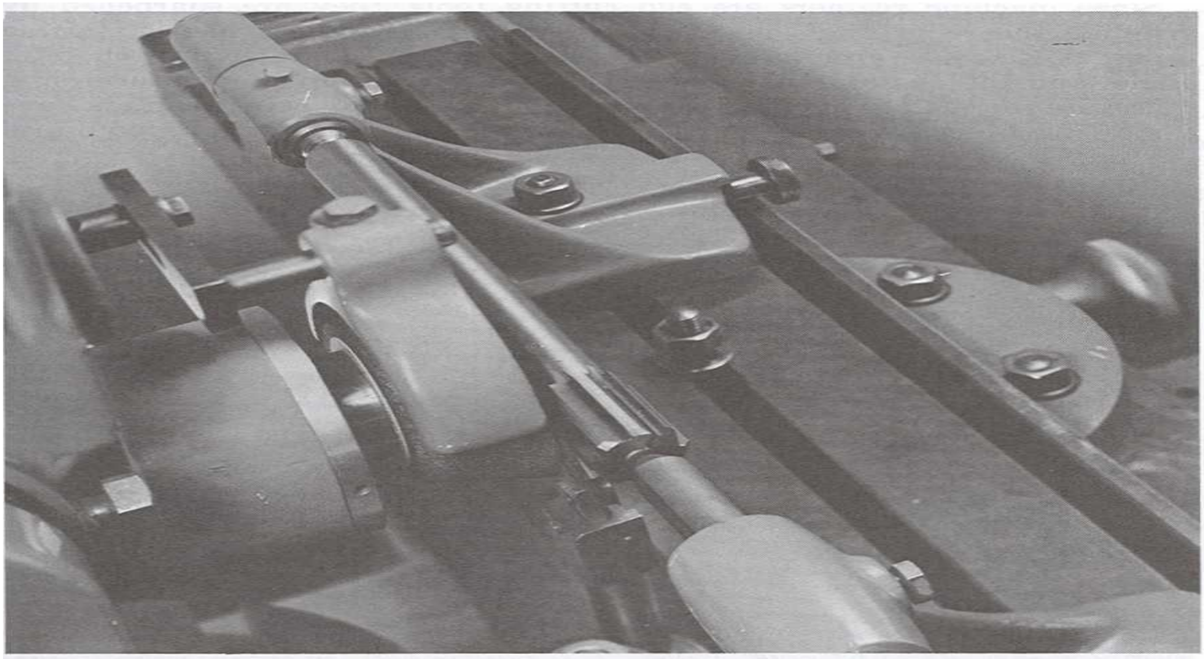


Figure31. Grinding Reamers

1.7.2 CYLINDRICAL GRINDING: with the aid of motorized work head, the cutter and tool grinder may use for cylindrical and plunge grinding. Work may be ground between centers or held in chuck, depending on the type of work.

Following are procedures to grind work parallel between centers:

- Mount the motorized work head on the left end of the table. **Fig 32**
- Examine the centers of the machine and the work to see that they are in good condition.

- Using the centering gage on the wheel head, adjust the wheel head to the tailstock center height.
- Mount a 152.4 mm straight grinding wheel on the wheel head spindle so that the wheel rotates downward at the front of the wheel. This will deflect the sparks downward.
- Mount a parallel, hardened and ground test bar between centers.
- Using a dial indicator, align the centers for height and then align the side of the bar with the table travel. Remove the bar and indicator.
- Mount the work between centers.
- Set the stop dogs so that the wheel overlaps the work by one-third the width of the wheel face at each end.
- Start the grinding wheel and work head. The work piece should revolve in the opposite direction to that of the grinding wheel.
- Bring the revolving work up until it just touches the grinding wheel.
- Traverse the table slowly and clean up the work piece. The traverse speed should be such that the work travels approximately one-quarter the width of the wheel for each revolution of the work.
- Measure each end of the work piece for size and taper. If taper exists, adjust as required.
- After the work is parallel, set the cross feed graduated collar to zero.
- Feed the work into the grinding wheel approximately 0.02 mm per pass until the work is within0.02 mm of finished size. Use 0.005 mm cuts for finishing.
- Feed in the work until the graduate collar indicates it is to the proper size. Note since work expands during grinding, it should never be measured for accurate size when warm.
- Traverse the table several times to permit the wheel to spark out.

The same procedure e is followed for taper grinding, except that the table must be swung to half the angle of the taper. After the work is cleaned up, the taper should be carefully checked for size and accuracy, and adjustments made as required. When taper grinding, it is most important that the center height of the wheel and the work piece be in line.

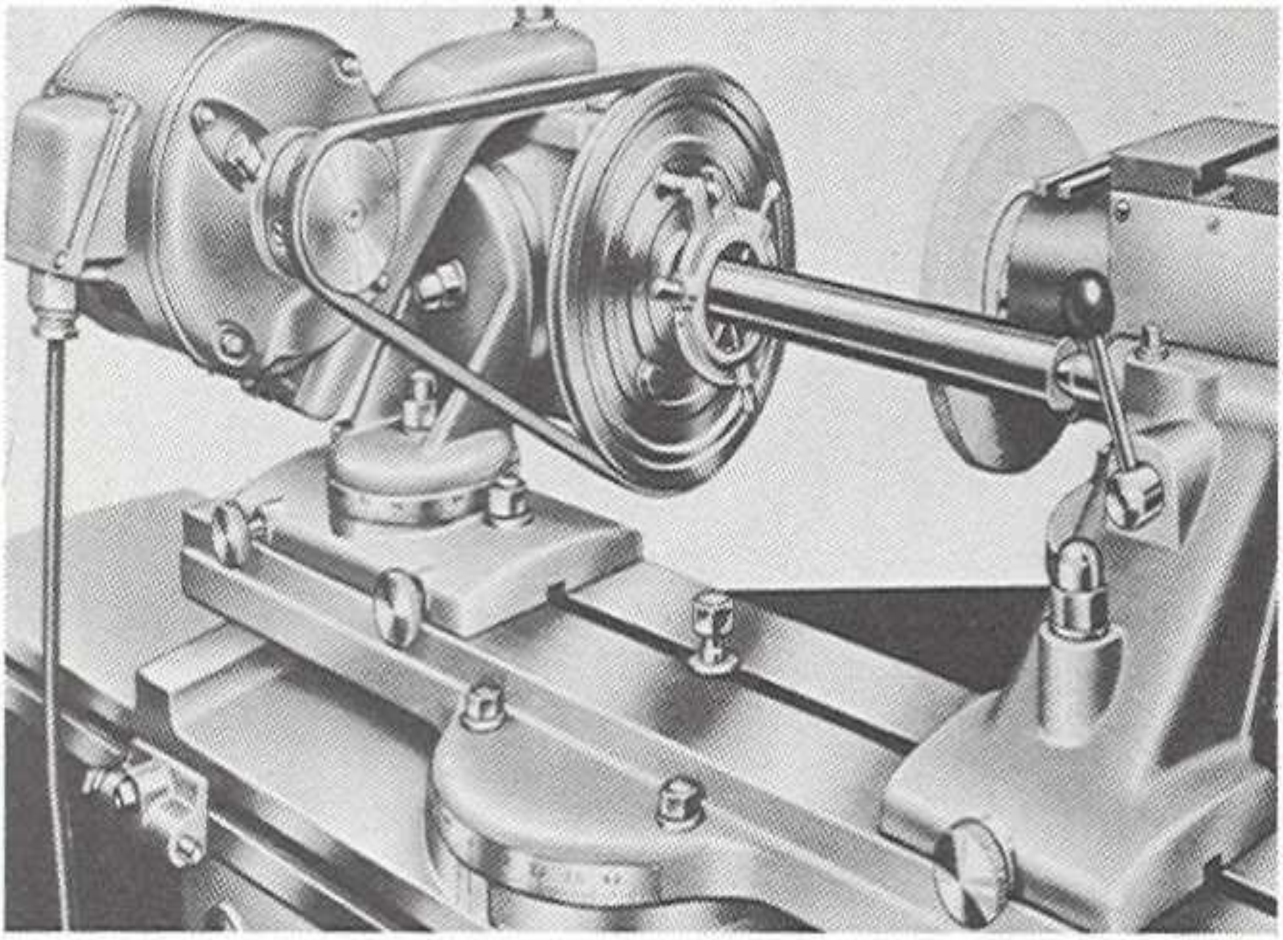


Figure32. Cylindrical grinding

1.7.3 INTERNAL GRINDING: Light internal grinding may be performed on the tool and cutter grinder by mounting the internal-grinding attachment on the wheel head. The work piece is held in a chuck mounted on the motorized work head.

Procedures

- Mount a test bar in the work head spindle and align it both vertically and horizontally. When grinding a tapered hole, the work head spindle must be aligned vertically and then swung to half the included angle of the taper.
- Mount the internal-grinding attachment on the work-head.
- Center the grinding wheel spindle using the centering gage.
- Mount the proper grinding wheel on the spindle.
- Mount a chuck on the motorized work head.
- Mount the work in the chuck. Care must be taken not to distort the work piece by gripping it too lightly.

- Set the rotation of the work head in an opposite direction to that of the grinding spindle.
- Start the grinding wheel and d the work piece.
- Carefully bring the wheel into the hole of the work piece.
- Set the table travel so that only one-third of the wheel overlaps the hole at each end.
- Clean up the inside of the hole and check for size parallelism, and bell-mouthing. Correct as required.
- Set the cross feed graduated collar to zero and determine the amount of material to be removed.
- Feed the grinding wheel in about 0.01 mm per pass.
- When work is close to the finished size, let the wheel spark out to improve the finish and remove the spring from the spindle.
- Finish grinds the hole to size.

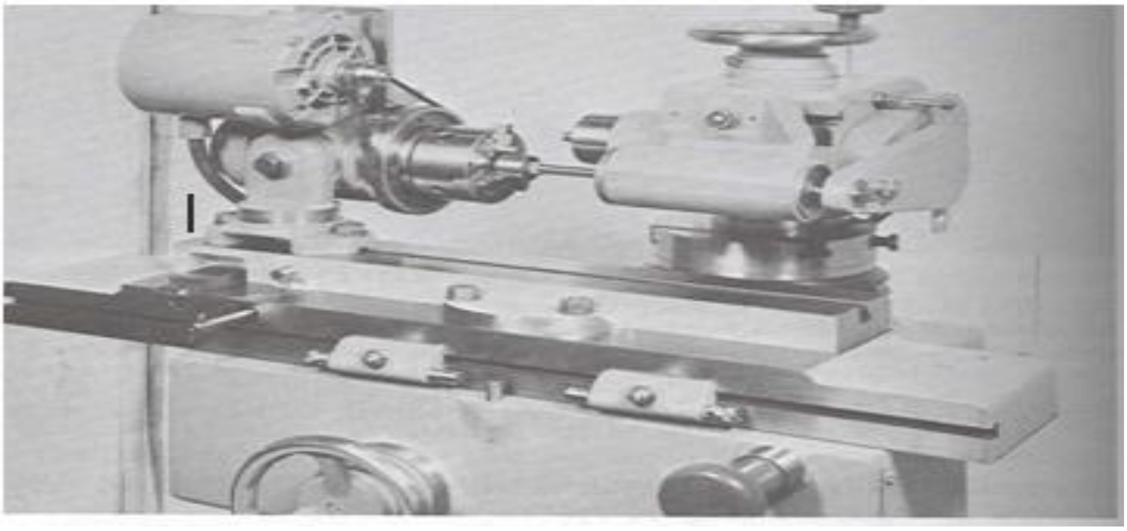


Figure33. Internal grinding

1.8 GRINDING SPEEDS AND FEEDS

In grinding, the speed of the grinding wheel in SFPM and the feed of the grinding wheel are as important as, and sometimes more important than, proper wheel selection. Occasionally, the grinder spindle should be checked with a tachometer to make sure it is running at its specified RPM. Too slow a speed will result in waste of abrasive, whereas an excessive speed will cause a hard grinding action and glaze the wheel, making the grinding inefficient. The feed of the grinding wheel will determine to a cetain extent the finish produced on the work and will vary for different types and shapes of grinding wheels.

1.8.1 Factors Governing Speed

> **WARNING** If a wheel is permitted to exceed the maximum safe speed, it may disintegrate and cause injury to the operator and damage to the grinding machine.

The various factors governing the speed in SFPM of a grinding wheel are as described below.

1.8.2 Safety

The grinding wheel should never be run at speeds in excess of manufacturer's recommendations, usually; each grinding wheel has a tag attached to it which states the maximum safe operating speed.

1.8.3 Condition of the Machine

Modern grinding machines and machines that are in good condition can safely turn a grinding wheel at speeds greater than machines that are older or in poor condition. Most grinding machines are equipped with spindle bearings designed for certain speeds which should not be exceeded. Poor quality will result from vibrations caused by inadequate rigidity or worn bearings that are not in the best condition. High speeds will intensify these defects.

1.8.4 Material Being Ground

The material being ground will generally determine the grain, grade, structure, and bond of wheel to be selected. For example, if the wheel is too soft for the material being cut, an increase in speed will make the wheel act harder. Conversely, if the wheel is too hard, as lower speed will make the wheel act softer.

1.8.5 Type of Grinding Wheel

The type of grinding wheel employed for a particular operation is one of the major considerations in the proper selection of cutting speed. In general practice, the wheel will be selected for the material to be cut. The recommended cutting speed can then be determined by the wheel type, bond, and grade of hardness

1.8.6 Calculating Wheel Size or Speeds

Both cutting speeds in SFPM and rotational speed in RPM must be known to determine the size wheel to be used on a fixed-speed grinding machine. To determine the grinding wheel size, use the following formula:

$$D = \frac{12 \times SDFPM}{RPM}$$

Where: - SFPM = Cutting speed of wheel (In surface feet per minute).
RPM = Revolutions per minute of wheel.
D = The calculated wheel diameter (in inches).

To obtain the **cutting speed in SFPM** when the wheel diameter and RPM are given, use the same formula in a modified form:

$$SFPM = \frac{D \times RPM}{12}$$

To obtain the **rotational speed in RPM** when the wheel diameter and desired cutting speed are known use the formula in another modified form:

$$RPM = \frac{12 \times SFPM}{D}$$

NOTE: As a grinding wheel wears down and as it is continually trued and dressed, the wheel diameter decreases, resulting in loss of cutting speed. As this occurs, it necessary to increase the rotational speed of the wheel replaces the wheel to maintain efficiency in grinding.

1.8.7 Work Speed for Cylindrical Grinding

In cylindrical grinding, it is difficult to recommend any work speeds since these are dependent upon whether the material is rigid enough to hold its shape, whether the diameter of the work piece is large or small, and so forth. Listed below are areas to consider when performing cylindrical grinding:

- The larger the diameter of the work piece, the greater is its arc of contact with the wheel. The cutting speed suitable for one diameter of work piece might be unsuitable for another.
- The highest work speed that the machine and wheel will stand should be used for roughing.
- The following cylindrical work speeds are only typical: steel shafts, 50 to 55 FPM; hard steel rolls, 80 to 85 FPM; chilled iron rolls, 80 to 200 FPM; cast iron pistons, 150 to 400 FPM; crankshaft bearings, 45 to 50 FPM; and crankshaft pins, 35 to 40 FPM.
- Higher work speeds increase the cutting action of the wheel and may ‘indicate that a harder wheel and a smaller depth of cut be used to reduce wheel wear.

1.8.8 Work Speed for Surface Grinding

Surface grinding machines usually have fixed work speeds of approximately 50 SFPM or have variable work speed ranges between 0 and 80 SFPM. As with cylindrical grinding, the higher work speeds mean that more material is being cut per surface foot of wheel rotation and therefore more wear is liable to occur on the wheel.

1.8.9 Feeds

The feed of the grinding wheel is the distance the wheel moves laterally across the work piece for each revolution of the piece in cylindrical grinding or in each pass of the piece in surface grinding. The following methods are recommended for determine feeds:

- The feed should be proportional to the width of wheel face and the finish desired. In general, the narrower the face of the wheel, the slower must be the traverse speed; the wider the wheel faces the faster can be the traverse speed.
- For roughing, the table should traverse about three quarter the wheel width per revolution or pass of the work piece.
- For an average finish, the wheel should traverse one-third to one-half the width of the wheel per revolution or pass of the work piece.
- In surface grinding with wheels less than 1 inch in width, the table traverse speed should be reduced about one half.

1.8.10 Depth of Cut

Methods for determining depth of cuts are recommended for determining feeds.

- In roughing, the cut should be as deep as the grinding wheel will stand, without crowding or springing the work. The depth of cut also depends on the hardness of the material. In cylindrical grinding, in addition to these factors, the cut depends on the diameter of the work. In any case, experience is the best guide. Generally, a cut of 0.001 to 0.003 inch in depth is used, depending on the size and condition of the grinding machine.
- For finishing, the depth of cut is always slight, generally from 0.0005 inch to as little as 0.00005 inches.
- An indication of the depth of cut is given by the volume of sparks thrown off. Also, an uneven amount of sparks indicates that the work piece or wheel is not concentric.

1.8.11 COOLANTS

Most grinding machines are equipped with coolant systems. The coolant is directed over the point of contact between the grinding wheel and the work. This prevents distortion of the work piece due to uneven temperatures caused by the cutting action. In addition, coolant keeps the chips washed away from the grinding wheel and point of contact, thus permitting free cutting.

Clear water may be used as a coolant, but various compounds containing alkali are usually added to improve its lubricating quality and prevent rusting of the machine and work piece. An inexpensive coolant often used for all metals, except aluminum, consists of a solution of approximately 1/4 pound of sodium carbonate (sal soda) dissolved in 1 gallon of water. Another good coolant is made by dissolving soluble cutting oil in water. For grinding aluminum and its alloys, a clear water coolant will produce fairly good results.

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I.TRUE OR FALSE ITEM (each 1 point)

1. An inexpensive coolant often used for all metals, except aluminum
2. Surface grinding machines usually have fixed work speeds

II.CHOOSE THE BEST ANSWER(each 1 point)

3. --------:- is the process of removing metal by the application of abrasives which are bonded to form a rotating wheel.
   A. Sanding B. Grinding C. Shaping D. All
4. For finishing, the depth of cut is always slight, generally from
   A. 0.0005 inch to as little as 0.00005 inches C. 0,003 to o,004
   B. 0.001 to 0.003 inch D. None

III.Matching ITEM(each 1 point)

Column ``A``	Column ``B``
5. Machine Safety	A. Remove Your Watch, Rings Etc Before Using The Machine
6. Personal Safety	B. Clean The Machine After Grinding
7.Workplace Safety	C. Keep All Tools Clear Of A Work Table.
	D. Be Obtained In Diamond And Straight Line Patterns.

***Note:* Satisfactory rating –above 3.5 points Unsatisfactory - below 3.5points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

I. True Or False
1.
2.

II. Choose
3.
4.

III. Matching
5.
6.
7.

INFORMATION SHEET-2	INTERNAL AND/OR EXTERNAL GRINDING

2.1 INTERNAL GRINDERS

These grinders are used for grinding internal bores and tubes which are generally tapered and those having more than one diameter. Fig. 34 shows the various operations possible on an Internal grinding machine. Internal grinding is frequently used on production arts that have not been heat treated to save the reaming cost. According to the construction, there are several types of internal grinders.

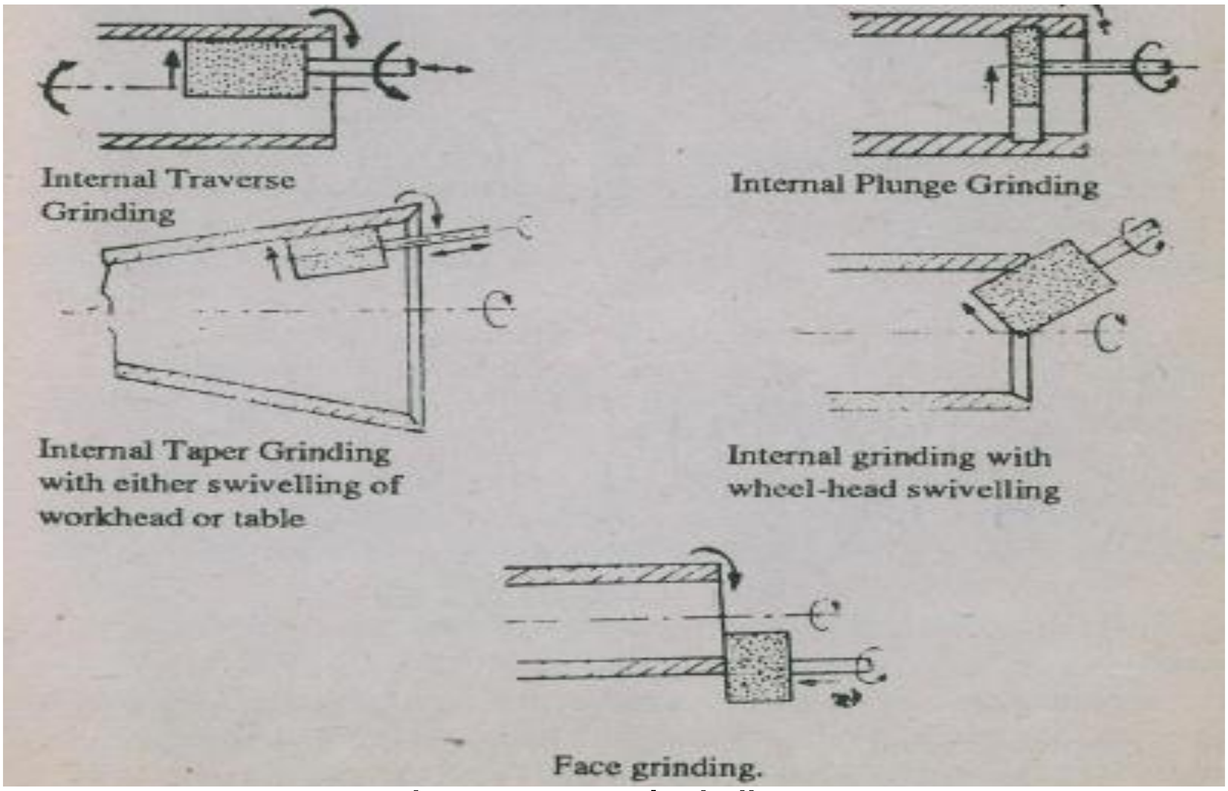


Figure34. Internal grinding

- The wheel is rotated in affixed position while the woke is slowly rotated and traversed back and forth.
- The wheel is rotated and at the same time reciprocated back and forth through the length of hole. The work is rotated slowly. This type of grinder is also called chucking grinder.
- The work remains stationary and the rotating wheel spindle is given an eccentric motion, according to the diameter of hole to be ground. Such a type of operation is used where the work is difficult to be rotated. Since in this operation, the motion of the grinding wheel is in the form of planet and hence it is frequently called planetary grinding (Fig. 35).

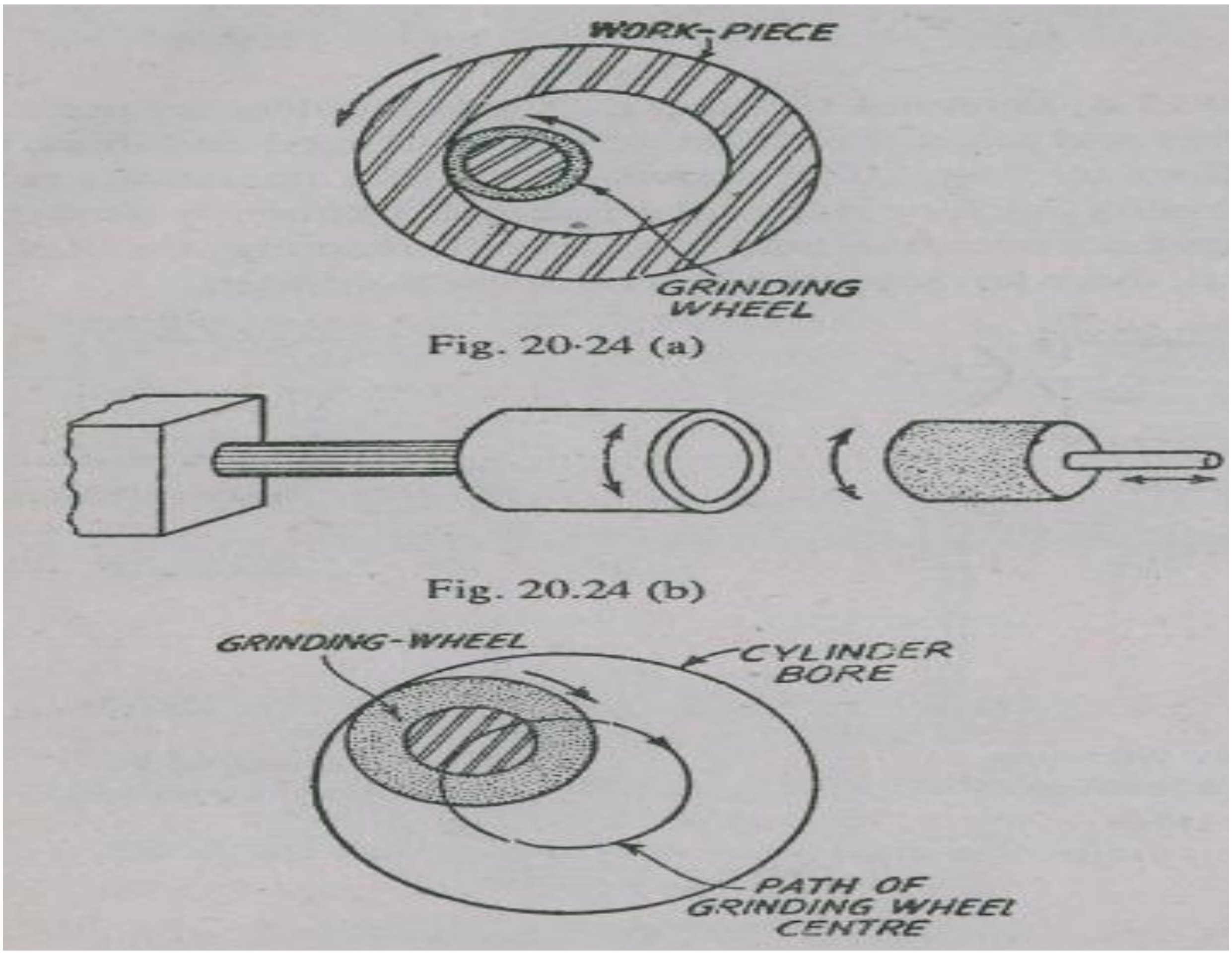


Figure35. Planetary type of grinding

- The work is rotated on the outside diameter by driven rolls, thus making it possible to grind the bores absolutely concentric with the outside diameter. This arrangement lends itself to production work since loading may be simplified and magazine feed may be used. This type of grinding operation is called internal centre less grinding. This is described in details below.

The internal grinding attachment is bolted to the wheel head on the universal tool and cutter grinder. The RPM is increased by placing a large pulley on the motor and a small pulley on the attachment.

The work piece should be set to rotate in the direction opposite that of the grinding wheel. The following step-by step procedure for grinding the bore of a bushing is outlined below as an example.

- Set up the work piece in an independent chuck and check and adjust its alignment.
- Mount the internal grinding attachment to the wheel head and adjust its position so that the grinding wheel is centered vertically with the mounted work piece.
- True and dress the grinding wheel.
- Set the proper wheel speed on the grinding machine by adjusting the pulleys and belts connecting the wheel spindle to the drive motor shaft.
- Set the proper rotational work feed. The speed should be 60 to 100 SFPM.
- Be sure sufficient clearance is allowed when setting the traversing speed so that the grinding wheel will not strike any part of the work piece or setup when the wheel is fed

into and retracted from the work piece. If two or more grinding wheels are used to complete internal grinding, true each wheel after mounting it to the spindle of the internal grinding attachment.

2.2 INTERNAL CENTRELESS GRINDING

This process is of recent development and is used for grinding internal surfaces of the relatively long work pieces. The arrangement is shown by a simple sketch in Fig. 36. The work piece is supported by a set of rollers **A** and fl and a regulating wheel **R**. One of the rollers simply serves the purpose of supporting and hence is called the supporting roller; the other is used for pressing the work piece against the regulating wheel and hence is called the pressure roller. The grinding wheel **G** and the work piece rotate in the same direction while the regulating wheel in the opposite direction. Another point of difference in the internal surface grinding is that grinding wheel is smaller in diameter than the regulating wheel.

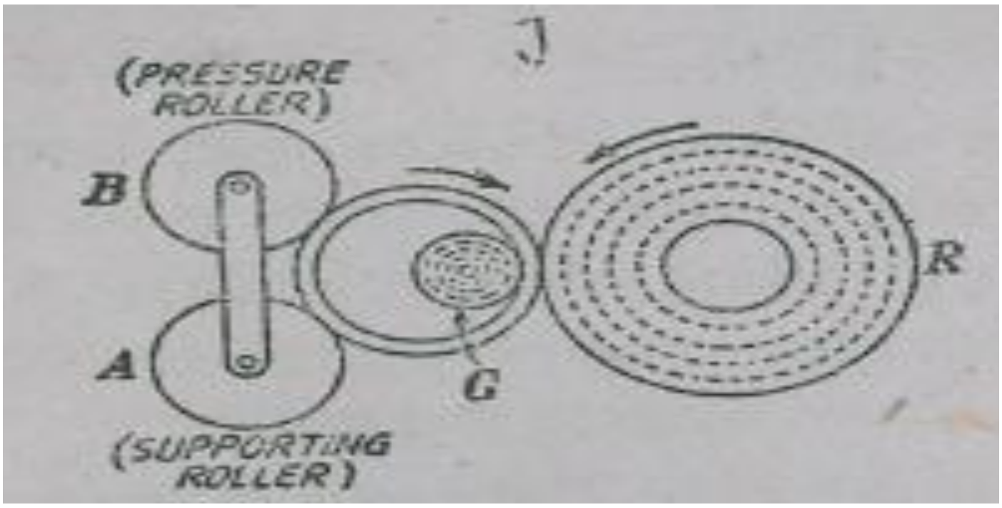


Figure36. Internal centre less grinding

This process may work either on the 'on-centre' principle as shown in Fig. 32 or on the 'above centre' principle in which line joining centers of work piece and regulating wheel makes an angle with horizontal line in the second quadrant. On-centre method is used for thin walled components. However, 'on-centre' method is prone to duplicate the errors of the outside diameter and errors of waviness and other form errors are also introduced which to some extent can be corrected by the 'above centre' principle.

LIMITATIONS

- Since the roundness of internal surface depends upon the external surface, the external surface must be ground first and internal grinding afterwards and
- Concentricity cannot be maintained. Lobbing. The most commonly occurring defect in external centre-less grinding is lobbing. In case of hot and cold rolled steel bars it is not possible to get a perfect round shape. The surface has some high spots and some low spots. During the process of centre-less grinding, these high and low spots cannot be ground.

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I.TRUE OR FALSE ITEM (each 1 point)

1. External grinding are used for grinding internal bores and tubes which are generally tapered and those having more than one diameter
2. The grinding wheel is rotated and at the same time reciprocated back and forth through the length of hole.
3. In internal grinding process the work is rotated rapidly.
4. The work is rotated on the outside diameter by driven rolls.
5. The work piece should be set to rotate in the direction opposite that of the grinding wheel.

6.In Internal centre less grinding the limitations is Concentricity which can be maintained.

7.The most commonly occurring defect in external centre-less grinding is lobbing.

8.internal centre less grinding used for grinding internal surfaces of the relatively long work pieces

.

Note: **Satisfactory rating –above 4 points** **Unsatisfactory - below 4 points**

You can ask you teacher for the copy of the correct answers.

OPERATION SHEET 1	OPERATING TOOL GRINDING MACHINES

1.1 **PROCEDURES FOR GRINDING PERIPHERY OF SIDE AND FACE CUTTER**

Steps 1- apply safety precaution.

Steps 2-cup-shaped wheel, clearance angle setting gauge, centre height gauge and mandrel.

Steps 3- Mount clearance angle setting gauge on loose head centre and set gauge at zero.

Steps 4- Secure cutter to mandrel and mount between centers.

Steps 5-Using the' centre height gauge set tooth of cutter on centre line and lock the mandrel to the clearance angle setting gauge with the thumb screw in the carrier.

Steps 6- Slacken the clamping screw in the zero scale of setting gauge, and rotate to the required clearance angle.

Steps7-Set tooth rest, with trip finger. To cutter tooth and release or remove the carrier clamping the mandrel.

Steps 8- Set wheel head and table at zero.

Steps 9-Position the wheel head centre to approximately the centre height of the loose head.

Steps 10- Position and secure wheel guard.

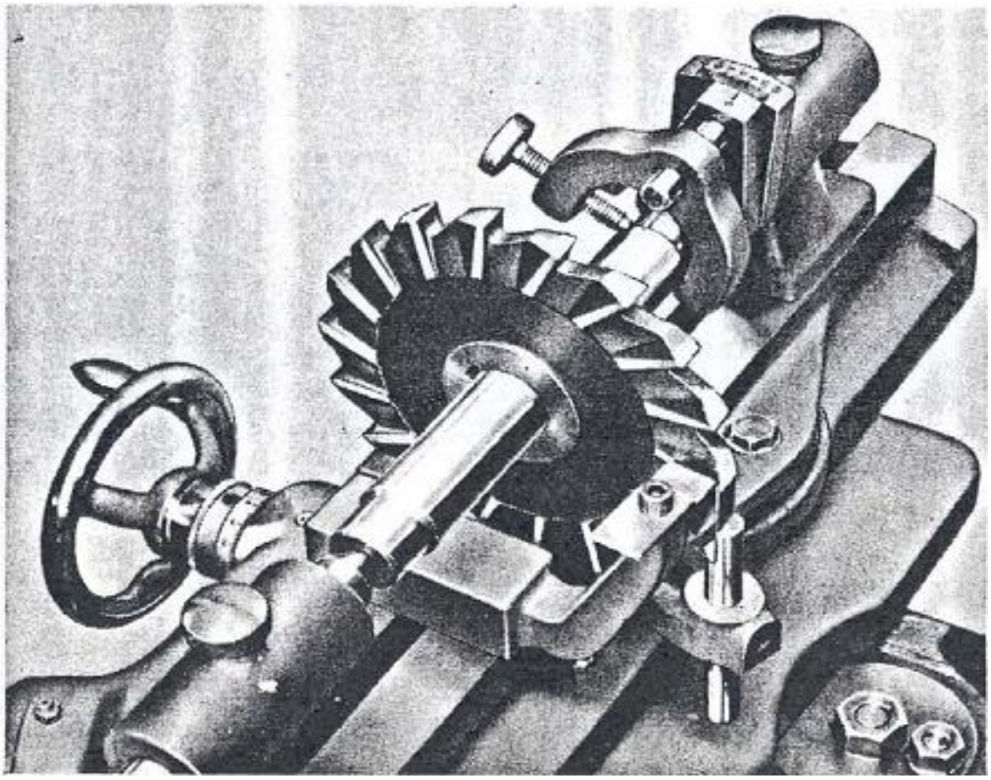


Figure1. Grinding Periphery of Side and Face

OPERATION SHEET 2	OPERATING TOOL GRINDING MACHINES

2.1 PROCEDURES FOR GRINDING SIDE FACE OF SIDE AND FACE CUTTER

Steps 1- apply safety precaution.
Steps 2- Use cup-shaped wheel, universal head and cutter arbor.
Steps 3- Set wheel head and table at zero.
Steps4- Clamp universal head on table, insert cutter arbor and secure cutter. Set universal head to give 3° approx. side clearance and from outer diameter to centre of cutter.
Steps 5- With face of tooth to be ground horizontal, clamp tooth rest on top of universal head and position on tooth.
Steps 6- Set wheel head centre above height of face of tooth to be ground, so wheel clears tooth below.
Steps 7- Position and secure wheel guard.

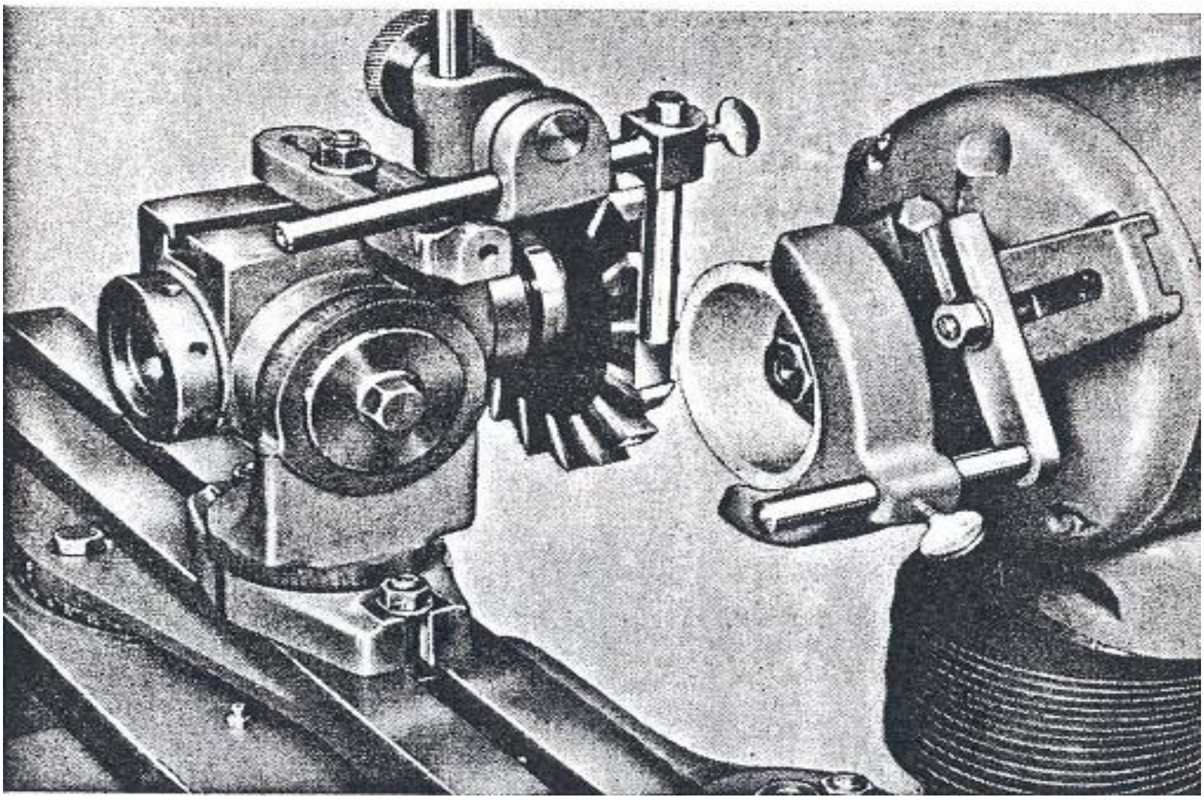


Figure38 2. Grinding Side Face of Side and Face Cutter

OPERATION SHEET 3	OPERATING TOOL GRINDING MACHINES

3.1 PROCEDURES FOR GRINDING LEAD OF REAMER

Steps 1- apply safety precaution
Steps 2- Use cup-shaped wheel, wheel extension, and clearance angle setting gauge, centre height gauge and short tooth rest finger shaft.
Steps 3- Mount clearance angle setting gauge on loose head centre, and set gauge to zero.
Steps4- Place reamer between centers.
Steps 5- Set wheel head at zero and the table to the required angle of lead.
Steps 6- Using the centre height gauge, set tooth of reamer on centre line and lock reamer to the clearance angle setting gauge with the thumb screw in the carrier.
Steps 7- Slacken the clamping screw in the zero scale of setting gauge, and rotate 10° to give required clearance angle.
Steps 8- Set tooth rest in spiral of lead to be ground and release or remove the carrier of the angle gauge.
Steps 9- Position table stop to avoid grinding centre.
Steps10-Set wheel head centre to approximately the centre height of the loose head. Position and secure wheel guard.

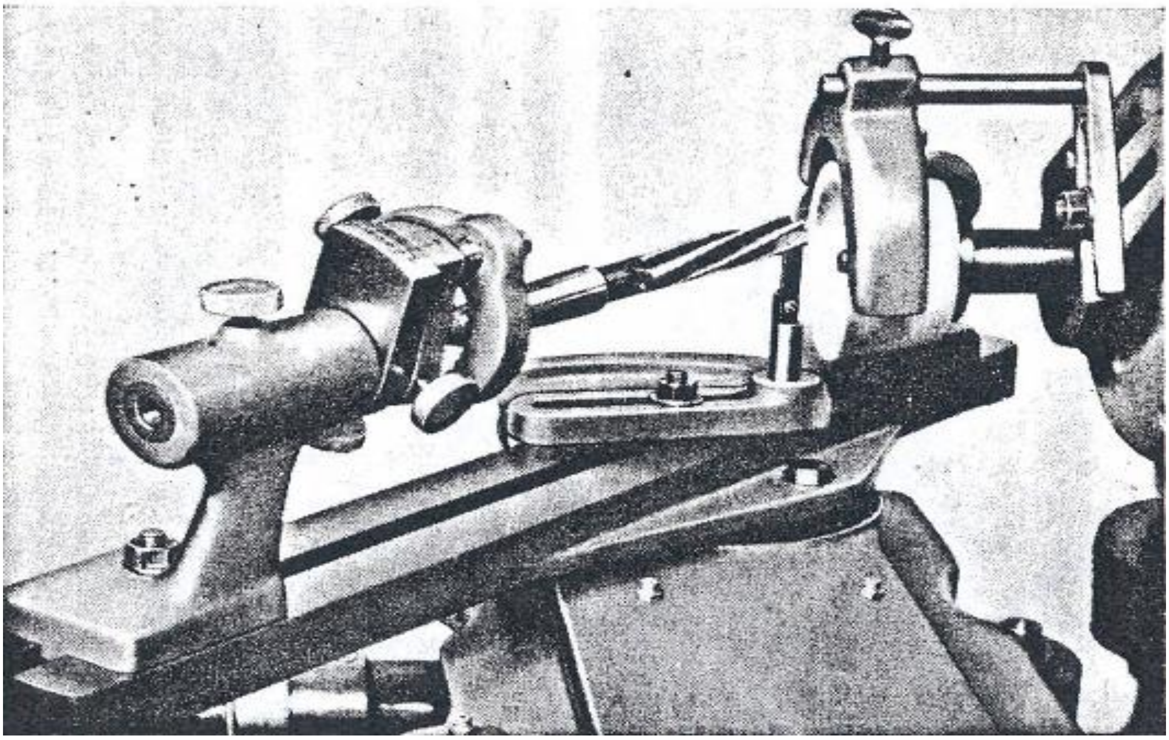


Figure 3.Grinding lead of reamer

OPERATION SHEET 4	OPERATING TOOL GRINDING MACHINES

4.1 PROCEDURES FOR SHARPENING SLITTING SAW (PERIPHERY)

Steps 1- Apply safety precaution
Steps 2- Use cup-shaped wheel, universal head, cutter arbor and scribing block.
Steps 3- Set wheel head and table at zero.
Steps 4- Clamp universal head on table, insert cutter arbor and secure slitting saw.
Steps 5- Set universal head at zero in both planes.
Steps 6- Using scribing block, set tooth to be ground below centre of universal head an amount corresponding to the clearance angle required (see chart at Linear Method) and lock in position.
Steps 7-Set tooth rest, with trip finger under tooth to be ground.
Steps 8- Position and secure wheel guard, and adjust wheel head centre to approximately the centre height of the cutter.

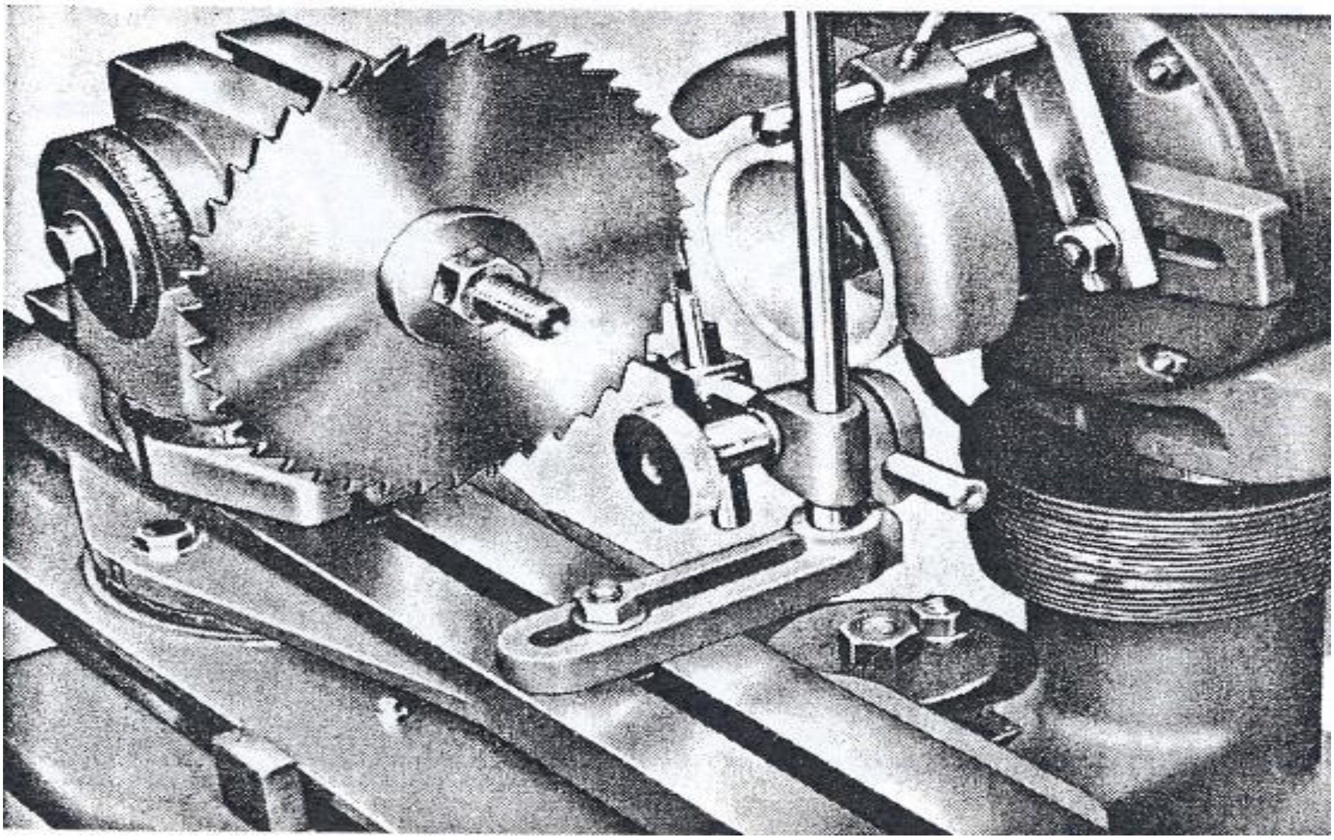


Figure 40. Sharpening Slitting Saw

OPERATION SHEET 5	OPERATING TOOL GRINDING MACHINES

5.1 PROCEDURES FOR REGASHING SLITTING SAW

Steps 1- Apply safety precaution
Steps 2- Use dish shaped wheel, wheel extension, universal head and cutter arbor.
Steps 3- Set wheel head and table at zero.
Steps 4- Clamp universal head on table, insert cutter arbor.
Steps 5- Set universal head at zero and in vertical position.
Steps 6- Position wheel head so that cutting face of grinding wheel is in line with centre of cutter arbor.
Steps 7- Mount slitting saw and clamp so that face is parallel to table movement.
Steps 8- Position tooth rest with trip finger behind tooth to be gashed.
Steps 9- Set table stop to give required gashing depth.
Steps 10- Set wheel head centre central about the saw, position and secure wheel guard.

NOTE: Depending on size and shape of cutter the micro adjustable finger can be used to set the required clearance angle.

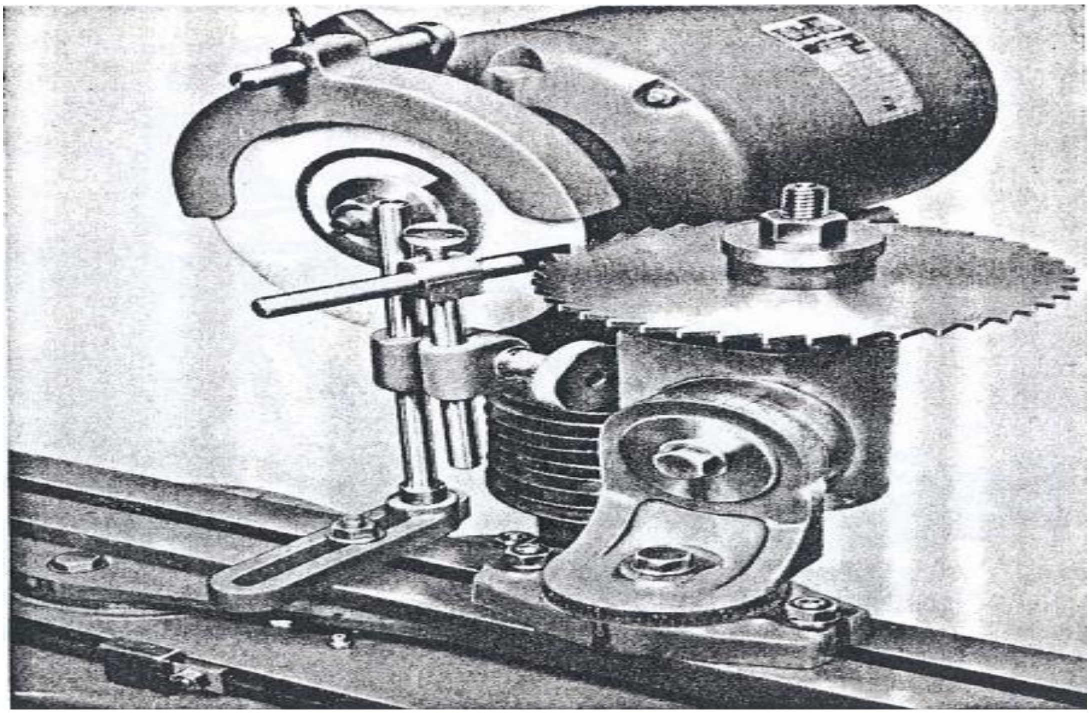


Figure 41. Regashing Slitting Saw

OPERATION SHEET 6	OPERATING TOOL GRINDING MACHINES

6.1 PROCEDURES FOR GRINDING PERIPHERY OF HELICAL SLAB CUTTER

Steps 1- Apply safety precaution

Steps 2- Use cup-shaped wheel and centre height gauge.

Steps 3-Set table at zero and wheel head at 30° approx. to ensure grinding takes place on one side of wheel only.

Steps 4- Mount tooth rest on wheel head Banjo arm.

Steps 5- Set tooth rest to centre height of loose heads, inclined at approximately the cutter helix angle and approximately on centre line of wheel head.

Steps 6- Secure cutter to mandrel and mount between centres.

Steps7- Lower wheel head the amount corresponding to clearance angle required (see table at Linear Method).

Steps 8- Position and secure wheel guard.

Steps 9- Keep cutter in contact with the finger during grinding. If preferred. the required clearance angle can be set by using the angular setting gauge.

NOTE: Care must be taken to ensure that teeth not being ground will clear the grinding wheel when the cutter rotates during grinding. Set up may be made easier depending on size and style of cutter if raising blocks are used under the loose heads.

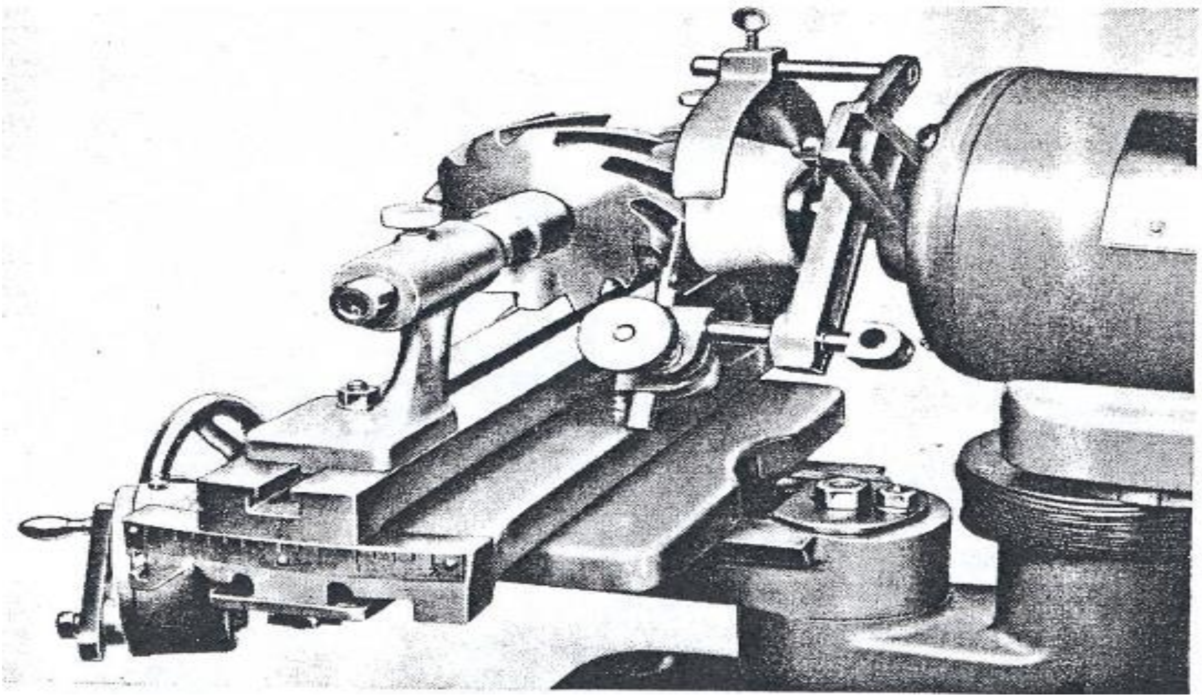


Figure 42. Grinding Periphery of Helical Slab Cutter

OPERATION SHEET 7	OPERATING TOOL GRINDING MACHINES

7.1 PROCEDURES FOR GRINDING END FACE OF END MILL

Steps 1- Apply safety precaution

Steps 2- Use cup-shaped wheel, end mill grinding attachment and angle bracket of universal head.

Steps 3- Set wheel head and table at zero.

Steps 4- Clamp angle bracket to table and fix vee attachment.

Steps 5- Mount end mill in vee attachment and hold with spring-loaded clamp.

Steps 6- Set length stop and rotate end mill until cutting edge is parallel to table.

Steps7- Set vee attachment at 5° approximate and swivel angle bracket 1° approximate to give clearances.

Steps 8- Mount tooth rest on attachment and set trip finger on tooth to be ground.

Steps 9- Set wheel head centre to approximate centre height of end mill, position and secure wheel guard.

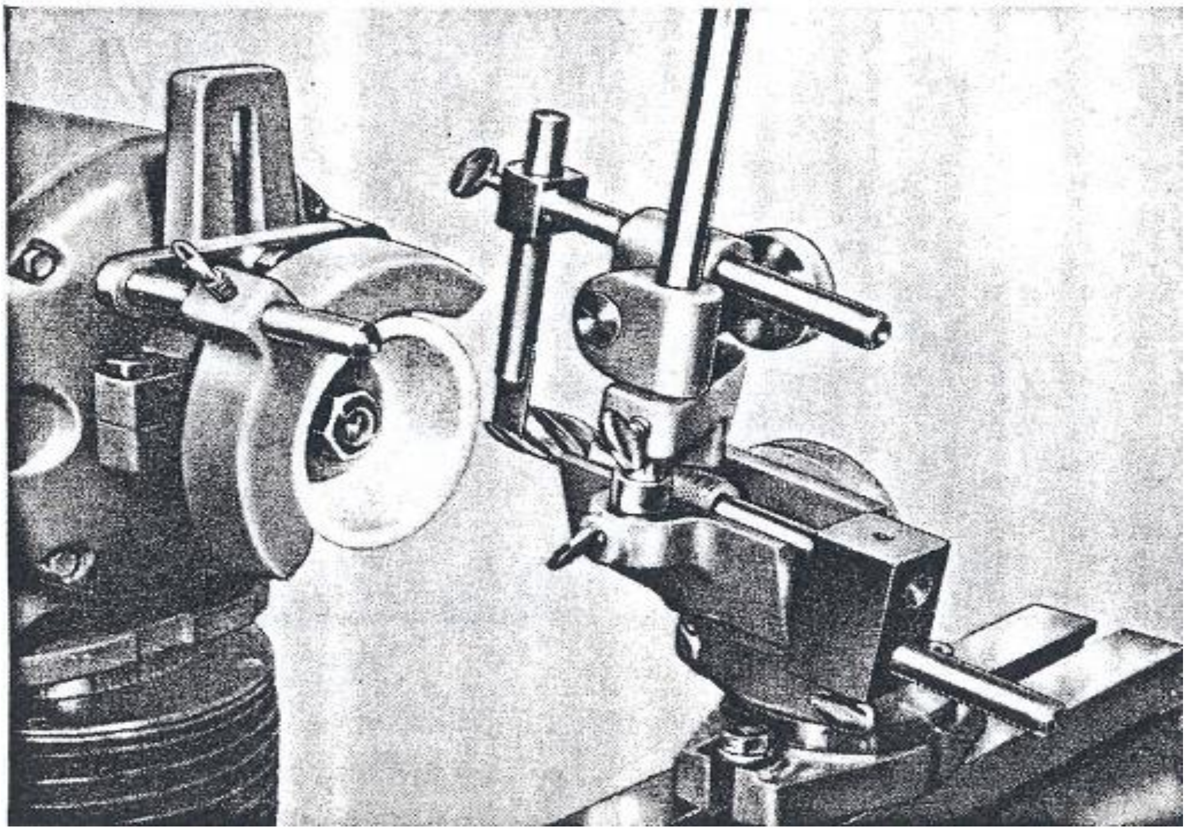


Figure 43. Grinding End Face of End Mill

OPERATION SHEET8	OPERATING TOOL GRINDING MACHINES

8.1 PROCEDURES FOR SHARPENING FORMED MILLING CUTTER

Steps 1- Apply safety precaution
Steps 2- Use dish-shaped wheel, micro-adjustable finger and wheel extension.
Steps 3- Set wheel head and table at zero.
Steps 4- Position cutting edge of grinding wheel on axis of centers.
Steps 5- Secure cutter to mandrel and mount between centers.
Steps 6-With cutting face of cutter in vertical plane, position tooth rest with micro-adjustable finger behind tooth to be cut.
Steps 7- Adjust height of wheel head to grind full face of cutter.
Steps 8- Position and secure wheel guard.
Steps 9- Apply feed (or cut) by rotating cutter with micro-adjustable finger, and then index from tooth to tooth in normal manner.

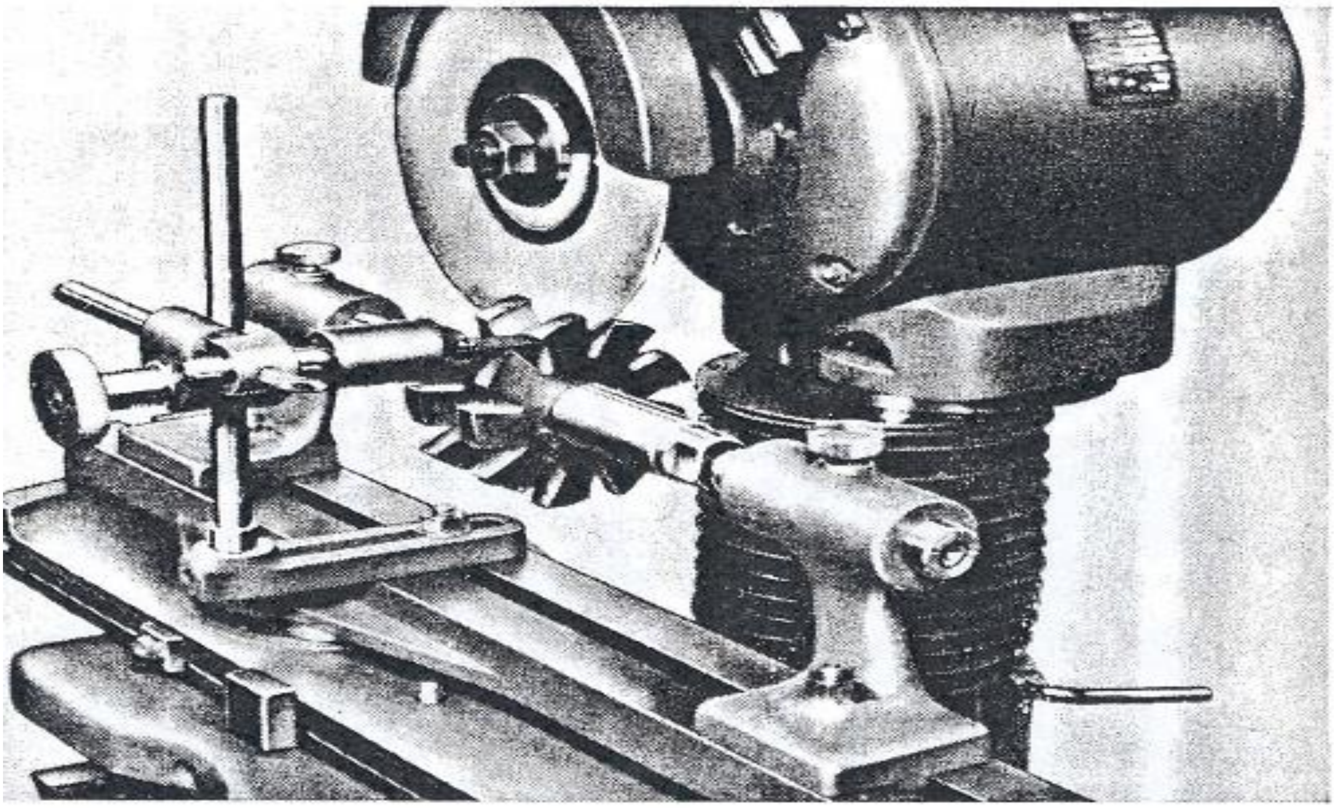


Figure 44. Sharpening Formed Milling Cutter

OPERATION SHEET 9	OPERATING TOOL GRINDING MACHINES

9.1 PROCEDURES FOR SHARPENING ANGLE CUTTER

Steps 1- Apply safety precaution
Use cup-shaped wheel, centre height gauge, clearance angle setting gauge, and short tooth rest finger shaft depending on diameter of cutter.
Steps 2- Set wheel head at zero and table to angle of cutter.
Steps 3- Mount clearance angle setting gauge on loose head centre and set at zero.
Steps 4- Secure cutter to mandrel and mount between centers.
Steps 5- Using centre height gauge, set tooth of cutter on centre line and lock mandrel to clearance angle gauge with thumb screw in the carrier.
Steps 6- Slacken the clamping screw in the zero scale of setting gauge, and rotate to the required clearance angle.
Steps 7- Set tooth rest, with trip finger, to cutter tooth and release or remove the carrier clamping the mandrel.
Steps 8- Position the wheel head centre to approximately the centre height of the loose head.

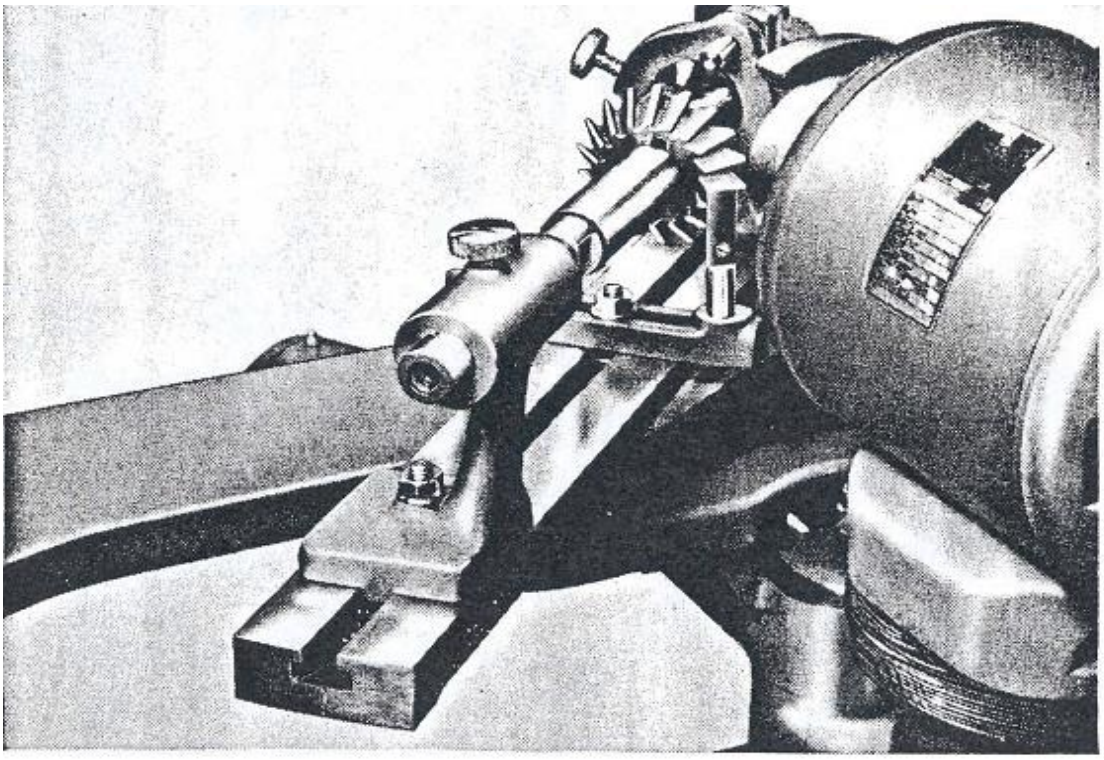


Figure 45. Sharpening Angle Cutter

OPERATION SHEET 10	OPERATING TOOL GRINDING MACHINES

10.1 PROCEDURES FOR SHARPENING ANGLE CUTTER

Steps 1- Apply safety precaution
Steps 2- Use cup-shaped wheel, wheel extension and radius grinding attachment.
Steps 3- Set table at zero and rotate wheel head 15° or more to ensure teeth not being ground do not foul the grinding wheel.
Steps 4- Dress wheel flat and true on face to table traverse movement with wheel dresser (Diamond) at centre line of grinding wheel. STOP MOTOR BEFORE PROCEEDING WITH FURTHER SETTING.
Steps 5- Clamp radius attachment on table and set setting bar, using slip gauge of width equal to radius required between the setting bar bracket and the setting diameter of the central pivot pin.
Steps 6- Clamp holder on swan neck end, set rotation limit dog so that the centre line of the holder is at right angles to table traverse movement.
Steps 7- Place setting centre in holder and set cutter finger on centre line.
Steps 8- Tilt bearing housing to clearance angle required (see table opposite).
Steps 9-.Place cutter in holder and slide forward until cutter contacts the setting bar. Lightly lock sleeve with grub screw and the holder locating rings to remove any end float.
Steps 10- Position finger under lip of cutter. If flutes are spiral as on end mills, etc. a constant rake cannot be acquired. As the tooth spirals downwards so the rake increases, therefore to produce a rake which will blend into the side teeth and also connect on the end, the front tooth should be set on centre line at the point where the radius blends into the side tooth. If tooth spirals upwards, the end of the tooth should be set on centre line at the point where the radius blends into the end tooth.
Steps 11- Remove or swing setting bar out of way of grinding wheel.
Steps 12- Wind in feed handle of machine, thus moving table, until cutter just touches the wheel. Set dial to zero.
Steps 13- Traverse table (longitudinally) so that cutter moves clear of grinding wheel.
Steps 14- Swing fixture head 90° so side of cutter is parallel with face of wheel and set other limit dog.
Steps 15- Wind swan neck on fixture until cutter just contacts the wheel and lightly locks in position.
Steps 16- Traverse table longitudinally until fixture head can swing 90° without fouling the wheel.
Steps 17- Start wheel and swinging head through 90° slowly traverse table (longitudinally) towards the wheel. This will produce a radius on the cutter.

Steps 18- Index to next tooth.

Cutter Diameter	Primary	Secondary
Up to $\frac{3}{16}$"	15°	30°
$\frac{3}{16}$" to $\frac{1}{2}$"	12°	25°
$\frac{1}{2}$" to $\frac{3}{4}$"	9°	18°
$\frac{3}{4}$" to 2"	7°	18°
Over 2"	6°	18°

NOTE: When grinding radii larger than 1/8" this should be carried out in two Operations, i.e. rough and finish to ensure accuracy and minimize wheel wear.

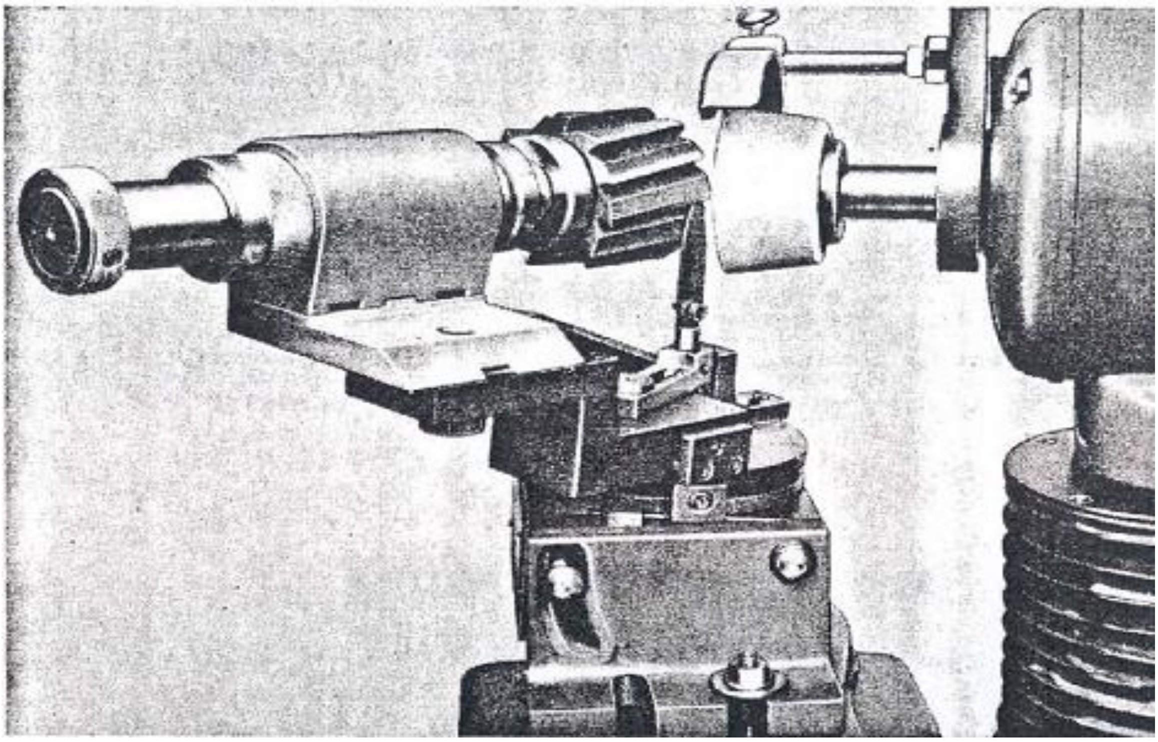


Figure46. Grinding Radius on End Mill

OPERATION SHEET 11	OPERATING TOOL GRINDING MACHINES

11.1 PROCEDURES FOR SHARPENING LATHE TOOL

Steps 1- Apply safety precaution

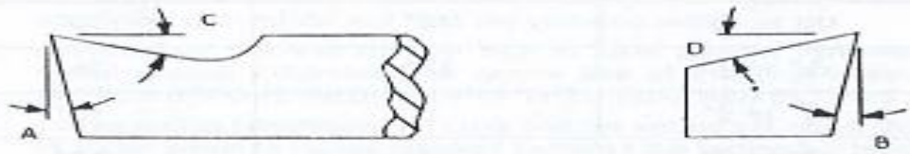
Steps 2- Use cup-shaped wheel, angle bracket of universal work support and vice.

Steps 3- Set wheel head and table at zero.

Steps 4- Clamp angle bracket to table, the vice to bracket and secure the tool to be ground.

Steps 5- Swivel the angle bracket and vice to the required clearance angles (see table below).

Steps 6- Set wheel head centre to the approximate height of tool cutting edge; position and secure wheel guard.



HIGH SPEED STEEL TOOL ANGLES

Material	Front Clearance A	Side Clearance B	Top Rake C	Side Rake D
Aluminium	9°	9°	30°	15°
Brass	7°	6°	0°	5°
Cast iron	5°	4°	10°	9°

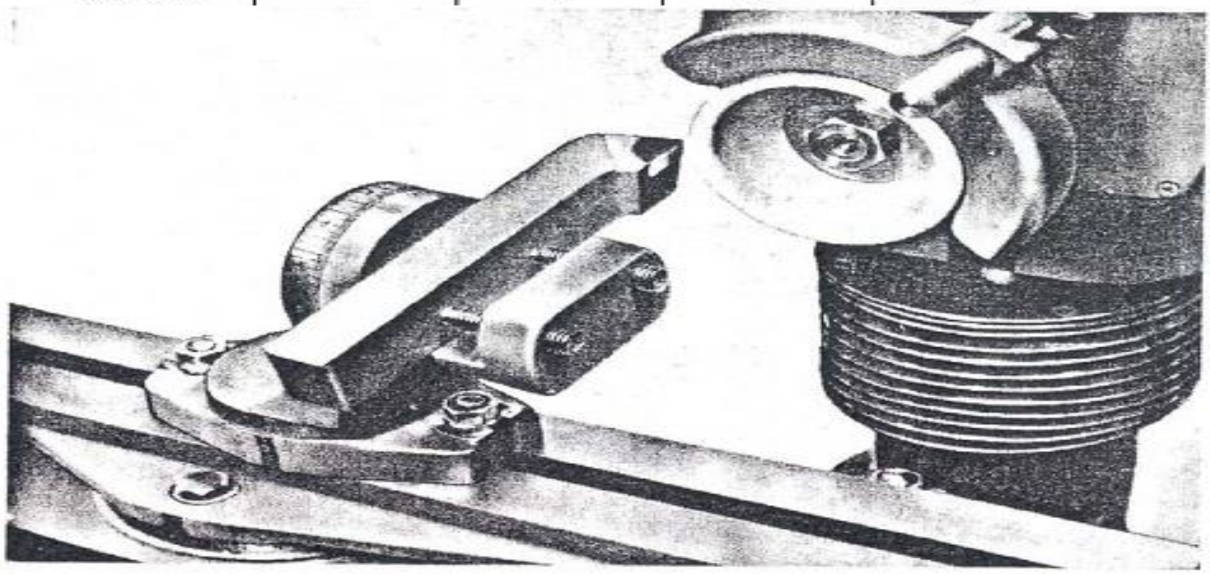


Figure 47. Sharpening Lathe Tool

LAP TEST	PRACTICAL DEMONSTRATION

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within --- hours.

TASK 1: grinding periphery of side and face cutter

TASK 2: Grinding sides face of side and face cutter

TASK 3: Grinding lead of reamer

TASK 4: Sharpening slitting saw (periphery)

TASK 5: Regashing slitting saw

TASK 6: Grinding periphery of helical slab cutter

TASK 7: Grinding end face of end mill

TASK 8: Sharpening formed milling cutter

TASK 9: Sharpening angle cutter

TASK 10: Sharpening angle cutter

TASK 11: Sharpening lathe tool

INSTRUCTION SHEET	LEARNING GUIDE #23

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Checking and measuring components

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, **upon completion of this Learning Guide, you will be able to**:

- Checking and measuring components using appropriate techniques, tools and equipment in conformance with specification

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the “Self-checks” which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to “Operation sheets
7. Perform “the Learning activity performance test” which is placed following “Operation sheets” ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

Information sheet-1	Checking and measuring components

1.1 Dimensions and tolerances

Dimensions and tolerances Is the total amount a specific dimension is permitted to vary, which is the difference between maximum and minimum permitted limits of size.

1.2 Geometry and tolerances

Geometry and tolerances Is the maximum or minimum variation from true geometric form or position that may be permitted in manufacture.

Geometric tolerance should be employed only for those requirements of a part critical to its functioning or interchangeability.

1.3 QUALITY CONFORMANCE FOR GROUND COMPONENTS

It is most important that milling cutters be ground properly and to the correct clearance angles. Otherwise the cutter will not cut efficiently and its life will be shortened considerably. There are three methods of determining tool clearance on a milling cutter. They are as follows.

- **Dial Indicator**: When a dial indicator is being used, clearance is determined by the movement of the indicator needle from the front to the back of the cutter land. The basic rule used to determine the clearance by this method is as follows. For a land of 1.58mm width, 1^0 of clearance is equivalent to 0.02mm on dial indicator. Thus 4^0 of clearance on 1.58mm land would register 0.10mm on the dial indicator. The cutter diameter does not affect the measurement.

- **Brown and sharp cutter clearance gage**: When this device is used the inside surface of the hardened arms(which are at 90^0) are placed on top of two teeth of the cutter. The cutter is revolved sufficiently to bring the face of the tooth in contact with the angle ground on the end of the hardened center blade. The clearance angle of the tooth should correspond with the angle marked on the end of the blade. Two gage blades are furnished with each gage and are stamped at each end with the diameters of the cutters for which they are intended. This cutter clearance gage measures all cutters from 12.7 to 203.2mm in diameter, except those with less than 8 teeth.

- **Starrett cutter clearance gage**: The starrett gage may be used to check the clearance in all types of cutters from 50.8mm to 762mm in diameter, and on small cutters and end from 12.7 to 50.8mm, providing the teeth are evenly spaced. This gage consists of a frame graduated from 0 to $30^{0,}$ a fixed foot, and a beam. An adjustable foot slides along the beam extension. A blade, which may be adjusted angularly and vertically, is used to check the angle of the land on a tooth. When in use, the feet are positioned on two alternate teeth of the cutter with the gage at right angle to the tooth face. The adjustable blade is then lowered on to the top of the middle tooth and adjusted until the angle corresponds to the angle of the land being checked. The land angle is indicated on the protractor on the top of the frame.

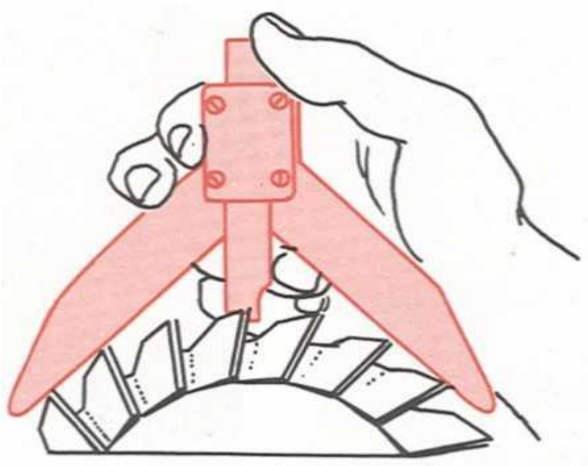


Figure48.Checking the clearance angle with a brawn and sharpe clearance gage

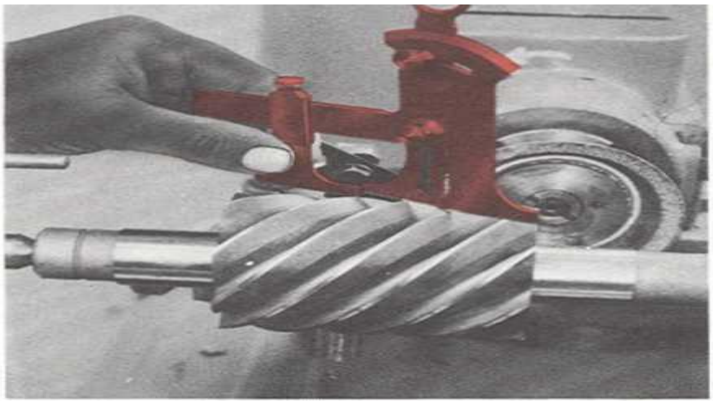


Figure 49.Checking the clearance angle with a Starrett cutter clearance gage

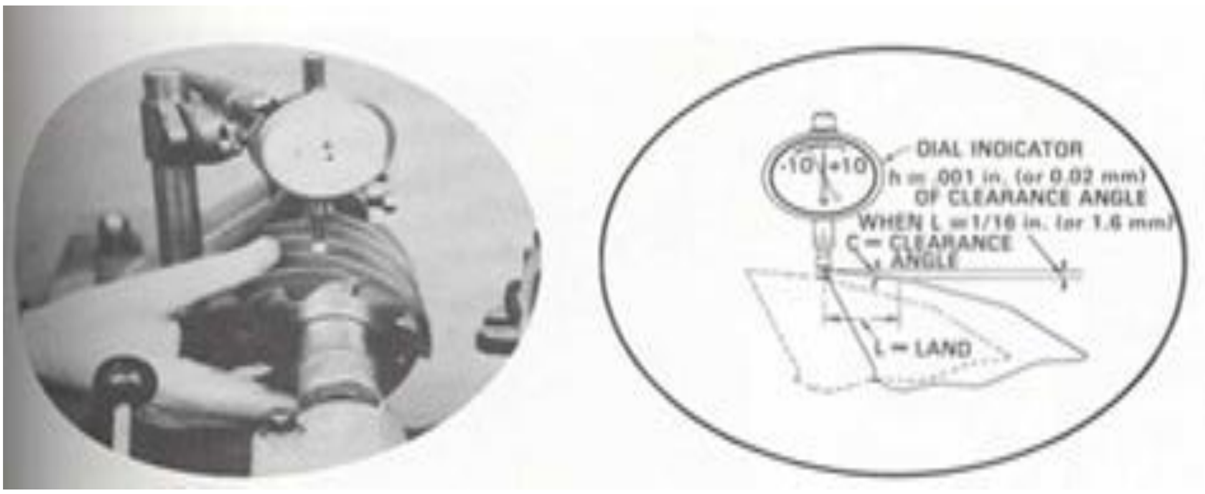


Figure50.measuring the clearance angle with a dial indicator

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I.TRUE OR FALSE ITEM (each 1 point)

1.On dial indicator 1^0 of clearance is equivalent to 0.02mm

2.It is not that much important that milling cutters be ground properly and to the correct clearance angles.

3.There are three methods of determining tool clearance on a milling cutter. They are as follows.

4.Geometric tolerance should be employed only for those requirements of a part critical to its functioning or interchangeability.

Note: **Satisfactory rating –above 4 points** **Unsatisfactory - below 4 points**

You can ask you teacher for the copy of the correct answers.

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