

## Chapter 5

# GRINDING MACHINES

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 workpiece, they act as tiny cutting tools, each particle cutting a tiny chip from the workpiece. 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 workpiece 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, modern production grinding machines are used for complete roughing and finishing of certain classes of work.

Grinding machines have some special safety precautions that must be observed. These are in addition to those safety precautions described in Chapter 1.

## SAFETY PRECAUTIONS

### GRINDING MACHINE SAFETY

Grinding machines are used daily in a machine shop. To avoid injuries follow the safety precautions listed below.

- Wear goggles for all grinding machine operations.
- Check grinding wheels for cracks (Ring Test Figure 5-11) before mounting.
- Never operate grinding wheels at speeds in excess of the recommended speed.
- Never adjust the workpiece or work mounting devices when the machine is operating
- Do not exceed recommended depth of cut for the grinding wheel or machine.
- Remove workpiece from grinding wheel before turning machine off.
- Use proper wheel guards on all grinding machines.
- On bench grinders, adjust tool rest 1/16 to 1/8 inch from the wheel.

## TYPES OF GRINDING MACHINES

From the simplest grinding machine to the most complex, grinding machines can be classified as utility grinding machines, cylindrical grinding machines, and surface grinding machines. The average machinist will be concerned mostly with floor-mounted and bench-mounted utility grinding machines, buffing machines, and reciprocating surface grinding machines.

### UTILITY GRINDING MACHINES

The utility grinding machine is intended for offhand grinding where the workpiece 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. Grinding machines come in various sizes and shapes as listed below.

#### 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 5-1 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 eyeshields, 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 tool 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.

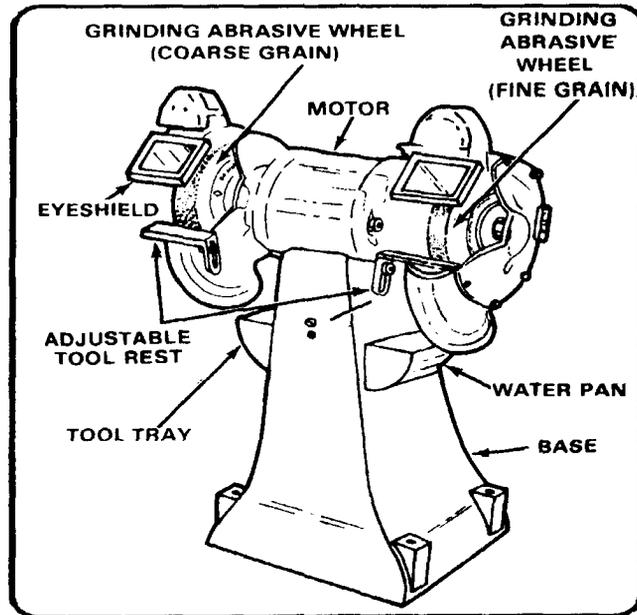


Figure 5-1. Floor-mounted utility grinding machine.

#### 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).

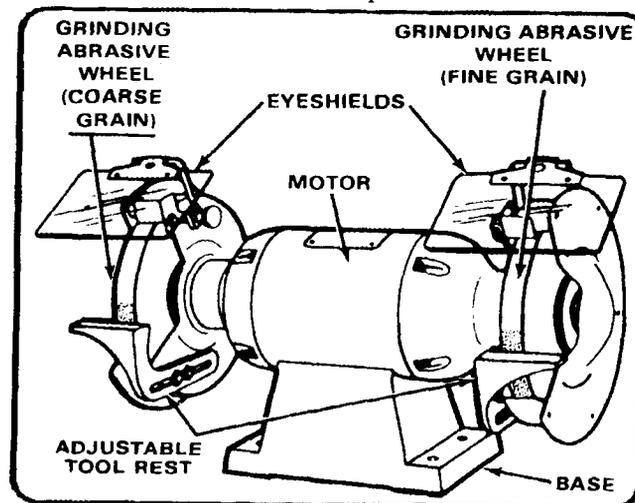


Figure 5-2. Bench-type utility grinding machine.

### Bench-Type Utility Drill Grinding Machine

The bench-type drill grinding machine is intended for drill sharpening. The accuracy of this type of grinder is not dependent on the dexterity and skill of the operator because the drill is placed in a holding device. The holding device places the drill in the correct position for the clearance and included angle. For more information on this machine refer to chapter 4.

### 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, eyeshields, 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.

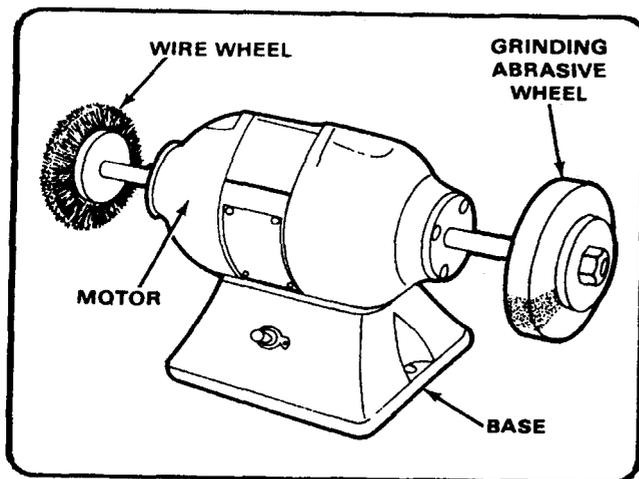


Figure 5-3. Bench type utility grinding and buffing machine

### Bench-Type Tool and Cutter Grinder

The bench-type tool and cutter grinder, see Figure 5-4, 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 of the typical bench-type tool and cutter grinder is as follows:

- Grinding wheel travel - 7 1/2-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 1/2-inch diameter.
- Swing in work head (diameter) - 4 1/2-inch diameter.

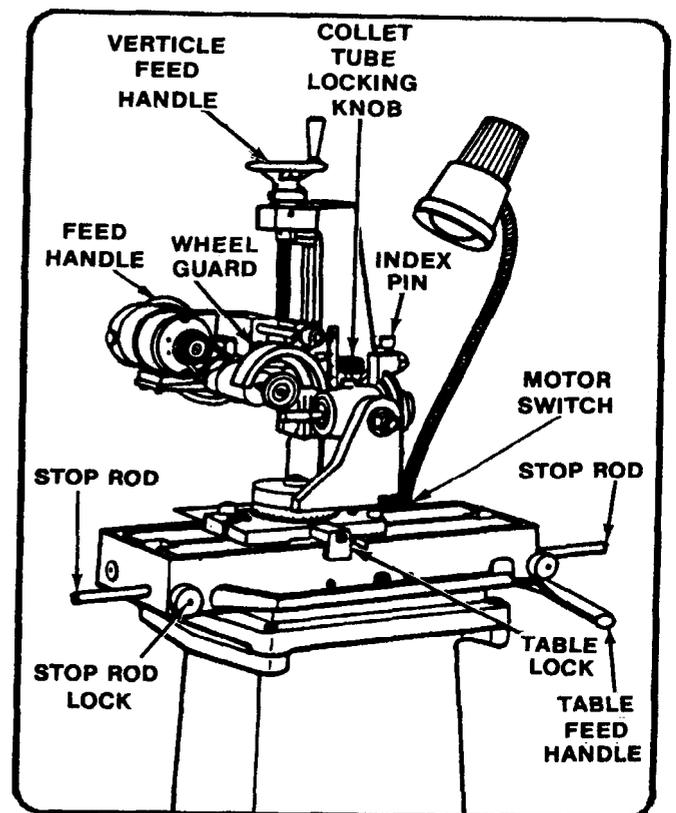


Figure 5-4. Bench-type tool and cutter grinder.

Nonspecialized cylindrical grinding machines in the Army maintenance system include the tool post grinding machine and the versa mil attachment.

### Tool Post Grinding Machine

The tool post grinding machine, see Figure 5-5, 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.

### Milling and Grinding Lathe Attachment

Also called a Versa-Mil this attachment is a versatile machine tool attachment that mounts to the carriage of a lathe. It performs internal and external cylindrical grinding among its other functions. Refer to Chapter 9 for a description of this machine.

### SURFACE GRINDING MACHINE

The surface grinding machine is used for grinding flat surfaces. The workpiece is supported on a rectangular table which moves back and forth and reciprocates beneath the grinding wheel. Reciprocating surface grinding machines generally have horizontal wheel spindles and mount straight or cylinder-type grinding abrasive wheels.

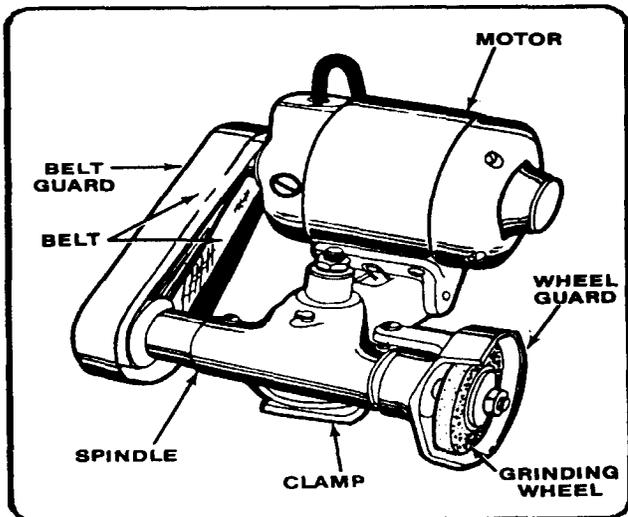


Figure 5-5. Tool post grinding machine.

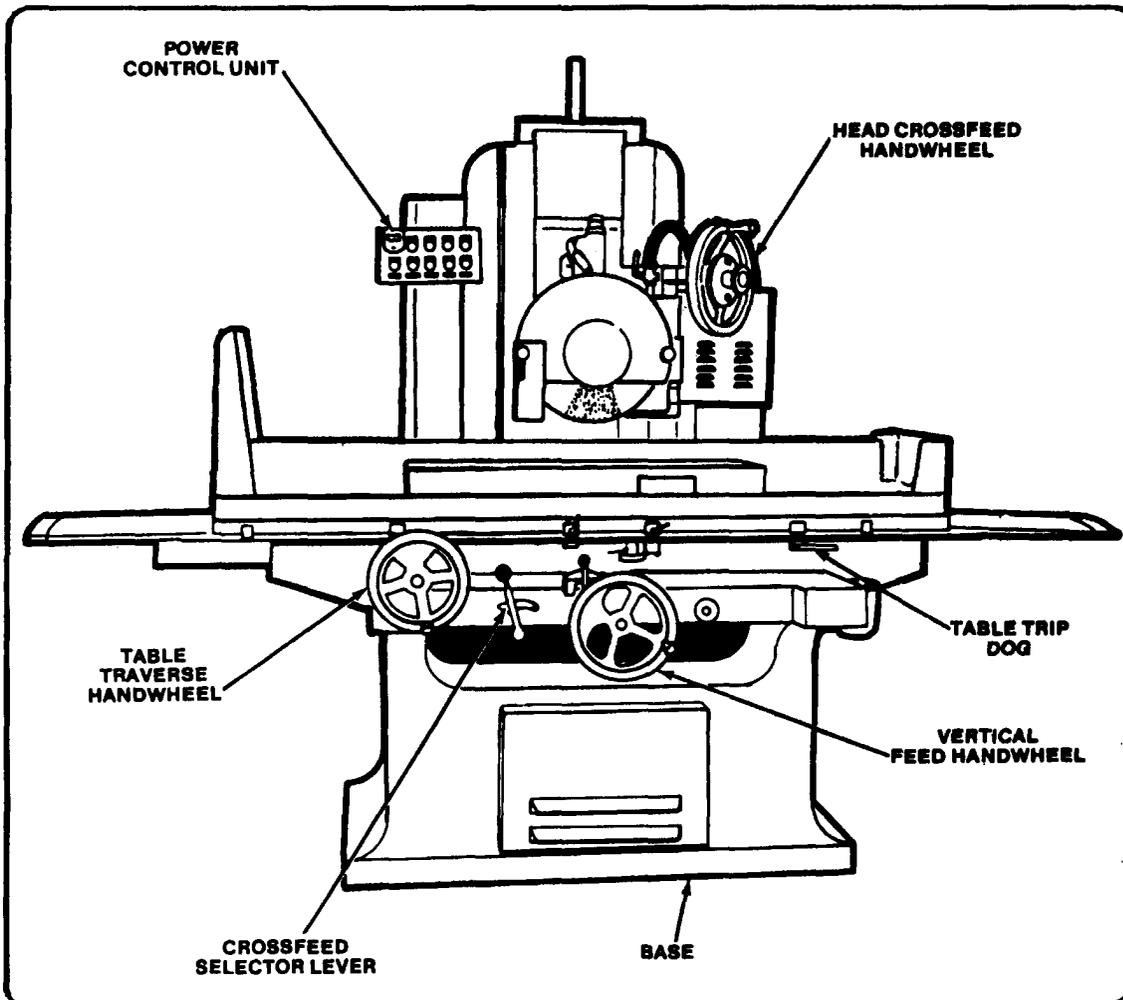


Figure 5-6. Reciprocating surface grinding machine.

## RECIPROCATING SURFACE GRINDING MACHINE

The reciprocating surface grinding machine is a horizontal-type surface grinding machine. Workpieces are fastened to the table and can be moved beneath the grinding abrasive wheel by hand or power feed. A magnetic chuck may be used

for fastening the workpiece to the table. This grinding machine has an internal pump and piping network for automatic application and recirculation of a coolant to the workpiece and wheel. The grinding abrasive wheel, mounted to the horizontal spindle is straight and cuts on its circumferential surface only. Grinding wheel speeds are adjustable.

## GRINDING WHEELS

### STANDARD TYPES OF GRINDING WHEELS

Grinding wheels come in many different sizes, shapes, and abrasives (Figure 5-7). 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 1/8-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.

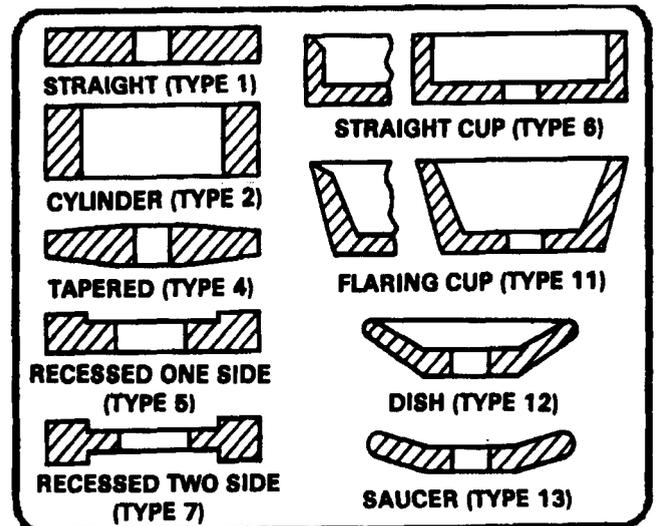


Figure 5-7. Standard types of grinding wheels.

## ABRASIVE MATERIALS

The abrasive grains are the cutting tool of a grinding wheel. They actually cut small pieces or chips off the work as the wheel rotates. The shape of each grain is irregular with several sharp cutting edges. When these edges grow dull, the forces acting on the wheel tend to fracture the abrasive grains and produce new cutting edges.

## 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.

### 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.

## 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 the grain size. A grinding abrasive wheel that is too soft will wear away too rapidly, the abrasive grain will be discarded from the wheel before its useful life is realized. On the other hand, if the wheel is too hard for the job, the abrasive particles will become dull because the bond will not release the abrasive grain, and the wheel's efficiency will be impaired.

Figure 5-8 illustrates sections of three grinding abrasive wheels with different spacing of grains. If the grain and bond materials in each of these are alike in size and hardness, the wheel with the wider spacing will be softer than the wheel with the closer grain spacing. Thus, the actual hardness of the grinding wheel is equally dependent on grade of hardness and spacing of the grains or structure.

## GRINDING WHEEL ABRASIVE

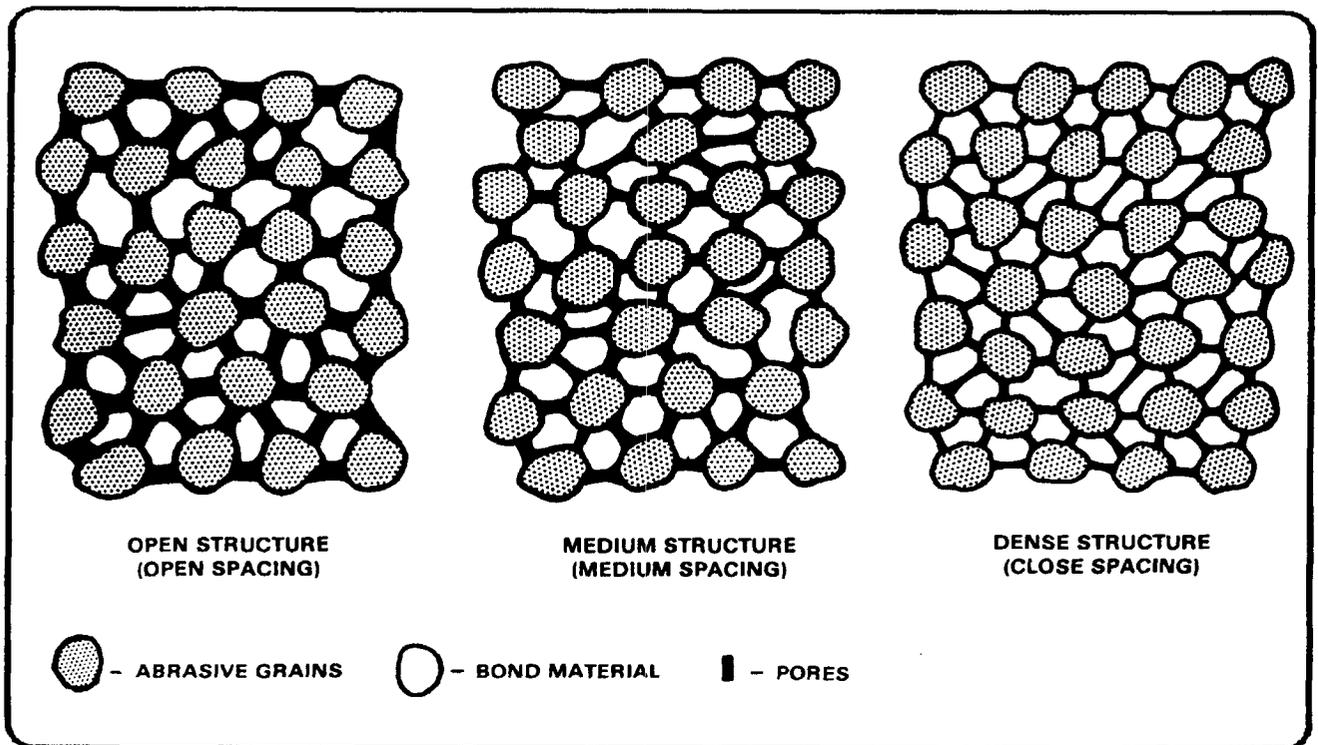


Figure 5-8. Grinding wheel abrasive.

## ABRASIVE WHEEL STRUCTURE

Bond strength of a grinding wheel is not wholly dependent upon the grade of hardness but depends equally on the structure of the wheel, that is, the spacing of the grain or its density. The structure or spacing is measured in number of grains per cubic inch of wheel volume.

## MARKINGS

Every grinding wheel is marked by the manufacturer with a stencil or a small tag. The manufacturers have worked out a standard system of markings, shown in Figure 5-9.

For an example use a wheel marked A36-L5-V23. The A refers to the abrasive which is aluminum oxide. The 36 represents the grain size. The L shows the grade or degree of hardness, which is medium. The 5 refers to the structure of the wheel and the V refers to the bond type.



**STANDARD SHAPES OF GRINDING WHEEL FACES**

Figure 5-10 illustrates standard shapes of grinding wheel faces. The nature of the work dictates the shape of the face to be used. For instance, shape A is commonly used for straight cylindrical grinding and shape E for grinding threads.

**SELECTION OF GRINDING WHEELS**

Conditions under which grinding wheels are used vary considerably, and a wheel that is satisfactory on one machine may be too hard or soft for the same operation on another machine. The following basic factors are considered when selecting grinding wheels, though it should be understood that the rules and conditions listed are flexible and subject to occasional exceptions.

**Tensile Strength of Material**

The tensile of material to be ground is the main factor in the selection of the abrasive to be used. Two types of abrasives are suited to different materials as shown below.

**Silicon Carbide**

- Gray and chilled iron
- Brass and soft bronze
- Aluminum and copper
- Marble and other stone
- Rubber and leather
- Very hard alloys
- Cemented carbides
- Unannealed malleable iron

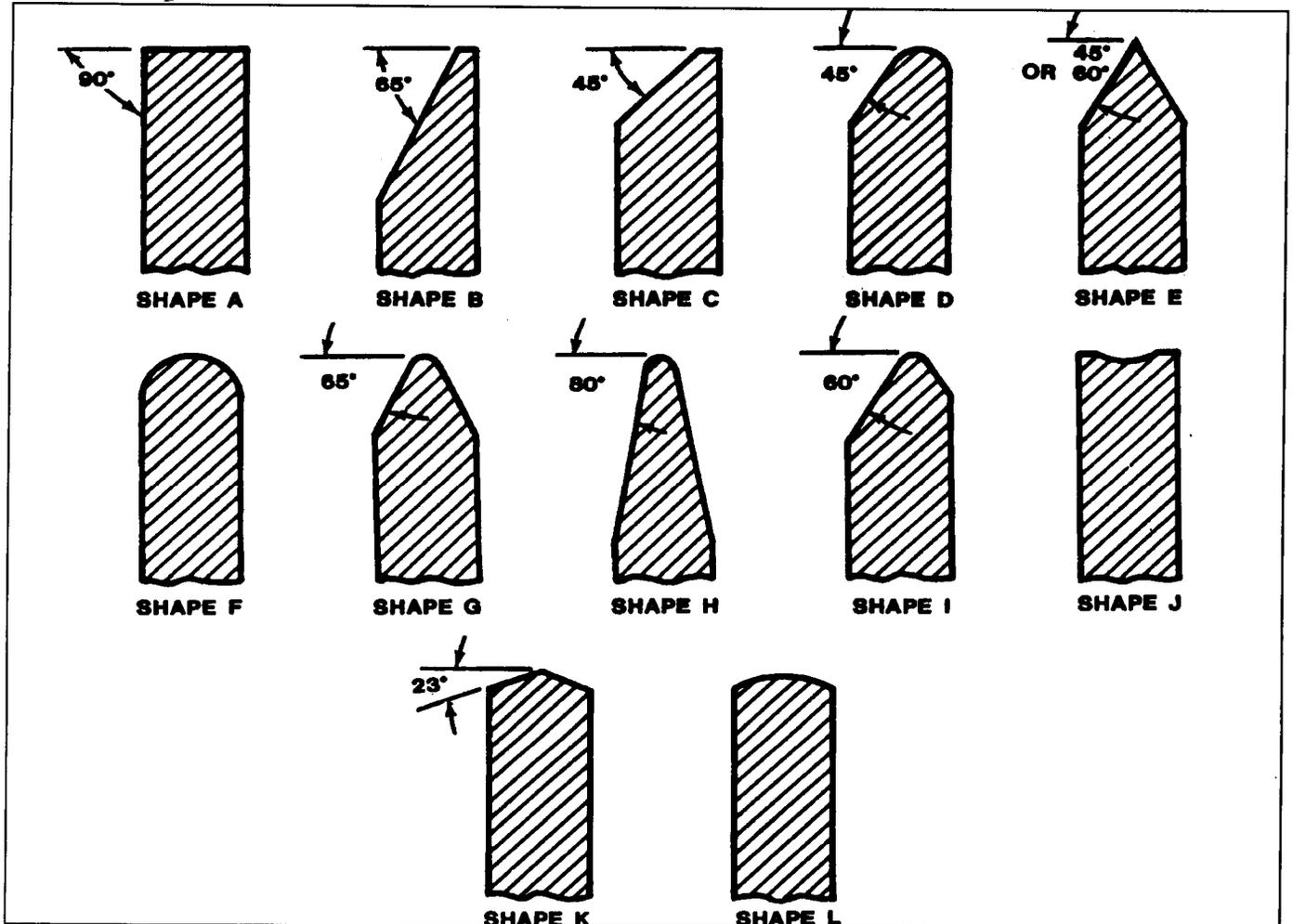


Figure 5-10. Standard shapes of grinding wheel faces.

## Aluminum Oxide

Carbon steels  
Alloy steels  
High speed steels  
Annealed malleable iron  
Wrought iron  
Hard bronzes

### Factors Affecting the Grain Size

Grain size to be chosen when selecting a grinding wheel depends upon the factors described below.

- The softer and more ductile the material, the coarser the grain size.
- The larger the amount of stock to be removed, the coarser the grain size.
- The finer the finish desired, the finer the grain size.

### Factors Affecting the Grade of Hardness

The factors described below will determine the proper grade of hardness of the grinding wheel.

- The harder the material, the softer the wheel.
- The smaller the arc of contact, the harder the grade should be. The arc of contact is the arc, measured along the periphery of the wheel, that is in contact with the work at any instance. It follows that the larger the grinding wheel, the greater the arc of contact and, therefore, a softer wheel can be used.
- The higher the work speed with relation to the wheel speed, the milder the grinding action and the harder the grade should be.
- The better the condition of the grinding machine and spindle bearings, the softer the wheel can be.

### Factors Affecting the Structure

The structure or spacing of the abrasive grains of wheel depends upon the four factors described below.

- The softer, tougher, and more ductile the material, the wider the grain spacing.
- The finer the finish desired, the closer, or more dense, the grain spacing should be.

- Surfacing operations require open structure (wide grain spacing).
- Cylindrical grinding and tool and cutter grinding are best performed with wheels of medium structure (medium grain spacing).

### Factors Affecting Bonding Material

The factors described below affect the selection of bonding material for the wheel desired.

- Thin cutoff wheels and other wheels subject to bending strains require resinoid, shellac, or rubber bonds.
- Solid wheels of very large diameters require a silicate bond.
- Vitrified wheels are usually best for speeds up to 6,500 SFPM and resinoid, shellac, or rubber wheels are best for speeds above 6,500 SFPM.
- Resinoid, shellac, or rubber bonds are generally best where a high finish is required.

### Selection

Refer to Table 5-1 in Appendix A for specific requirements for typical grinding and materials (grinding wheel selection and application).

## INSPECTION OF GRINDING WHEELS

When a grinding wheel is received in the shop or removed from storage, it should be inspected closely for damage or cracks. Check a small wheel by suspending it on one finger or with a piece of string. Tap it gently with a light nonmetallic instrument, such as the handle of a screwdriver (Figure 5-11).

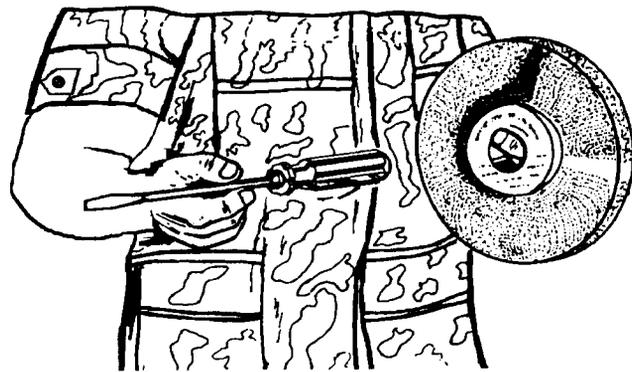


Figure 5-11. Checking for cracks.

Check a larger wheel by striking it with a wooden mallet. If the wheel does not give a clear ring, discard it. All wheels do not emit the same tone; a low tone does not necessarily mean a cracked wheel. wheels are often filled with various resins or greases to modify their cutting action, and resin or grease deadens the tone. Vitrified and silicate wheels emit a clear metallic ring. Resin, rubber, and shellac bonded wheels emit a tone that is less clear. Regardless of the bond, the sound of a cracked wheel is easy to identify.

### MOUNTING GRINDING WHEELS

The proper mounting of a grinding wheel is very important. An improperly mounted wheel may become potentially dangerous at high speeds.

The specified wheel size for the particular grinding machine to be used should not be exceeded either in wheel diameter or in wheel width. Figure 5-12 illustrates a correctly mounted grinding wheel.

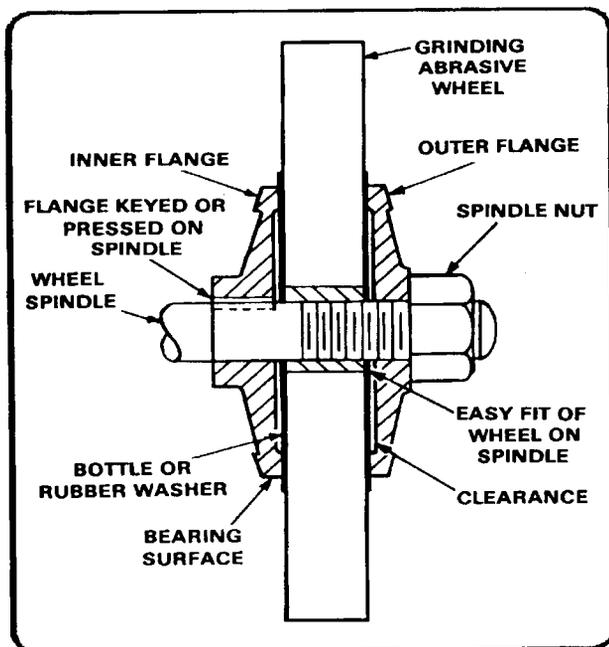


Figure 5-12. Correctly mounted wheel.

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.

### 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 5-13).

#### 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.

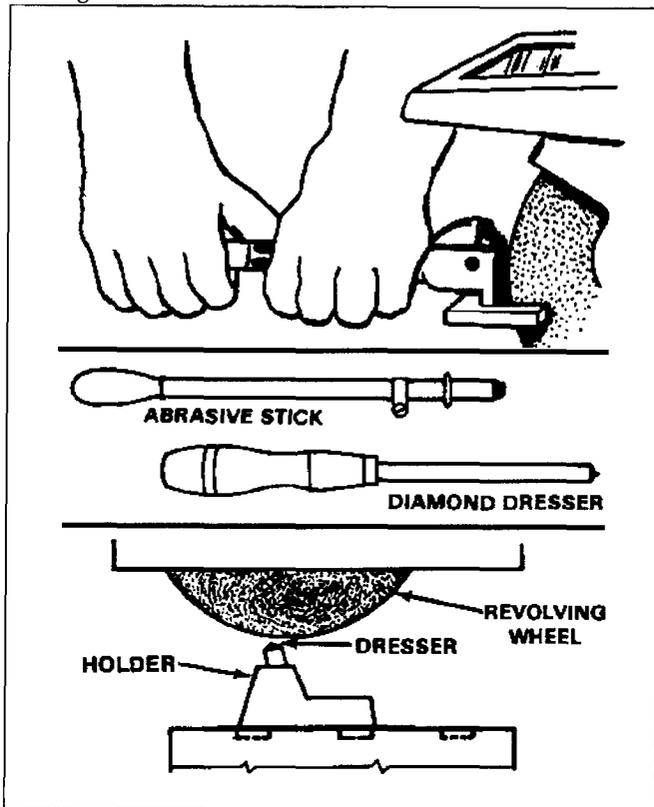


Figure 5-13. Dressing tools.

### 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  $3^{\circ}$  to  $15^{\circ}$  in the direction of rotation and  $30^{\circ}$  to the plane of the wheel as shown in Figure 5-14 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.

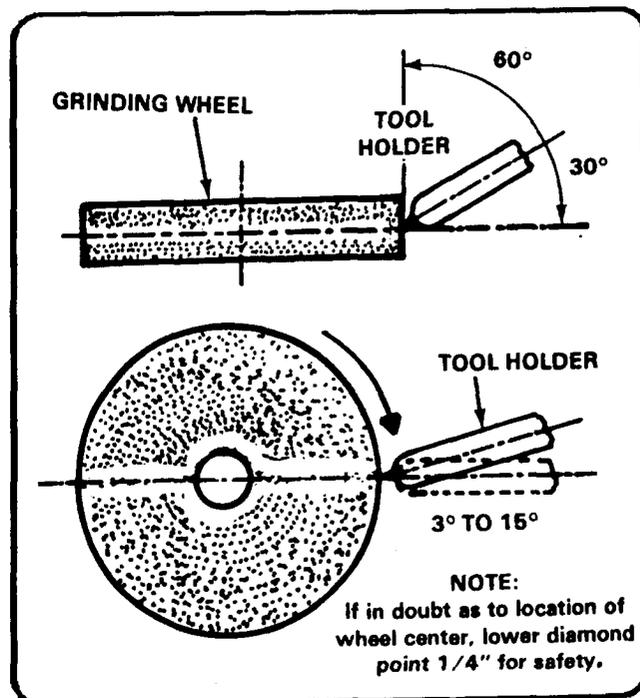


Figure 5-14. Position of diamond dresser.

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 handstone 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.

## BUFFING AND POLISHING WHEELS

Buffing and polishing wheels are formed of layers of cloth felt or leather glued or sewed together to form a flexible soft wheel.

Buffing wheels are generally softer than polishing wheels and are often made of bleached muslin (sheeting), flannel, or other soft cloth materials. The material is cut in various diameters and sewed together in sections which are put together to make up the buffing wheel. The buffing wheel is often slotted or perforated to provide ventilation.

Polishing wheels are made of canvas, felt, or leather sewed or glued together to provide various wheel grades from soft to hard. The harder or firmer wheels are generally used for heavier work while the softer and more flexible wheels are used for delicate contour polishing and finishing of parts on which corners and edges must be kept within rather strict specifications.

Buffing and polishing wheels are charged with abrasives for operation. The canvas wheels are generally suitable for use with medium grain abrasives, while felt, leather, and muslin wheels are suitable for fine grain abrasives. Buffing abrasives are usually made in the form of cakes, paste, or sticks which are applied to the wheel in this form. Polishing abrasives are fixed to polishing wheels with a glue.

## WIRE WHEELS

A wire wheel consists of many strands of wire bound to a hub and radiating outward from the hub in the shape of a wheel. The wire wheel is used in place of a grinding wheel for cleaning operations such as removal of rust or corrosion from metal objects and for rough-polishing castings, hot-rolled steel, and so forth. The wire wheel fastens to the wheel spindle of the grinding machine in the same manner as a grinding wheel.

## LAYING OUT AND MOUNTING WORK

### LAYING OUT WORK

There are no special rules for laying out work for grinding operations. Most layout requirements will be dictated by the specific grinding machine to be used. In many cases, the workpiece will be turned on a lathe or machined in some other manner before grinding. The grinding is in preparation for the final finishing of the workpiece to the desired dimensions.

### GRINDING ALLOWANCE

In planning work to be ground, the amount of metal to be removed should be based on the capabilities of the grinding machine. If the grinding machine is modern and in good condition, leave as much as 1/32-inch or even more on large machine steel parts, but generally not more than 1/64-inch on small machine parts.

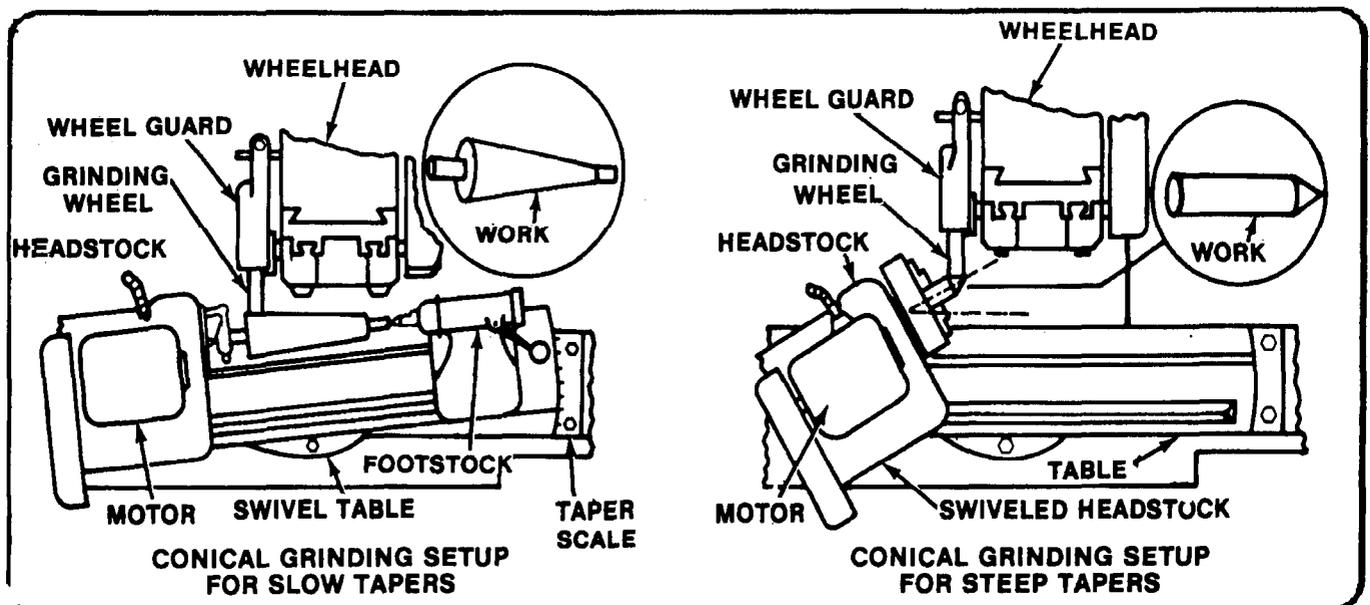


Figure 5-15. Conical grinding setups.

## Cylindrical Grinding

If cylindrical grinding is to be performed, such as grinding of workpieces mounted in the grinding may be done with the workpiece set up between centers, held in a chuck and supported by a center rest, or clamped to a faceplate as in lathe setups.

### MOUNTING WORKPIECES

#### General

Offhand grinding requires no mounting of the workpiece. Mounting for cylindrical, surface, and tool and cutter grinding is described below.

#### Mounting Workpiece for Cylindrical Grinding

Cylindrical grinding may be done with the workpiece setup between centers, held in the chuck and supported by a center rest, or clamped to the faceplate as in lathe setups.

Use the following methods when mounting the workpiece between centers:

- Use a dead center in the tailstock spindle. This method is preferred because it eliminates any error caused by wear in the machine's spindle bearings. Before grinding check the accuracy and alignment of centers and correct if necessary.
- To grind the centers, follow the procedures for grinding lathe centers in Chapter 7.
- After the centers are accurate, align the centers by one of the methods prescribed for aligning lathe centers.
- Position the workpiece between the centers, and use a lathe dog to revolve the workpiece.

Use the following methods and procedures when mounting the workpiece for conical grinding.

- Workpieces for conical grinding can be set up in a chuck or between centers.
- The table is swiveled to the required taper by means of the graduations on the end of the table (Figure 5-15).

- Since the table on a universal grinder is limited as to the degree that it can be swiveled, steep conical tapers are normally ground by swiveling the headstock to the angle of the taper desired (Figure 5-15).
- Remember when a workpiece is to be conically ground, the workpiece axis and the grinding wheel axis must be at the same height. Otherwise, the workpiece will not be ground at the correct angle.

#### Workpiece Mounted for Internal Grinding

Listed below are the proper procedures and methods to perform internal grinding.

Internal grinding is done with the universal tool and cutter grinder with an internal grinding attachment (Figure 5-16). Note that the belt and pulleys are exposed; during actual operation, this area should be covered with a guard. Since internal grinding uses small grinding wheels, the spindle and quill must operate at a high speed to get the required SFPM. Most internal grinding attachments come with several sizes of quills. Use the largest one possible for the hole being ground. The smaller quills tend to spring away from the work easily and produce tapers and irregularities.

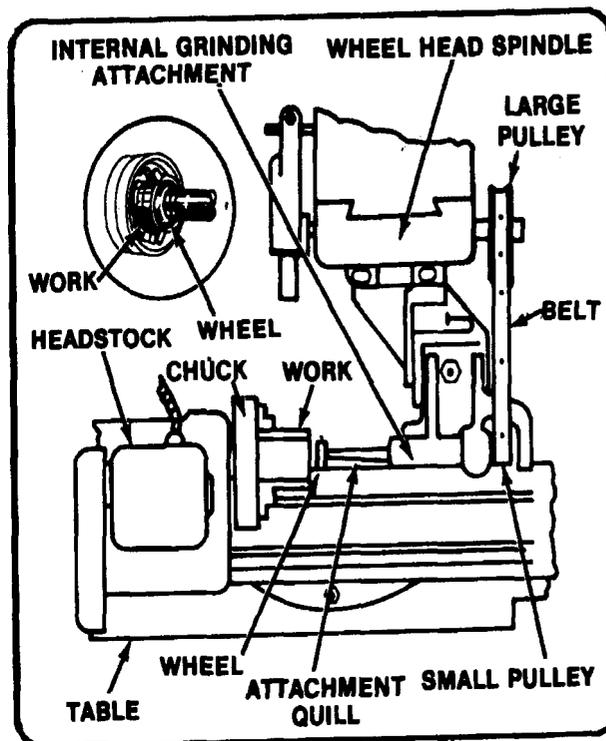


Figure 5-16. Internal grinding setup.

One condition that is more pronounced in internal grinding than in external grinding is that the larger area of contact may cause the wheel to load and glaze quickly which in turn causes vibration and produces poor surface finishes. Therefore, it is important to pay particular attention to the condition of the wheel and to use either a coarser grain wheel to provide more chip clearance or a softer grade wheel that will break down more easily. During grinding, let the grinding wheel run out of the end of the hole for at least one-half the width of the wheel face but not more than two-thirds. If the wheel clears the work each time the table reciprocates, it will grind bell-mouthed hole because of spring in the quill.

Internal conical tapers can also be ground on a universal grinding machine, using a combination of the rules for external conical grinding and those for straight internal grinding. The main thing to remember is to be sure that the axis of the quill is at center height with the axis of the work.

### **Mounting Workpiece for Surface Grinding**

A workpiece for surface grinding is usually held to the reciprocating worktable by a magnetic chuck. It may also be held in a vise or clamped directly to the table.

The two types of magnetic chucks are permanent magnet and electric. The electric chucks are built in larger sizes and are more powerful. However, the permanent-magnet chucks are less dangerous, since accidental release of work (due to power failure) is not likely to occur.

### **Mounting Workpiece for Tool and Cutter Grinding**

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

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

## **GENERAL GRINDING OPERATIONS**

### **GENERAL**

Efficient grinding depends primarily upon the proper setup of the machine being used. If the machine is not securely mounted, vibration will result, causing the grinder to produce an irregular surface. Improper alignment affects grinding accuracy, and it is good practice to check the security and plumb of the machine every few months. It is advisable to place a strip of cushioning material under the mounting flanges, along with any necessary aligning shims, to help absorb vibration.

When a grinding wheel is functioning properly, the abrasive grains cut very small chips from the workpiece and at the same time a portion of the bond of the wheel is worn away. As long as the bond is being worn away as fast as the abrasive grains of the wheel become dull, the wheel will continue to work well. If the bond is worn away too rapidly, the wheel is too soft and will not last as long as it should. If the cutting grains wear down faster than the bond, the face of the wheel becomes glazed and the wheel will not cut freely.

### **CLASSES OF GRINDING**

Precision and semiprecision grinding may be divided into the following classes:

#### **Cylindrical Grinding**

Cylindrical grinding denotes the grinding of a cylindrical surface. Usually, "Cylindrical grinding" refers to external cylindrical grinding and the term "internal grinding" is used for internal cylindrical grinding. Another form of cylindrical grinding is conical grinding or grinding tapered workpieces.

#### **Surface Grinding**

Surface grinding is the grinding of simple plain surfaces.

#### **Tool and Cutter Grinding**

Tool and cutter grinding is the generally complex operation of forming and resharpening 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 workpiece 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 workpiece to keep the wheel and workpiece cool, to wash away the loose abrasive, and to produce a better finish.

## 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 certain extent the finish produced on the work and will vary for different types and shapes of grinding wheels.

### 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.

#### 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.

#### 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.

## 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.

## 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 (Table 5-1 in Appendix A).

## 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:

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

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:

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

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

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

**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 is necessary to increase the rotational speed of the wheel or replace the wheel to maintain efficiency in grinding.

### 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 workpiece is large or small, and so forth. Listed below are areas to consider when performing cylindrical grinding:

- The larger the diameter of the workpiece, the greater is its arc of contact with the wheel. The cutting speed suitable for one diameter of workpiece 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.

### 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.

### Feeds

The feed of the grinding wheel is the distance the wheel moves laterally across the workpiece 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 face 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 workpiece.
- For an average finish, the wheel should traverse one-third to one-half the width of the wheel per revolution or pass of the workpiece.
- In surface grinding with wheels less than 1 inch in width, the table traverse speed should be reduced about one-half.

### 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 inch.
- 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 workpiece or wheel is not concentric.

### 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 workpiece 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 workpiece.

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.

## OFFHAND GRINDING

Offhand grinding is the process of positioning and feeding the workpiece against a grinding wheel by hand. Offhand grinding is used for reducing weld marks and imperfections on workpieces, and general lathe tool, planer tool, shaper tool, and drill grinding. Deciding depth of cut and feed is based on the operator's knowledge of grinding.

Offhand grinding is performed on utility grinding machines which generally have fixed spindle speeds and fixed wheel size requirements, so that the cutting speed of the wheel is constant and cannot be changed for different materials. Therefore, the operator must use care in feeding and not overload the wheel by taking too heavy a cut, which would cause excess wear to the grinding wheel. Similarly, he must be careful not to glaze the wheel by applying excessive pressure against the wheel.

The one variable factor in most offhand grinding is the selection of grinding abrasive wheels, although limited to one diameter. For example, a softer or harder wheel can be substituted for the standard medium grade wheel when conditions and materials warrant such a change. Lathe tool grinding is described in Chapter 7. Drill sharpening and drill grinding attachments and fixtures are described in Chapter 4.

## TOOL AND CUTTER GRINDING

### Grinding Milling Cutters

Milling cutters must be sharpened occasionally to keep them in good operating condition. When grinding milling cutters, care must be exercised to maintain the proper angles and clearances of the cutter. Improper grinding can result in poor cutting edges, lack of concentricity, and loss of form in the case of formed tooth cutters. Milling cutters cannot be sharpened by offhand grinding. A tool and cutter grinding machine must be used.

### Bench-Type Tool and Cutter Grinding Machine

The bench-type tool and cutter grinding machine described here is typical of most tool and cutter grinding machines. It is designed for precision sharpening of milling cutters, spot facers and counterbores, reamers, and saw blades. The grinding machine contains a 1/4-HP electric motor mounted to a swivel-type support bracket which can be adjusted vertically and radially on the grinder column. The column is fixed to the grinder base which contains T-slots for attaching grinder fixtures used to support the tools that are to be ground.

The motor shaft or wheel spindle accepts grinding wheels on each end. One end of the spindle contains a wheel guard and tool rest for offhand grinding of lathe tools and so forth. Cup, straight, and 15° bevel taper abrasive grinding wheels are used with this machine. Fixtures used for grinding tools and cutters include a center fixture for mounting reamers, taps, and so forth between centers; an outside diameter fixture for chucking arbor-type milling cutters and shanked peripheral cutting edge tools; and an end mill fixture for supporting end cutting tools to the grinder base.

### Grinding Formed Milling Cutters

Use the following methods and procedures when grinding formed milling cutters.

- Formed milling cutters are usually ground with a cup or dish grinding wheel of medium grain (36 to 60 grain).
- It is important that formed cutters be ground only on the face, never on the land. Grinding the land destroys the shape of the cutter. Also important, the face must be ground so that the exact rake angle is retained or the cutter will cut unevenly.
- Formed cutters are ground by radial grinding. Correctly ground cutter teeth are shown at A and B, Figure 5-17. At A, the tooth is ground without rake; only cutters originally shaped without rake should be reground without rake. At B, a correctly ground tooth is shown with positive rake. Rake angles are commonly between 10° and 15° from the radius passing through the cutting edge, 12° being the most commonly used angle. The tooth shown at C, has excessive positive rake this tooth will gouge, making an excessively deep cut, and the cutting edge will dull rapidly with hard materials. The tooth shown at D, Figure 5-17 has negative rake; this tooth will drag and make a shallow cut.

On new cutters, the back (Figure 5-17) of each tooth should be ground accurately before grinding the face. This procedure is recommended so that an accurate reference surface is provided for the index finger of the grinding machine attachment. Another method of assuring this alignment is by mounting another cutter containing the same number of teeth on the same arbor with the cutter being ground. With the second cutter properly aligned and locked in place, the index finger can be used against the second cutter's teeth.

**NOTE:** A positive rake angle is a rake angle that increases the keenness of the cutting edge. A negative rake angle is one that decreases or makes the cutting edge more blunt.

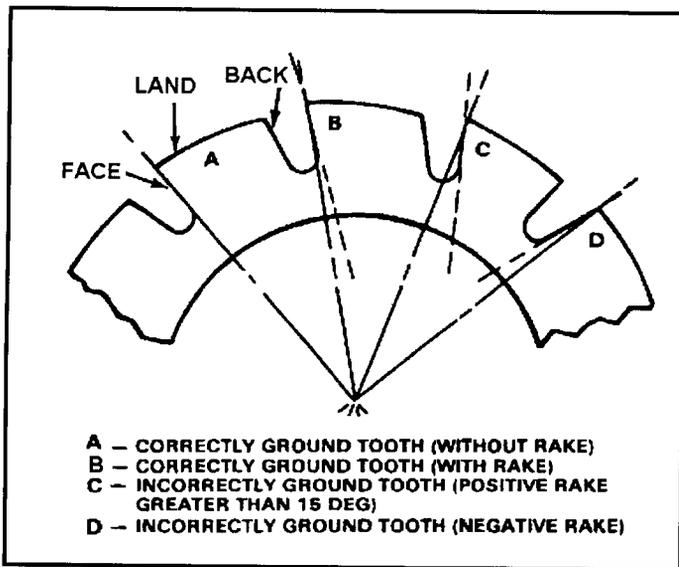


Figure 5-17. Correct and incorrect grinding of formed milling cutter teeth.

The grinding wheel should be set up so that the wheel traverse is aligned with the face of one tooth (Figure 5-18). The alignment should be checked by moving the grinding wheel away from the cutter, rotating the cutter, and rechecking the traverse on another tooth. After this alignment is accomplished, the depth of cut, is regulated by rotating the cutter slightly, thus maintaining the same rake angle on the sharpened cutter. The depth of cut should never be obtained by moving the cutter or grinding wheel in a direction parallel to the wheel spindle. Doing this would change the rake angle of the cutter.

### Grinding Plain Milling Cutters

Plain milling cutters with saw-tooth type teeth are sharpened by grinding the lands on the periphery of the teeth. The lands may be ground using a straight grinding wheel or a cup-shaped grinding wheel.

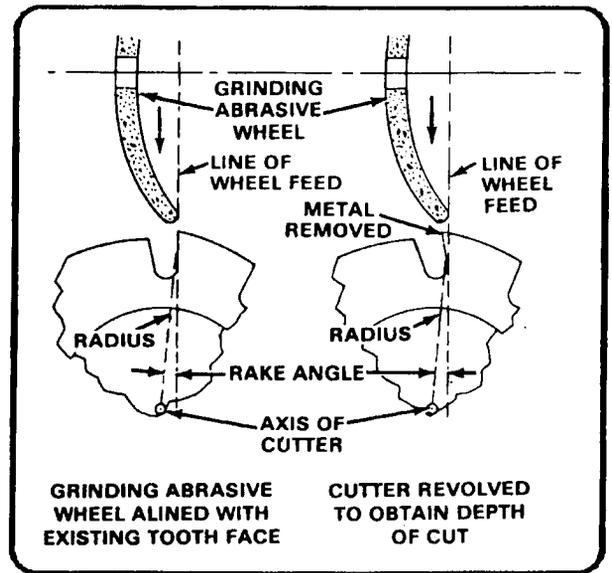


Figure 5-18. Aligning formed milling cutter and grinding wheel.

The important consideration when grinding this type of cutter is the primary clearance angle or relief angle of the land (Figure 5-19). If the primary clearance angle is too large, the cutting edge will be too sharp and the cutter will dull quickly. If the primary clearance angle is too small, the cutter will rub rather than cut and excessive heat will be generated.

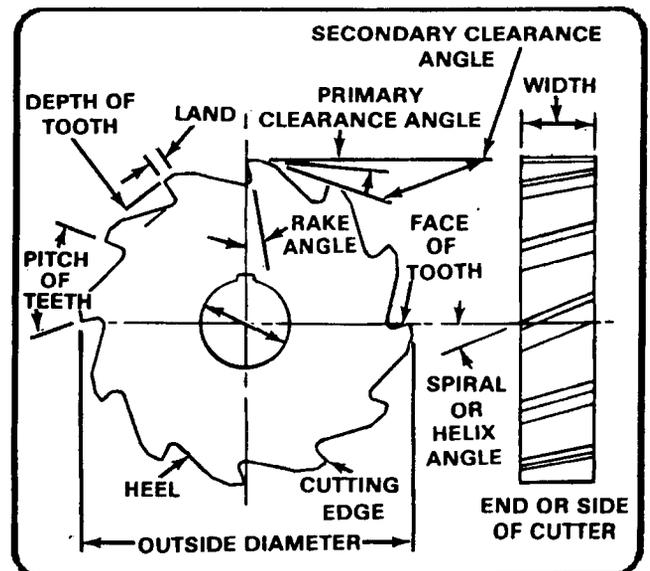


Figure 5-19. Milling, cutter nomenclature.

The primary clearance angle (Figure 5-19) should be between 3° and 5° for hard materials and about 10° for soft materials like aluminum. For cutters under 3 inches in diameter, a larger clearance angle should be used: 7° for hard materials and 12° for soft materials.

The clearance angle for end and side teeth should be about 2° and the face of these cutters should be ground 0.001- or 0.002-inch concave toward the center to avoid any drag.

To grind the lands of milling cutter teeth to primary clearance angle, the teeth are positioned against the grinding wheel below the wheel's axis (Figure 5-20).

To obtain the primary clearance angle when grinding with a straight wheel, lower the indexing finger or raise the grinding wheel a distance equivalent to 0.0088 times the clearance angle times the diameter of the grinding wheel. For example, to find the distance below center of the indexing finger (Figure 5-20) for a cutter with a 5° clearance angle, being ground by a straight wheel 6 inches in diameter, the calculation is as follows:  $0.0088 \times 5 \times 6 = 0.264$  inch. The indexing finger would then be set 0.264 inch below the wheel axis. The milling cutter axis should also be 0.264 inch below the wheel axis.

To obtain the primary clearance angle when grinding with a cup wheel, the formula for a straight wheel is used except that instead of wheel diameter being used in the formula, the cutter diameter is used. In this case, the index finger is set to the calculated distance below the axis of the milling cutter (Figure 5-20) instead of below the axis of the wheel.

Table 5-3 in Appendix A is provided to save time in calculating distances below center for primary clearance angles. The same figures can be used for straight wheel or cup wheel grinding, substituting the wheel diameter for the cutter diameter or vice versa.

The land of each tooth (Figure 5-19) should be from 1/32 to 1/16-inch wide, depending upon the type and size of the milling cutter. As a result of repeated grinding of the primary clearance angle, the land may become so wide as to cause the heel of the tooth to drag on the workpiece. To control the land width, a secondary clearance angle (Figure 5-19) is ground. This angle is usually ground to 30°, although the exact angle is not critical. Generally, an angle between 20° and 30° is sufficient to define the land of the tooth.

## Grinding End Milling Cutters

The peripheral teeth of end milling cutters are ground in the same manner as the teeth of a plain milling cutter. When grinding the end teeth of coarse-tooth end milling cutters, the cutter is supported vertically in a taper sleeve of the end mill fixture and then tilted to obtain the required clearance angle. The end mill fixture is offset slightly to grind the teeth 0.001 to 0.002 inch lower in the center to prevent dragging. A dish-shaped grinding wheel revolving about a vertical spindle is used to grind end milling cutters.

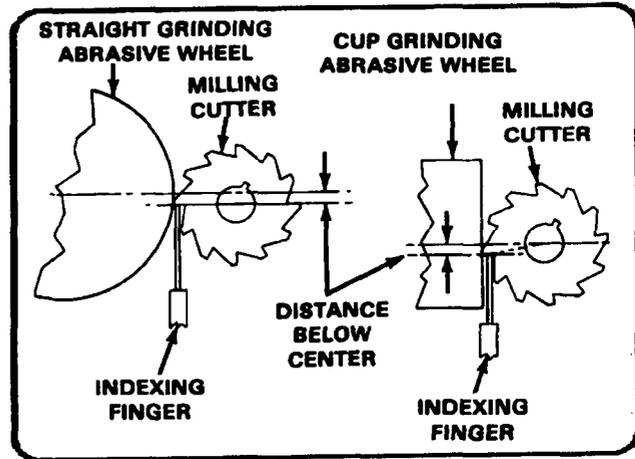


Figure 5-20. Grinding primary clearance angle.

## Removing the Burrs

After the milling cutter is ground, the cutting edges should be honed with a fine oilstone to remove any burrs caused by grinding. This practice will add to the keenness of the cutting edges and keep the cutting edges sharper for a longer period of time.

## CYLINDRICAL GRINDING

Cylindrical grinding is the practice of grinding cylindrical or conical workpieces by revolving the workpiece in contact with the grinding wheel. Cylindrical grinding is divided into three general operations: plain cylindrical, conical grinding (taper grinding), and internal grinding. The workpiece and wheel are set to rotate in opposite directions at the point of contact (Figure 5-21).

### Plain Cylindrical Grinding

The step-by-step procedure for grinding a straight shaft is given below. The shaft has been roughly turned prior to grinding.

- Check and grind headstock and tailstock centers if necessary.
- Check drilled centers of workpiece for accuracy.
- Place a grinding wheel of the proper grain, grade, structure, and bond on the wheel spindle.
- Place wheel guards in position to cover the wheel adequately.
- Set the proper wheel speed on grinding machine (Table 5-2 in Appendix A).
- Place the diamond dresser and holder on the machine table and true and dress the grinding wheel.



Mount the headstock and footstock on the table.

- Attach the proper size drive dog on the headstock end of the workpiece.
- Mount the workpiece between headstock and tailstock centers. Use lubricant (oil and white lead mixture) on tailstock center. Make sure centers fit drill center holes correctly with no play.
- Set the proper rotational work speed on the wheel head. The general range of work speed for cylindrical grinding is 60 to 100 SFPM. Heavy rough grinding is sometimes performed at work speeds as low as 20 or 30 SFPM. Soft metals such as aluminum are sometimes ground at speeds up to 200 SFPM.
- Position the table trip dogs to allow minimum table traverse. The wheel should overlap each end of the workpiece not more than one-half the wheel width to assure a uniform straight cut over the length of the workpiece.
- Calculate the table traverse feed using this formula.

$$TT = (WW \times FF \times WRPM) \div 12$$

Where TT = Table travel in feet per minute  
 WW = Width of wheel  
 FF = Fraction of finish  
 WRPM = Revolutions per minute of workpiece  
 12 = Constant (inches per foot)

The fraction of finish for annealed steels is 1/2 for rough grinding and 1/6 for finishing; for hardened steels, the rate is 1/4 for rough grinding and 1/8 for finishing.

For example, a 1-inch-wide wheel is used to rough grind a hardened steel cylinder with a work RPM of 300.

**Table travel =**  
 $(1 \times 1/4 \times 300) \div 12 = (75) \div 12 = 6.25 \text{ FPM}$

After the calculations have been completed, set the machine for the proper traverse rate, turn on the table traverse power feed, and grind the workpiece.

Check the workpiece size often during cutting with micrometer calipers. Check the tailstock center often and readjust if expansion in the workpiece has caused excessive pressure against the drilled center in the workpiece.

The finishing cut should be slight, never greater than 0.001 inch, and taken with a fine feed and a fine grain wheel.

If two or more grinding wheels of different grain size are used during the grinding procedure, each wheel should be dressed and trued as soon as it is mounted in the grinding machine.

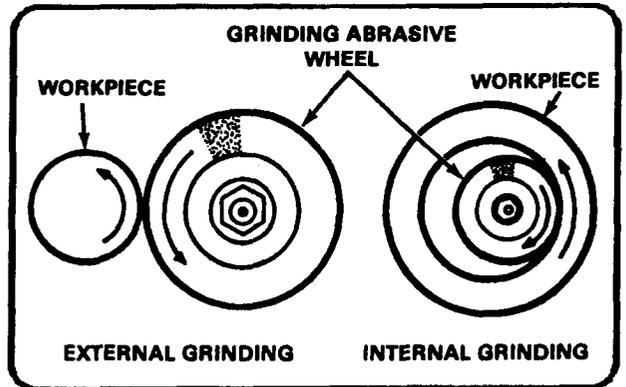


Figure 5-21. Direction of rotation for cylindrical grinding.

### Conical Grinding

Most conical grinding is performed in the same manner as plain cylindrical grinding. Once the grinding machine is set up, the table is swiveled until the correct taper per inch is obtained. Steep conical tapers are normally ground by swiveling the headstock to the angle of taper. Whichever method is used, the axis of the grinding wheel must be exactly at center height with the axis of the work.

## INTERNAL GRINDING

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 workpiece 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 workpiece 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 workpiece.
- 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 workpiece or setup when the wheel is fed into and retracted from the workpiece.

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.

## SURFACE GRINDING

Surface grinding or grinding flat surfaces, is characterized by a large contact area of the wheel with the workpiece, as opposed to cylindrical grinding where a relatively small area of contact is present. As a result, the force of each abrasive grain against the workpiece is smaller than that applied to each grain in cylindrical grinding. In surface grinding the grinding wheel should be generally softer in grade and wider in structure than for cylindrical grinding.

### OPERATION

The following sequence is provided as a step-by-step example of a typical surface grinding operation.

- Adjust the surface grinding machine so that grinding head and worktable are absolutely parallel.
- Place a grinding wheel of the proper grain, grade, structure, and bond on the wheel spindle.
- Place the guard over the wheel and check security of all adjustable members of the grinding machine for rigidity and lack of backlash.
- True and dress the grinding wheel.
- Mount the workpiece to the worktable. Make sure the surface to be ground is parallel to the worktable and the grinding wheel.
- Adjust wheel speed, work speed, and work feed.
- Proceed with grinding, adjusting depth of cut as necessary. Check for accuracy between each cut and determine that the workpiece is square and the wheel is not out of alignment. If it is necessary to use more than one grinding wheel to complete the grinding, each wheel should be trued and dressed after it is mounted.

## SPECIAL OPERATIONS ON GRINDING MACHINES

### CLEANING

A wire wheel mounted to a utility grinding machine is used for cleaning operations such as removing rust, paint, or dirt from metal objects. If the utility grinding machine on which

the wire wheel is to be mounted is equipped with wheel guards and tool rests, these parts should be removed or swung out of the way so that the objects to be cleaned can be brought against the wheel without interference.

To clean objects with a wire wheel, place the object firmly against the wire wheel. Work the object back and forth across the face of the wheel until all traces of rust, paint, or dirt are removed. Avoid excessive pressure against the face of the wire wheel to prevent spreading the steel wires. Keep the point of contact below the center of the wheel to avoid kickback of the workpiece.

## POLISHING, BUFFING, AND LAPPING

Polishing, buffing, and lapping are three closely related methods for finishing metal parts. The three different methods of finishing are listed below.

### Polishing

Polishing is an abrading process in which small amounts of metal are removed to produce a smooth or glossy surface by application of cushion wheels impregnated or coated with abrasives. Polishing may be used for reduction or smoothing of the surface to a common level for high finish where accuracy is not important, or it may be employed for removing relatively large amounts of material from parts of irregular contour. Rough polishing is performed on a dry wheel using abrasives of No. 60 grain (60 grains per linear inch) or coarser. Dry finish polishing is a similar process where No. 70 grain to No. 120 grain abrasives are used. Oiling is the term applied to polishing with abrasive finer than No. 120 grain. In this process, the abrasive is usually greased with tallow or a similar substance.

### Buffing

Buffing is a smoothing operation which is accomplished more by plastic flow of the metal than by abrading. The abrasives are generally finer than those used in polishing and instead of being firmly cemented to the wheel are merely held by a "grease cake" or similar substance. Buffing is used to produce a high luster or color without any particular regard to accuracy of dimension or plane. Cut down buffing produces a rapid smoothing action with fast-cutting abrasives and relatively hard buffing wheels. It is accomplished with high speeds and heavy pressures to allow a combined plastic flow and abrading action to occur. Color buffing is the imparting of a high luster finish on the workpiece by use of soft abrasives and soft buffing wheels.

### Lapping

Lapping, like polishing, is an abrading process in which small amounts of material are removed. Unlike polishing,

however, lapping is intended to produce very smooth, accurate surfaces, and is never used instead of polishing or buffing when clearance is the only consideration. Lapping is accomplished by charging metal forms called laps with flour-fine abrasives and then rubbing the workpiece with the lap. The lap may be of any shape and may be designed to fit into most power machine tools. The only requirements of the lap are that it be of softer material than the material being lapped, and that it be sufficiently porous to accept the imbedded abrasive grain. Common materials for laps are soft cast iron, copper, brass, and lead. Some laps are flat and others are cylindrical to fit on steel arbors for internal lapping of bores. A cutting oil is recommended for most lapping operations.

### Polishing and Buffing Speeds

The proper speed for polishing and buffing is governed by the type of wheel, workpiece material, and finish desired. For polishing and buffing in general where the wheels are in perfect balance and correctly mounted, a speed of approximately 1,750 RPM is used for 6-inch to 8-inch wheels; up to 6-inch wheels use 3,500 RPM. If run at a lower rate of speed, the work tends to tear the polishing material from the wheel too readily, and the work is not as good in quality.

### Polishing Abrasives

The abrasive grains used for polishing must vary in characteristics for the different operations to which they are applied. Abrasive grains for polishing are supplied in bulk form and are not mixed with any vehicle. The abrasives, usually aluminum oxide or silicon carbide, range from coarse to fine (1 to 20 grains per inch).

### Buffing Abrasives

Buffing abrasives are comparatively fine and are often made up in the form of paste, sticks, or cakes; the abrasive being bonded together by means of grease or a similar vehicle. The abrasive sizes for buffing are 280, 320, 400, 500, and 600. Some manufacturers use letters and numbers to designate grain size such as F, 2F, 3F, 4F, and XF (from fine to very fine). Pumice, rottenstone, and rouge are often used as buffing abrasives.

### Lapping Abrasives

Only the finest abrasives are used for lapping. These may be either natural or artificial. Abrasives for lapping range from No. 220 to No. 600 or No. 800 which are very fine flours. Lapping compounds are generally mixed with water or oil so that they can be readily applied to the lap.