TRAINING CIRCULAR
No. 9-524

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 29 October 1996

FUNDAMENTALS OF MACHINE TOOLS

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*This publication supersedes TC 9-524, 19 March 1990.

Preface

The purpose of this training circular is to provide a better understanding of power-driven machine tools. It also supplements technical manuals in the 9-3400-series covering power-driven machine tools.

One of the main objectives is for this publication is to be clear and understandable. Illustrations throughout this publication show the step-by-step process of many machine shop operations. The tables, charts, formulas, weights, and measurements in this publication can be a ready reference for selecting the proper tooling and math formulas for machining different materials.

The proponent of this publication is HQ TRADOC. Send comments and recommendations on DA Form 2028 directly to the Department of the Army, Training Directorate, ATTN: ATCL-AO, 801 Lee Avenue, Fort Lee, Virginia 23801-1713.

Unless this publication states otherwise, masculine nouns and pronouns do not refer exclusively to men.

Chapter 1

INTRODUCTION TO THE MACHINE SHOP

GENERAL INFORMATION

FORMS, RECORDS, AND REPORTS

Accurate records are valuable. Unit officers are responsible for completion of forms, records, and reports. DA Pam 738-750 lists records, reports, and authorized forms that are normally used for inspection and repair. Properly executed forms authorize and record repair or replacement of materiel. The forms, records, and reports document the work required, follow the progress of the work within the shops, and indicate the status of the material upon completion of repairs.

FIELD REPORT OF ACCIDENTS

The reports necessary to comply with the requirements of the Army Safety Program are prescribed in detail in AR 385-40. These reports are required for any accidents involving injury or damage. For a listing of all forms, refer to DA Pam 25-30.

Any deficiencies detected in the equipment covered herein should be immediately reported in accordance with DA Pam 738-750. These reports will be submitted as an Equipment Improvement Recommendation on SF 368.

DEFINITION OF MACHINE TOOLS

Machine tools are power-driven equipment designed to drill, bore, grind, or cut metal or other material.

LISTING OF MACHINE TOOLS

A complete list of machine tools including specialized machine tools currently authorized for issue is in Component List C 3405/70-lL.

SPECIALIZED MACHINE TOOLS

In view of the different design and operating features incorporated in specialized machine tools (cylinder boring machines, brake reliners, valve seat grinders. and so forth) by various manufacturers, no attempt has been made to include information pertinent to them in this manual. For complete information on these tools, see pertinent TM 9-3400-, TM 9-5100-, and TM 9-9000-series technical manuals covering the specific machines.

RISK-MANAGEMENT

To assure a high degree of safety, no machine -tool is to be used unless the risk management process as outlined below is understood and applied by the user and the supervisor:

1. Identify the potential hazard(s) that the machine tool can generate.

2. Assess the probability and severity of the hazard(s) by utilizing the Risk Assessment Matrix in figure 1-1. Risk acceptance decision authority for the risk levels is as follows:

a. Extremely high - CG, TRADOC; DCG, TRADOC; or the Chief of Staff, TRADOC.

b. High - Major subordinate commands, installation commanding generals, and school commandants of general officer rank.

c. Moderate and low - Delegated to the appropriate level in your unit chain of command.

3. Determine the risk control measures that will eliminate the hazard(s) or reduce the risk.

4. Implement the risk control measures before and during operation of the machine tool to eliminate the hazards or reduce their risks.

5. Supervise and evaluate the process. Enforce the established standards and risk control measures. Evaluate the effectiveness of the control measures and adjust/update them as necessary.

			PROBABILITY				
			Frequent	Likely	Occasional	Remote	Unlikely
			A	B	C	D	E
SEVERITY	Catastrophic	I	Extremely High	Extremely High	High	High	Moderate
	Critical	II	Extremely High	High	High	Moderate	Low
	Marginal	III	High	Moderate	Moderate	Low	Low
	Negligible	IV	Moderate	Low	Low	Low	Low

Figure 1-1. Risk assessment matrix.

PROBABILITY

A. **FREQUENT** - Individual soldier/item - Occurs often in the career/equipment service life. All soldiers or item inventory exposed - Continuously experienced during operation/mission.

B. **LIKELY** - Individual soldier/item - Occurs several times in career/equipment service life. - All soldiers or item inventory exposed. - Occurs frequently during operator/mission.

C. **OCCASIONAL** - Individual soldier/item. - Occurs sometimes in career/equipment service life. All soldiers or item inventory exposed. Occurs sporadically, or several times in inventory service or operations/mission.

D. **REMOTE** - Individual soldier/item - Possible to occur in career/equipment service life. All soldiers or item inventory exposed, Remote chance of occurrence - Expected to occur sometime in inventory service life or operation/mission.

E. **UNLIKELY** - Individual soldier/item - Can assume will not occur in career/equipment/service life. All soldiers or item inventory exposed. - Possible, but improbable; occurs only very rarely during operation/mission.

SEVERITY

I. CATASTROPHIC - Death or permanent total disability. System loss. Major property damage.

II CRITICAL - Permanent partial disability. Temporary total disability in excess of 3 months. Major system damage. Significant property damage.

III. MARGINAL - Minor injury. Lost workday accident with compensable injury/illness. Mirror system damage. Minor property damage.

IV. NEGLIGIBLE - First aid or minor supportive medical treatment. Minor system impairment.

RISK LEVELS

EXTREMELY HIGH - Loss of ability to accomplish mission.

HIGH - Significantly degrades mission capabilities in terms of required mission standards.

MODERATE- Degrades mission capabilities in terms of required missions standards.

LOW - Little or no impact on accomplishment of mission.

MACHINE SHOP WORK

SCOPE

Machine shop work is generally understood to include all cold-metal work by which an operator, using either power driven equipment or hand tools, removes a portion of the metal and shapes it to some specified form or size. It does not include sheet metal work and coppersmithing.

LAYING OUT WORK

"Laying out" is a shop term which means to scribe lines, circles, centers, and so forth, upon the surface of any material to serve as a guide in shaping the finished workpiece. This laying out procedure is similar to shop drawing but differs from it in one important respect. The lines on a shop drawing are used for reference purposes only and are not measured or transferred. In layout work, even a slight error in scribing a line or center may result in a corresponding or greater error in the finished workpiece, For that reason, all scribed lines should be exactly located and all scriber, divider, and center points should be exact and sharp.

SCRIBING LINES ON METAL

The shiny surface, found on most metals, makes it difficult to see the layout lines.

Layout dye (Figure 1-2), when applied to the metal surface, makes it easier for the layout lines to be seen. Layout dye is usually blue and offers an excellent contrast between the metal and the layout lines.

Before applying layout dye, ensure that all grease and oil has been cleaned from the work surface. Otherwise the dye will not adhere properly.

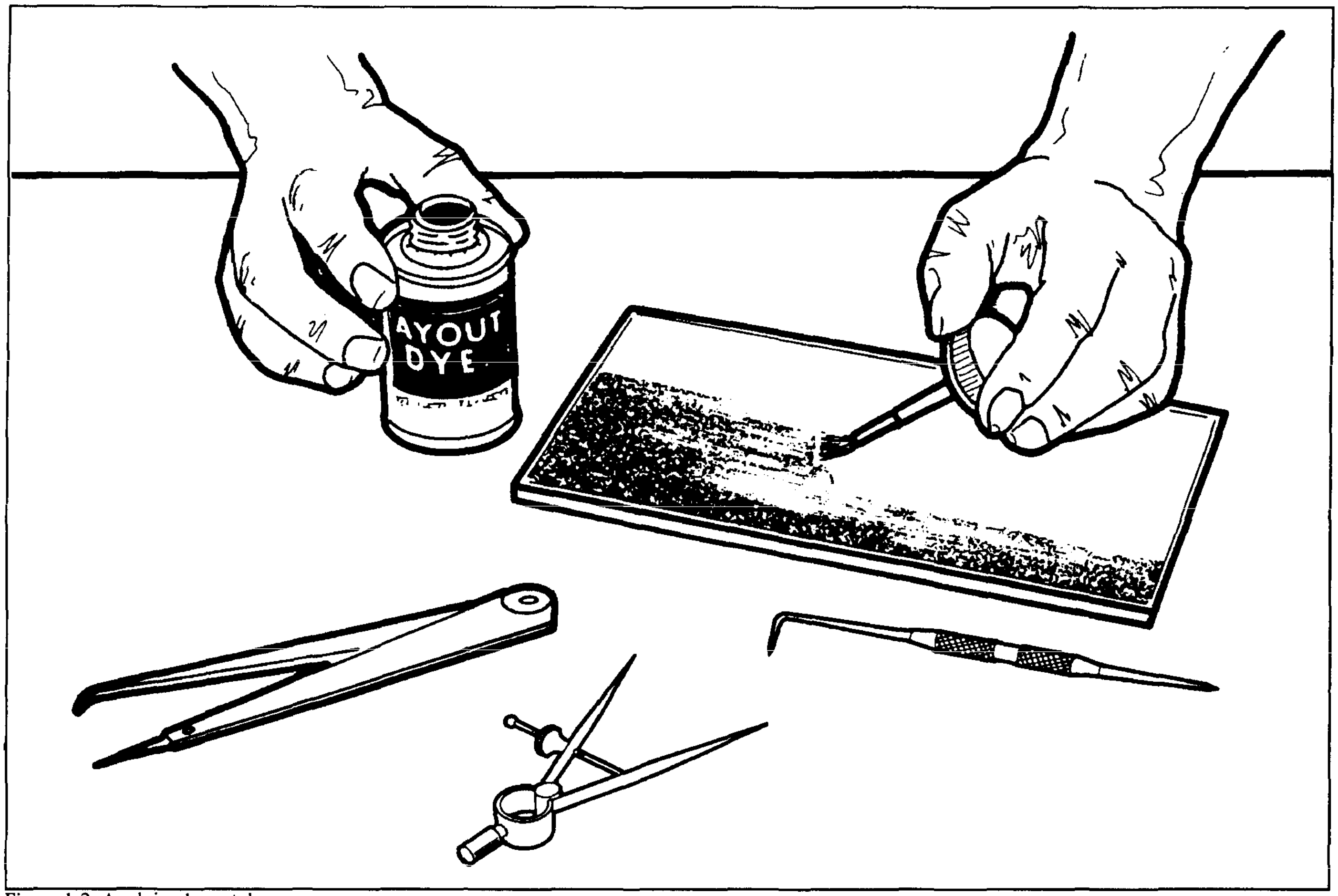


Figure 1-2. Applying layout dye.

COMMON LAYOUT TOOLS

Scriber

To obtain an accurate layout, fine lines must be scribed in the metal. A scriber (Figure 1-3) is the layout tool that is used to produce these lines. The point is made of hardened steel and is kept chain by honing on an oilstone.

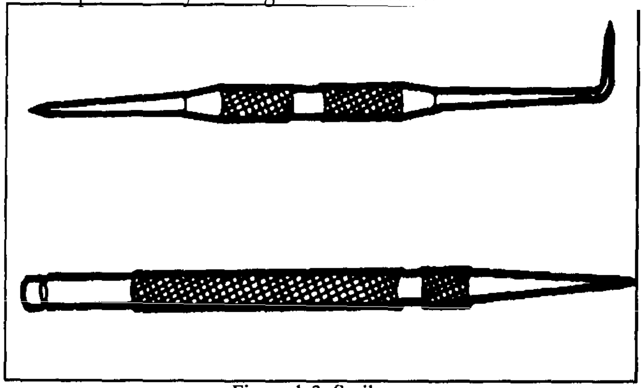


Figure 1-3. Scribers.

Divider

When laying out circles, arcs, and radii, it is best to use the divider (Figure 1-4). The legs of the divider must be of the same length and be kept sharp. The divider cart be used to

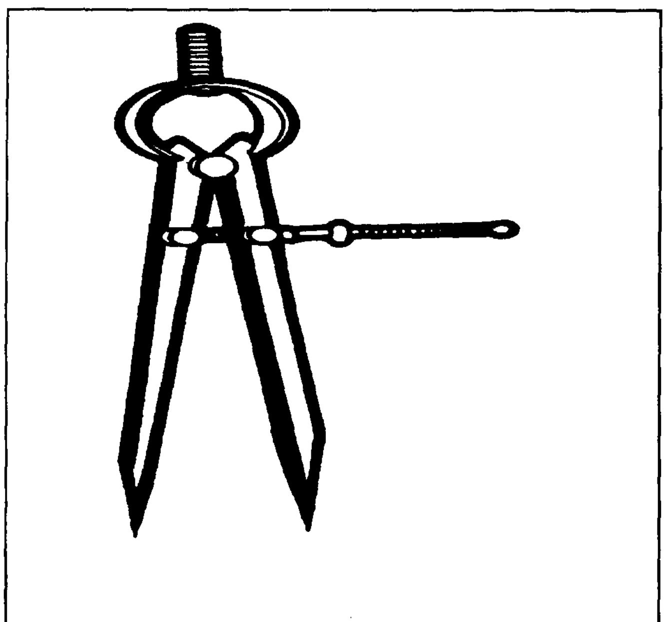


Figure 1-4. Divider.

lay out and measure distances (Figure 1-5). To set the divider to the correct length, place one point on an inch mark of a steel rule and open the divider until the other leg matches the correct measure-merit required (Figure 1-6).

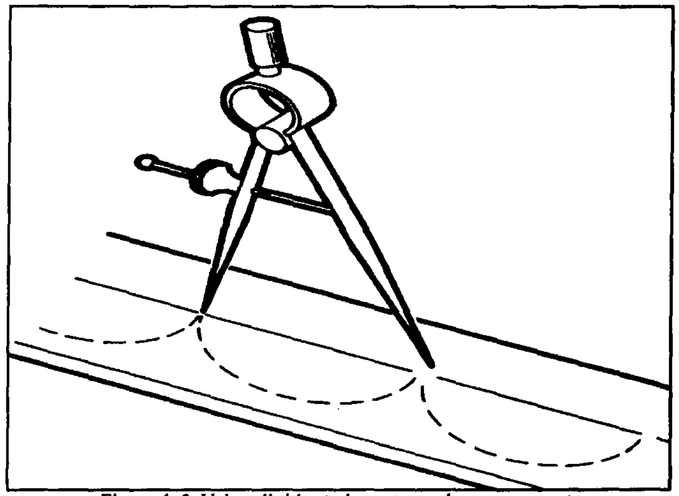


Figure 1-5. Using divider to layout equal measurement.

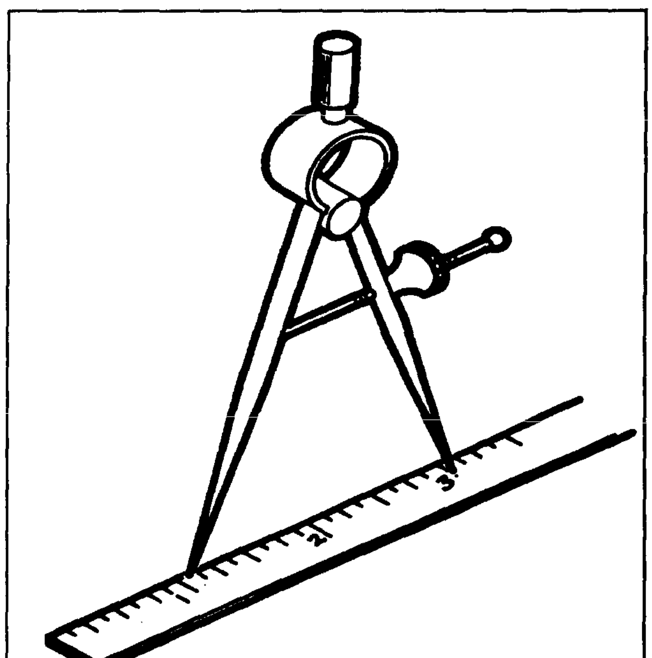


Figure 1-6. Correct method of setting dividers.

Trammel

When scribing circles, arcs, and radii that are too large to be produced with the divider, a trammel should be used (Figure 1-7). The trammel is made of three main parts: the beam, two sliding heads with scriber points, and an adjusting screw that is attached to one of the heads. The trammel can be made to scribe larger distances with the use of extension rods. This layout tool is set in the same manner as the divider.

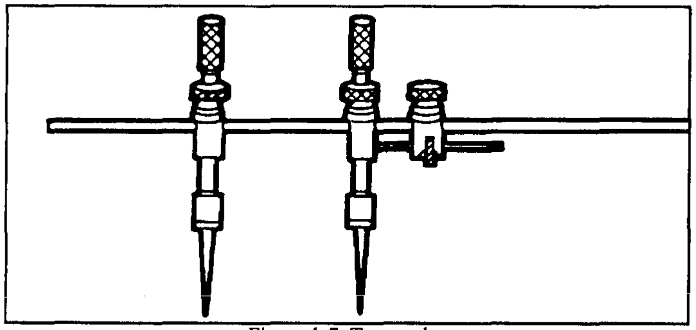


Figure 1-7. Trammel.

Hermaphrodite Caliper

The hermaphrodite caliper (Figure 1-8) is a tool used to lay out lines that are parallel with the edges of the workpiece (Figure 1-9). It can also be used to locate the center of cylindrical shaped workplaces (Figure 1-10).

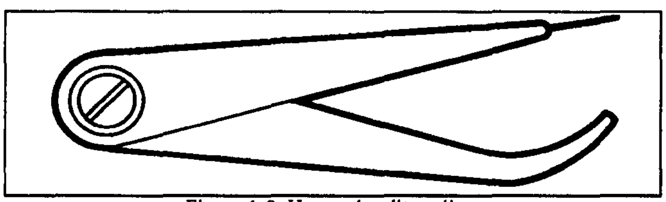


Figure 1-8. Hermaphrodite calipers.

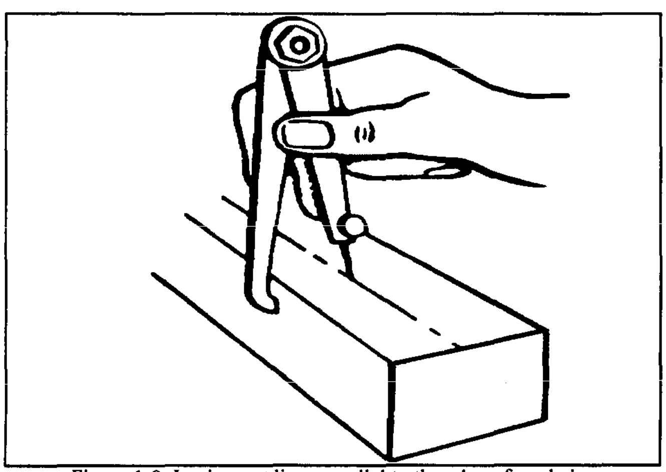


Figure 1-9. Laying out lines parallel to the edge of workpiece.

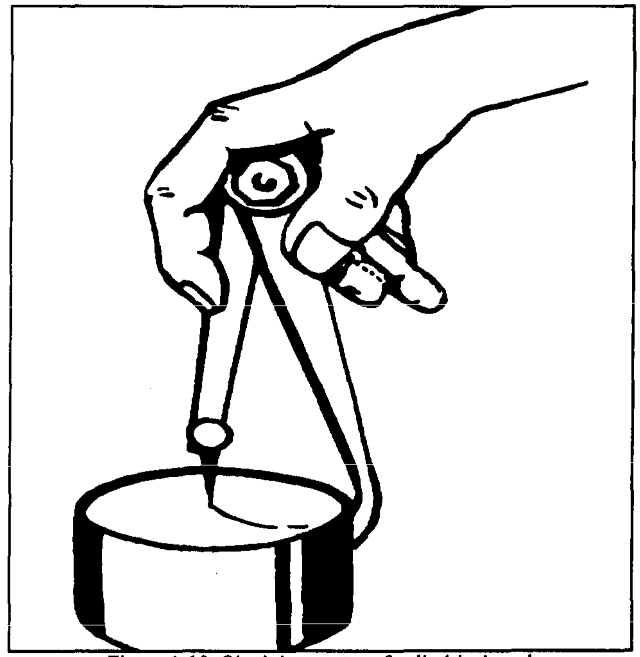


Figure 1-10. Obtaining center of cylindrical work.

Surface Gage

A surface gage (Figure 1-11) is used for many purposes, but is most often used for layout work. The gage can be used to scribe layout lines at any given distance parallel to the work surface (Figure 1-12).

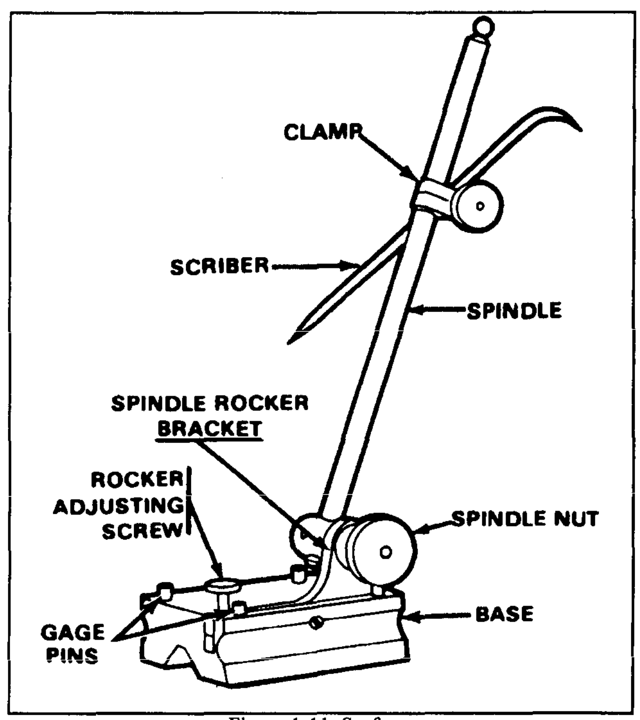


Figure 1-11. Surface gage.

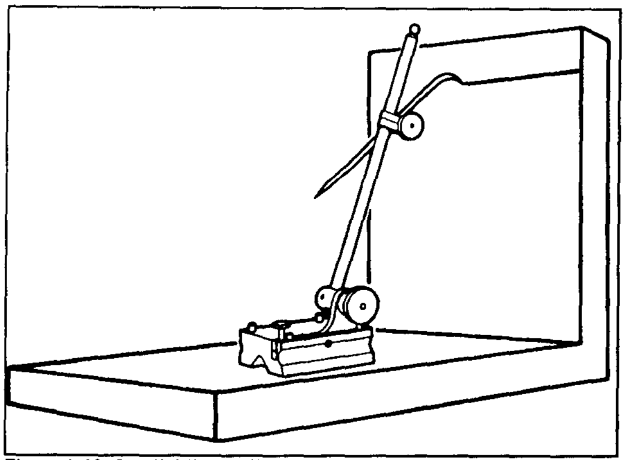


Figure 1-12. Parallel line scribed with surface gage.

The spindle may be adjusted to any position with respect to the base and tightened in place with the spindle nut (Figure 1-11). The rocker adjusting screw provides for finer adjustment of the spindle by pivoting the spindle rocker bracket. The scriber can be positioned at any height and in any desired direction on the spindle by adjusting the scriber. A surface plate and combination square (Figure l-13) are needed to set the surface gage to the correct dimension.

Surface Plate

A surface plate (Figure l-14) provides a true, smooth, plane surface. It is used in conjunction with surface and height gages as a level base on which the gages and the workpiece are placed to obtain accurate measurements. These plates are made of semi-steel or granite and should never be used for any job that would scratch or nick the surface.

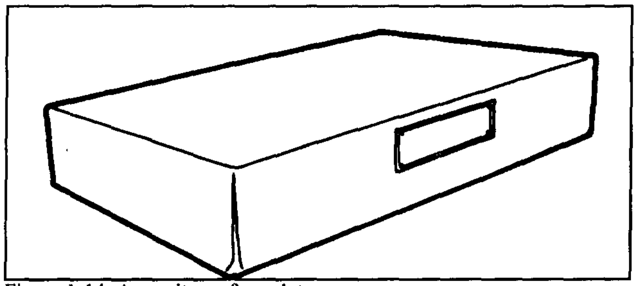


Figure 1-14. A granite surface plate.

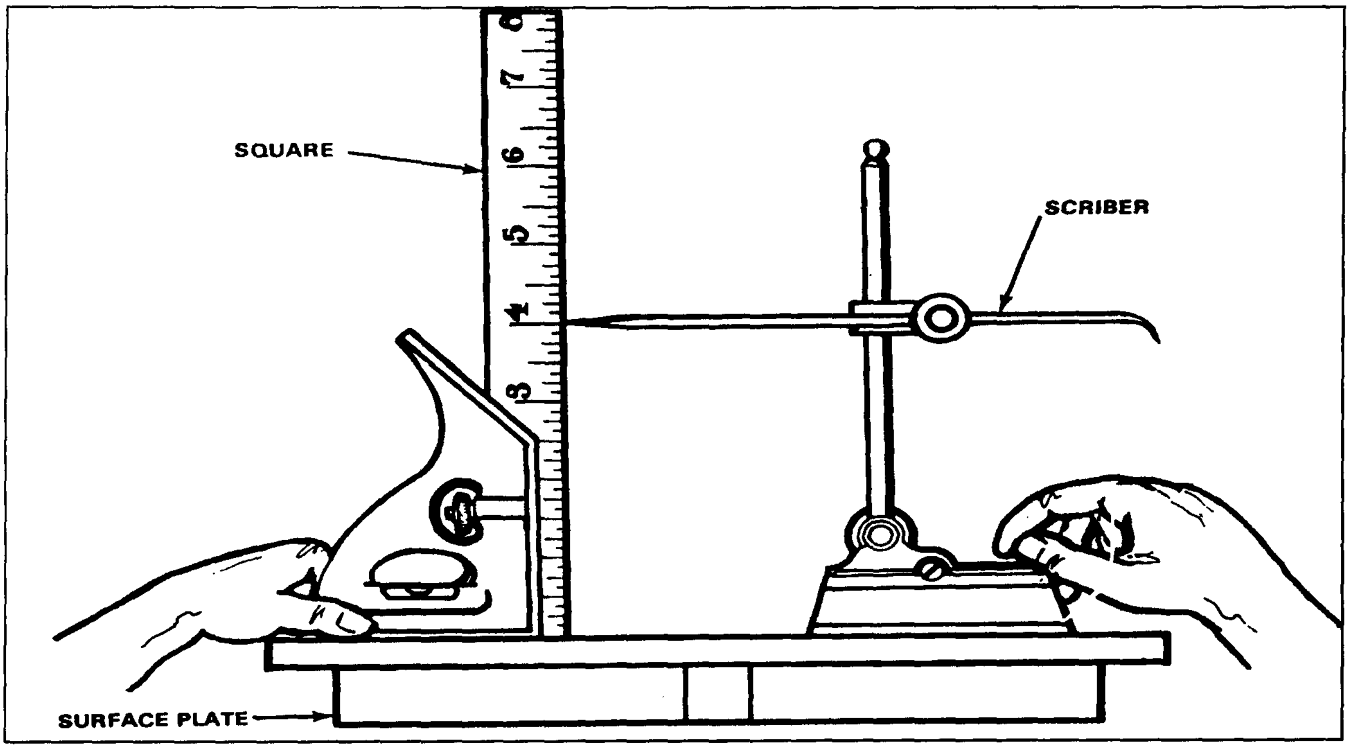


Figure 1-13. Setting surface gage scriber on surface plate 2.

Vernier Height Gage

The vernier height gage (Figure 1-15) is a caliper with a special foot block to adapt it for use on a surface plate. Height gages are available in several sizes: the most common are the 10, 18, and 24 inch gages in English measure and the 25 and 46 cm gages in metric measure. Like the vernier caliper, these height gages are graduated in divisions of 0.025 inch and a vernier scale of 25 units for reading measurements to thousandths of an inch. Always be sure the bottom of the foot block (Figure 1-15) is clean and free from burrs.

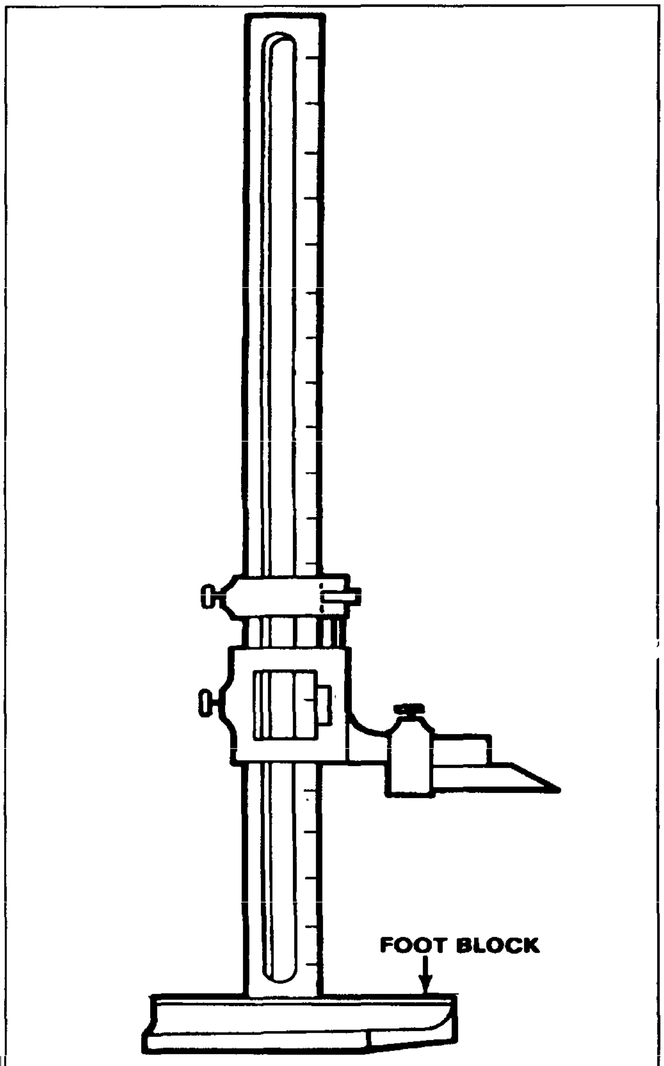


Figure 1-15. Vernier height gage.

Figure 1-16 shows the height gage with a tungsten carbide marker. This marker is used to lay out lines on glass, hardened steel. or other hard materials.

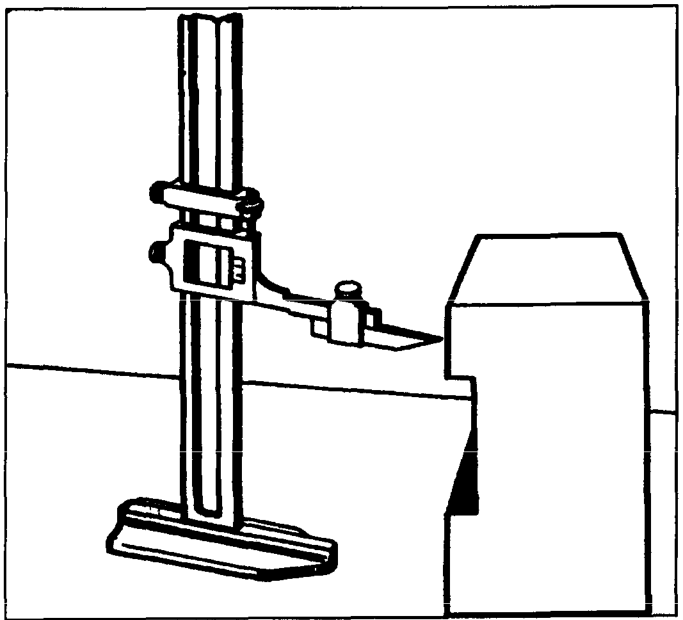


Figure 1-16. Using height gage with carbide marker.

Figure 1-17 illustrates the use of an offset scriber with the height gage. This scriber reaches below the gage base. Do not attempt to adjust the sliding jaw while it is clamped to the upright beam.

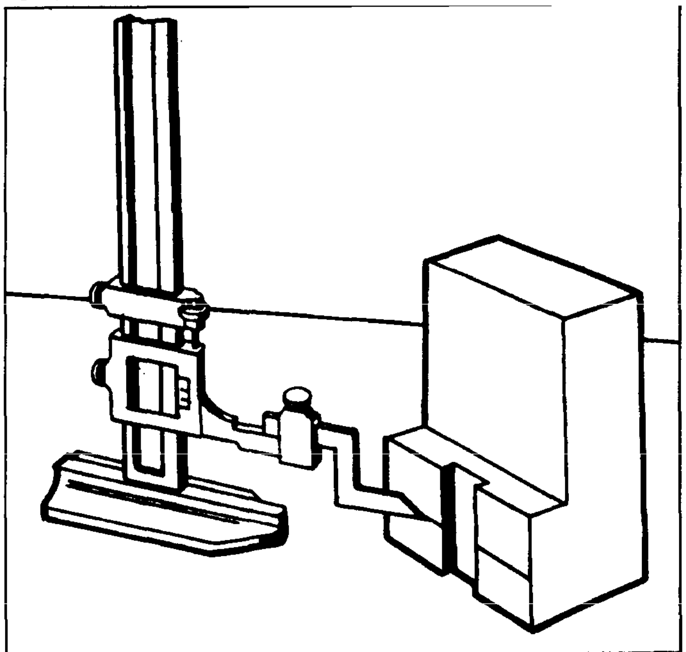


Figure 1-17. Using height gage with offset scriber.

Combination Square Set

The combination square set (Figure 1-18) is used for a number of layout operations. The set consists of a blade (graduated rule), square head, protractor, and center head.

Blade

The blade is designed to allow the different heads to slide along the blade and be clamped at any desired location. The groove in the blade is concave to eliminate dirt buildup and permit a free and easy slide for the heads. By removing all the heads, the blade may be used alone as a rule.

Square Head

The square head is designed with a 45° and 90° edge, which makes it possible to be used as a try square and miter square. By extending the blade below the square, it can be used as a depth rule. The square head can also be used as a level.

Protractor Head

The protractor head is equipped with a revolving turret graduated in degrees from 0 to 180 or to 90 in either direction. It is used to measure or lay out angles to an accuracy of 1°.

Center Head

The center head, when inserted on the blade, is used to locate and lay out the center of cylindrical workplaces.

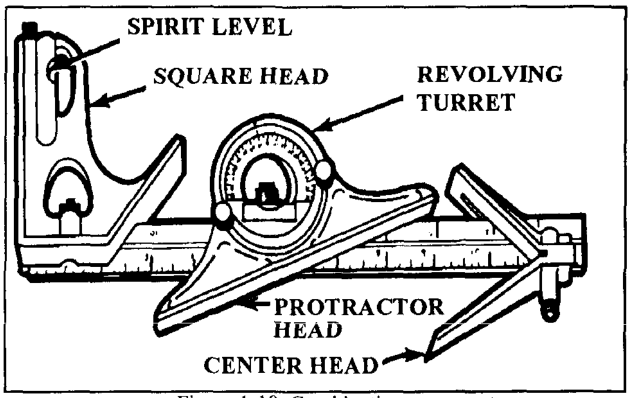


Figure 1-18. Combination square set.

Bevel Protractor

The bevel protractor (Figure 1-19) consists of an adjustable blade with a graduated dial. The blade is usually 12 inches long and 1/16 inch thick. The dial is graduated in degrees through a complete circle of 360°. The most common use for this tool is laying out precision angles. The vernier scale is used for accurate angle adjustments and is accurate to 5 minutes or 1/12°.

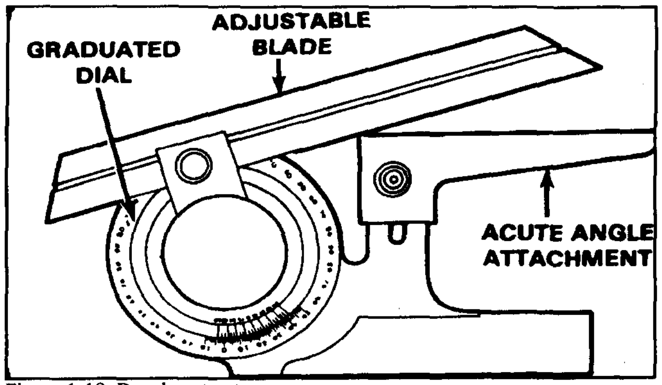


Figure 1-19. Bevel protractor.

STEPS IN MAKING A LAYOUT

Planning before beginning any layout is one of the most important steps. Each job may require different layout tools depending on the accuracy needed; however, there are certain procedures which should be followed in any layout. Figure 1-20 shows a typical layout.

- Study the shop drawing or blueprint carefully before you cut off the stock. Allow enough material to square the ends if required.
- Remove all oil and grease from the work surface and apply layout dye.
- Locate and scribe a reference or base line. All the other measurements should be made from this. If the workpiece already has one true edge, it can be used in place of the reference line.
- Using the base line as a reference line, locate and scribe all center lines for each circle, radius, or arc.
- Mark the points where the center lines intersect using a sharp prick punch.
- Scribe all circles, radii, and arcs using the divider or trammel.
- Using the correct type protractor, locate and scribe all straight and angular lines.
- Scribe all lines for internal openings.
- All layout lines should be clean, sharp, and fine. Reapply layout dye to all messy, wide, or incorrect lines and rescribe.

The layout tools mentioned in this section are only the most commonly used. For more information on the use and care of these tools and other layout and measuring tools, refer to TM 9-243.

JIGS AND FIXTURES

The primary purpose of jigs and fixtures is to align the tool and hold the workpiece properly during machining. A fixture is a device which holds the work while cutting tools are in operation. It differs from a jig in that it has no guides or special arrangements for guiding tools. A jig is also a fixture for locating or holding the work and guiding the cutting tool in operations such as drilling, reaming, counterboring, and countersinking.

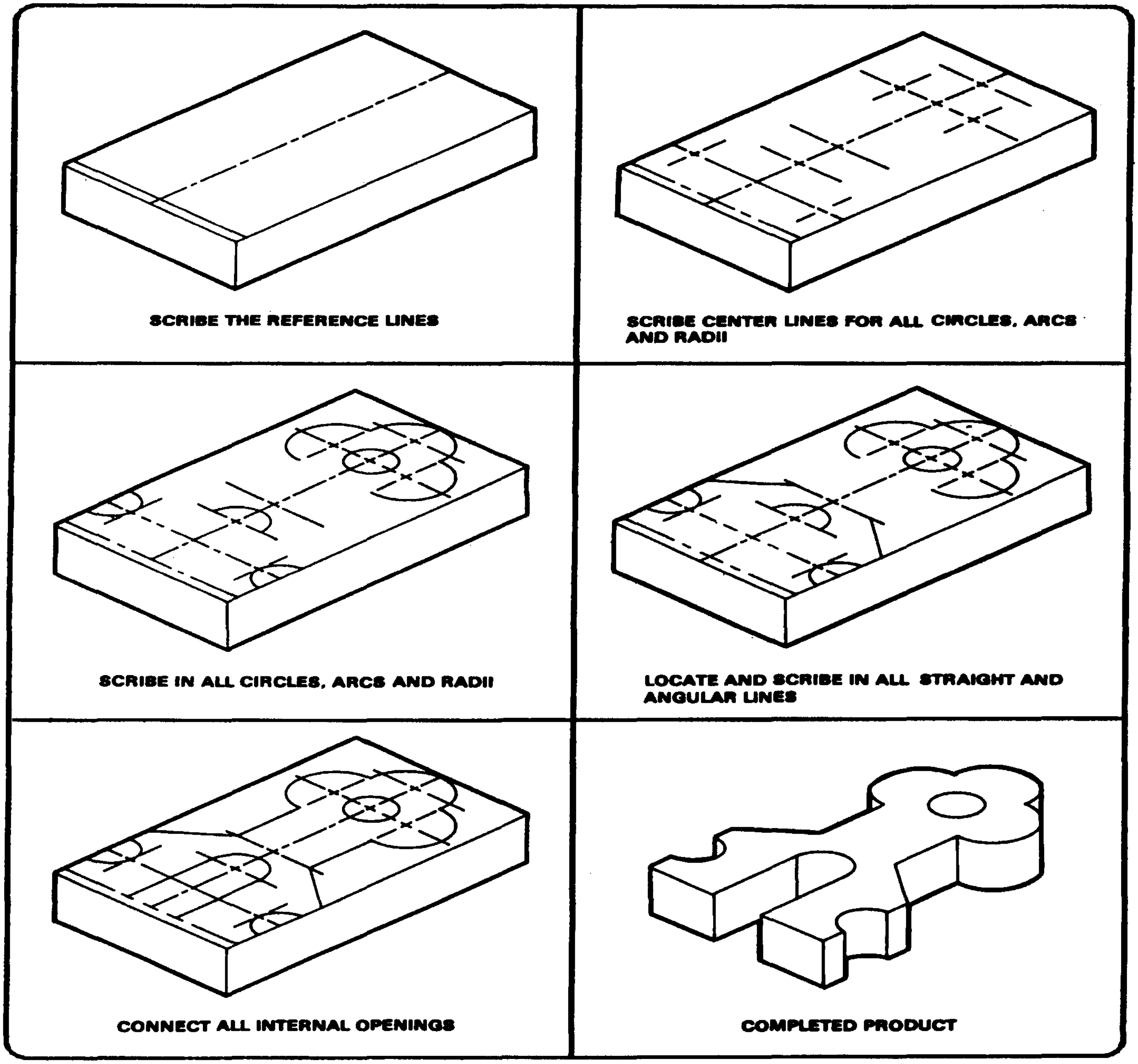


Figure 1-20. Typical Layout.

Jigs and fixtures can greatly reduce the cost of manufacturing large quantities of parts. Their use is also an advantage when the interchangeability and accuracy of the finished products are important. They also can be used in low or limited production jobs if extreme accuracy must be maintained. One of their greatest advantages is that relatively unskilled labor can accomplish the job using these special tools.

MECHANICAL DRAWINGS AND BLUEPRINTS

Mechanical Drawings

A mechanical drawing, made with special instruments and tools, gives a true representation of an object to be made, including its shape, size, description, material to be used, and method of manufacture.

Blueprints

A blueprint is an exact duplicate of a mechanical drawing. These are the most economical and satisfactory working drawings in use. They do not soil easily and are comparatively easy to read. Blueprint paper is a good grade of white paper coated with a chemical solution. making it greenish yellow. A blueprint is made by placing a tracing of a mechanical drawing on a sheet of blueprint paper and exposing it to light. During exposure. the light penetrates where there are no lines or printing on the tracing but does not penetrate where there are lines or printing. The print is then washed in water. which changes the exposed chemical to a dark blue and washes the chemical off where lines and printing prevented exposure. In other words. the process leaves white lines on dark blue background.

Working From Drawings

Detail prints usually show only the individual part or piece that must be produced. They show two or more orthographic (straight-on) views of the object. and in special cases. they may show an isometric projection. without dimension lines, near the upper right corner. An isometric projection shows how the part will look when made. Each drawing or blueprint carries a number. located in the upper left-hand corner and in the title box in the lower right-hand corner of the print. The title box also shows the part name, the scale used, the pattern number. the material required. the assembly or subassembly print number to which the part belongs. the job order number, the quantity and date of the order. and the names or initials of the persons who drew. checked. and approved the drawings (Figure 1-20). Accurate and satisfactory fabrication of a part described on a drawing depends upon the following:

- Correctly reading the drawing and closely observing all data on the drawing.
- Selecting the correct tools and instruments for laying out the job.
- Use the baseline or reference line method of locating the dimensional points during layout. thereby avoiding cumulative errors.
- Strictly observing tolerances and allowances.
- Accurate gaging and measuring of work throughout the fabricating process.
- Giving due consideration when measuring for expansion of the workpiece by heat generated by the cutting operations. This is especially important when checking dimensions during operations, if work is being machined to close tolerances.

Limits of Accuracy

Work must be performed within the limits of accuracy specified on the drawing. A clear understanding of tolerance and allowance will help you avoid making small, but potentially large errors. These terms may seem closely related but each has a very precise meaning and application. The paragraphs below point out the meanings of these terms and the importance of observing the distinctions between them.

Tolerance

Working to the absolute or exact basic dimension is impractical and unnecessary in most instances: therefore, the designer calculates. in addition to the basic dimensions, an allowable variation. The amount of variation. or limit of error permissible is indicated on the drawing as plus or minus (+) a given amount. such as + 0.005 or + 1/64. The difference between the allowable minimum and the allowable maximum dimension is tolerance. When tolerances are not actually specified on a drawing, fairly concrete assumptions can be made concerning the accuracy expected. by using the following principles, For dimensions which end in a fraction of an inch. such as 1/8, 1/16, 1/32, 1/64. consider the expected accuracy to be to the nearest 1/64 inch. When the dimension is given in decimal form the following applies: If a dimension is given as 2.000 inches, the accuracy expected is +0.005 inch: or if the dimension is given as 2.00 inches, the accuracy expected is +0,010 inch. The +0.005 is called in shop terms, "plus or minus five thousandths of an inch.” The + 0.010 is called “plus or minus ten thousandths of an inch.”

Allowance

Allowance is an intentional difference in dimensions of mating parts to provide the desired fit. A clearance allowance permits movement between mating parts when assembled. For example, when a hole with a 0.250-inch diameter is fitted with a shaft that has a 0.245-inch diameter, the clearance allowance is 0.005 inch. An interference allowance is the opposite of a clearance allowance. The difference in dimensions in this case provides a tight fit. Force is required when assembling parts which have an interference allowance. If a shaft with a 0.251-inch diameter is fitted in the hole identified in the preceding example, the difference between the dimensions will give an interference allowance of 0.001 inch. As the shaft is larger than the hole, force is necessary to assemble the parts.

Precautions

Be sure you have the correct print for the part to be made or repaired. You want the print which has not only the correct title, but also the correct assembly number. Never take a measurement with a rule directly from the print because the tracing from which the print was made may not have been copied from the original drawing perfectly and may contain scaling errors. Also, paper stretches and shrinks with changes in atmospheric conditions. Dimensions must be taken only from the figures shown on the dimension lines. Be very careful in handling all blueprints and working drawings. When they are not in use, place them on a shelf, in a cabinet, or in a drawer. Return them to the blueprint file as soon as the job is done. Blueprints and working drawings are always valuable and often irreplaceable. Make it a point never to mutilate, destroy, or lose a blueprint.

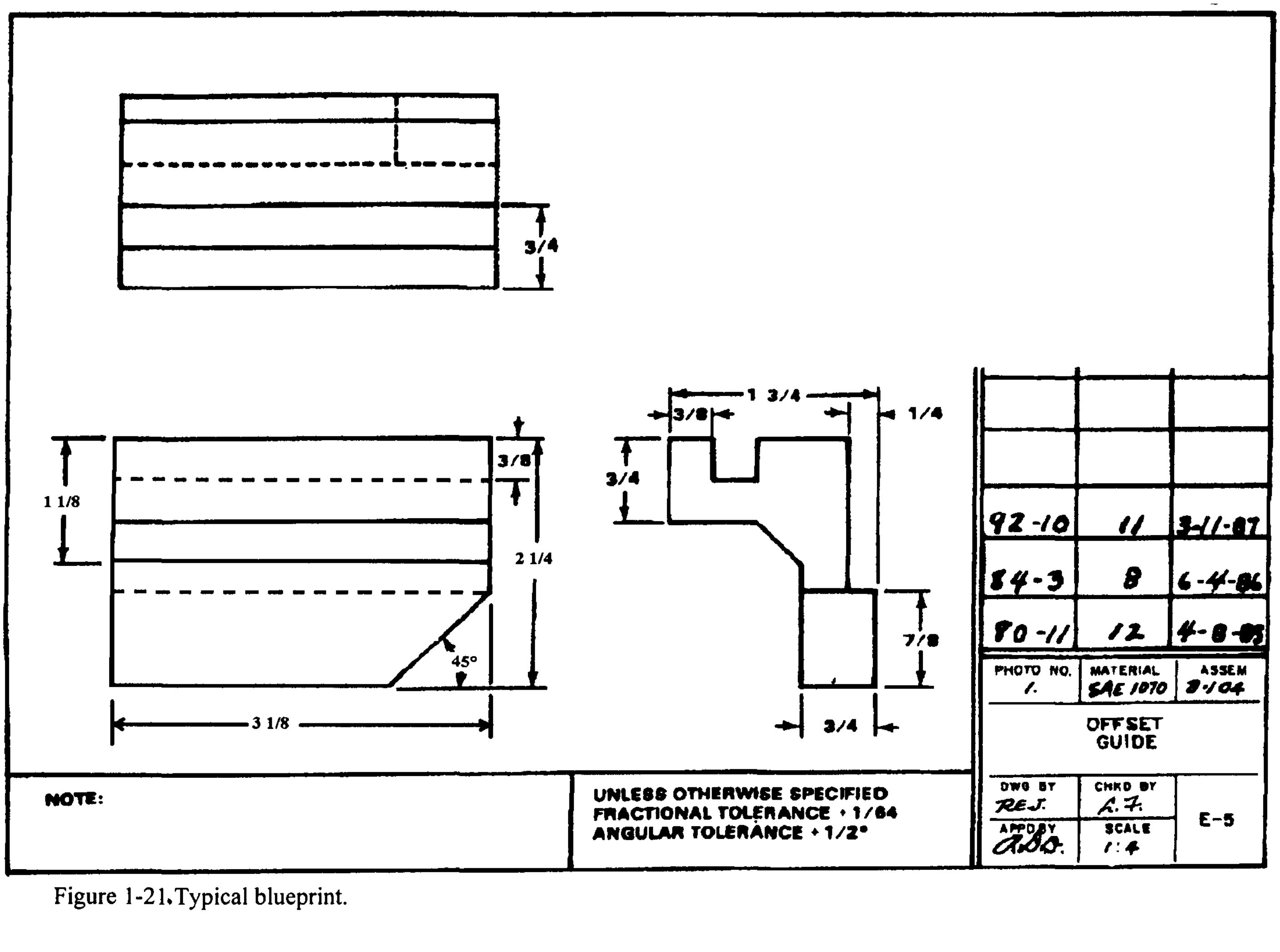


Figure 1-21. Typical blueprint.

GENERAL SHOP SAFETY

All tools are dangerous if used improperly or carelessly. Working safely is the first thing the user or operator should learn because the safe way is the correct way. A person learning to operate machine tools must first learn the safety regulations and precautions for each tool or machine. Most accidents are caused by not following prescribed procedures. Develop safe work habits rather than suffer the consequences of an accident.

Most of the safety practices mentioned in this section are general in nature. Safety precautions for specific tools and machines are described in detail in the chapters along with the description of the equipment. Study these carefully and be on the alert to apply them.

EYE PROTECTION

Using eye protection in the machine shop is the most important safety rule of all. Metal chips and shavings can fly at great speeds and distances and cause serious eye injury. Safety glasses must be worn when working with handcutting tools, since most handcutting tools are made of hardened steel and can break or shatter when used improperly.

There are many different types of safety glasses available in the supply system; however, the ones that offer the best protection are the safety glasses with side shields. Safety goggles should be worn over prescription glasses. For specific information about eye protection, contact the Occupational Health Clinic or refer to TB MED 586.

HAZARDOUS NOISE PROTECTION

Noise hazards are very common in the machine shop. High intensity noise can cause permanent loss of hearing. Although noise hazards cannot always be eliminated, hearing loss is avoidable with ear muffs, ear plugs, or both. These are available through the local supply system or from the Occupational Health Clinic. Ear plugs must be properly fitted by qualified personnel. For specific information on hearing protection, refer to TB MED 501.

FOOT PROTECTION

The floor in a machine shop is often covered with razor-sharp metal chips, and heavy stock may be dropped on the feet. Therefore, safety shoes or a solid leather shoe must be worn at all times. Safety shoes are available in the supply system. These have a steel plate located over the toe and are designed to resist impact. Some safety shoes also have an instep guard.

GRINDING DUST AND HAZARDOUS FUMES

Grinding dust from abrasive wheels is made up of extremely fine particles of the metal and the wheel. Some grinding machines are equipped with a vacuum dust collector. When operating a grinder without a vacuum, wear an approved respirator to avoid inhaling the dust. Whenever possible, use coolant when grinding. This will aid in dust control. Grinding dust can be very dangerous to your health, especially beryllium or parts used in nuclear systems. These materials require careful control of grinding dust.

Metals such as zinc give off toxic fumes when heated above their boiling point. Inhaling these fumes may cause temporary sickness, or death. The fumes produced from lead and mercury are very harmful, as their effect is cumulative in the body and can cause irreversible damage. When unsure of the materials being machined, it is advisable to wear a respirator. For more specific information on respirator safety, refer to TB MED 502.

PROPER LIFTING PROCEDURES

Using improper lifting procedures may result in a permanent back injury. Back injury can be avoided if the correct lifting procedures are followed. When lifting heavy or large objects, get some assistance or use a hoist or forklift.

Objects within your ability can be lifted safely as long as the following procedures are followed:

- Keep your back straight.
- Squat down, bending at the knees.
- Use the leg muscles to do the work and lift slowly. Do not bend over the load as this will put excessive strain on your spine.
- Carry the object where it is comfortable, and pay close attention to where you are walking and objects around you.
- When placing the object back on the floor, use the same procedures as when it was lifted.

ELECTRICAL SAFETY

Exposure to electrical hazard will be minimal unless the operator becomes involved with machine repair. The machine operator is mostly concerned with the on and off switch on the machine tool. However, if adjustments or repairs must be made, the power source should be disconnected. If the machine tool is wired permanently, the circuit breaker should be switched off and tagged with an appropriate warning statement. Most often the power source will not be disconnected for routine adjustment such as changing machine speeds. However, if a speed change involves a belt change, make sure that no other person is likely to turn on the machine while the operator's hands are in contact with belts and pulleys.

SAFETY RULES FOR MACHINE TOOLS

Since different cutting tools and machining procedures are used on various machine tools, the safety precautions for each may vary. The following are general safety rules for any machine tool:

- Gears, pulleys, belts, couplings, ends of shafts having keyways, and other revolving or reciprocating parts should be guarded to a height of 6 feet above the floor. The guards should be removed only for repairing or adjusting the machine and must be replaced before operating it.
- Safety setscrews should be used in collars and on all revolving or reciprocating members of the machine tool or its equipment.
- Do not operate any machine tool without proper lighting.
- Never attempt to operate any machine tool until you fully understand how it works and know how to stop it quickly.
- Never wear loose or torn clothing and secure long hair, since these items can become caught in revolving machine parts. Ties should be removed and shirt sleeves should be rolled up above the elbow.
- Gloves should never be worn when operating machinery except when absolutely necessary.
- Always stop the machine before cleaning it or taking measurements of the workpiece.
- Do not lubricate a machine while it is in motion. Injury to the operator and damage to the machine may result from this practice.
- Never remove metal chips, turnings, or shavings with your hands; they may cause a serious cut. If the shavings are long, stop the machine and break them with pliers or a bent rod, and then brush chips off the machine. Remove cast-iron chips, which break into small pieces, with a brush. Never wipe away chips when the machine is operating.
- Always wear safety glasses or goggles while operating machine tools. Also, wear respiratory protection if operation creates hazardous dust. All persons in the area where power tools are being operated should also wear safety eye protection and respirators as needed.
- Know where tire extinguishers are located in the shop area and how to use them.
- Never wear jewelry while working around machine tools. Rings, watches, or bracelets maybe caught in a revolving part which could result in the hand being pulled into the machine.
- Avoid horseplay. Tools are very sharp and machines are made of hard steel. An accidental slip or fall may cause a serious injury.
- Never use compressed air without a safety nozzle to clean machines or clothing. It will blow sharp, dangerous metal chips a long distance.
- Keep the floor around machines free of tools, stock, oil, grease, and metal chips. Tripping over metal on the floor, especially round bars, can cause dangerous falls. Wipe up all oil, grease, and cutting fluid spills on the floor as soon as possible to prevent a fall. Metal chips are very sharp and can easily become embedded in the soles of shoes, making them very slippery, especially when walking on a concrete floor.
- Never place tools or other materials on the machine table. Cluttering up a machine with tools or materials creates unsafe working conditions. Use a bench or table near the machine for this purpose.
- Always use a rag when handling sharp cutters such as milling cutters and end mills.

- Do not expose power tools to rain or use in damp or wet locations.
- Always secure the workpiece. Use clamps or a vise. It is safer than using your hands, and it frees both hands to operate the tool
- Do not abuse electrical cords. Never carry a tool by its cord or yank it to disconnect it from a receptacle. Keep electrical cords away from heat, oil, and sharp edges. Have damaged or worn power cords and strain relievers repaired or replaced immediately.
- Remove adjusting keys and wrenches. Form a habit of checking to see that keys and wrenches are removed from tools before turning them on.
- Do not operate any machine tool while under the influence of drugs, alcohol, or any medication that could cause drowsiness.

SAFETY COLOR CODE MARKINGS AND SIGNS

USE OF PAINT

All maintenance shops and work areas should be marked with the correct colors to identify hazards, exits, safe walkways, and first-aid stations. It is acceptable to use material other than paint, such as decals and tapes, in the appropriate, similar colors. Listed below are the main colors authorized for use in maintenance shops.

Red color markings should be used to identify the following equipment or locations:

- Fire alarm boxes (pull boxes).
- Fire blanket boxes.
- Fire extinguishing containers.
- Fire extinguishers, unless painting is unnecessary. For large areas and when the extinguisher is not readily visible to the area occupants, use red on the housing wall or support above the extinguisher to show its location.
- Fire hose locations.
- Fire pumps.
- Fire sirens.
- Sprinkler piping.
- Fire buckets.
- Fire reporting telephone stations.
- Store all idle tools in a safe, dry place.
- Provide visitors to the work area required personnel protection equipment.
- An exception may be made to comply with local laws or when current facilities provide green exit signs.
- Emergency stop buttons for electrical machinery.
- Emergency stop bars on hazardous machines.
- Yellow color markings should be used to identify the following equipment or locations:
- Industrial areas where particular caution is needed, such as handrails, guardrails, bottom edge of overhead doors, or top and bottom treads of stairways.
- Fire hydrant barrels.
- Caution signs.
- Piping systems containing flammable material.
- Waste containers for highly combustible material.
- A hazardous area or a safe aisle within a hazardous area.

- Lower pulley blocks and cranes.
- Coverings and guards for guy wires.
- Pillars, posts, or columns that are physical or shop hazards.
- Fixtures suspended from ceilings or walls that extend into normal operating areas.
- Corner markings for storage piles.
- Exposed and unguarded edges of platforms, pits, and wells.

Green color markings normally on a white color background should be used for the following equipment or locations:

- First-aid equipment.
- First-aid dispensaries.
- Stretchers.
- Safety starting buttons on machinery.
- Safety instruction signs.

Black and white are the basic colors for designating housekeeping and interior traffic markings. The following are examples of where solid white, solid black, single-color striping, alternate stripes of black and white, or black and white squares will be used.

- Locations and width of aisles in nonhazardous areas.
- Dead ends of aisles or passageways.
- Directional signs.
- Locations of refuse cans.
- White corners of rooms or passageways.
- Clear floor area around first-aid, fire-fighting, and their emergency equipment.

Blue color markings are used on the outside of switch boxes electrical controls that are the starting point or power source for hazardous electrical machinery or equipment.

Orange markings are used to designate dangerous parts of machines or energized equipment, including electrical conduits, which may cut, crush, shock, or injure.

CATEGORIES OF SIGNS

Signs are placed in categories according to their purpose. Use the examples in the following paragraphs as guides when choosing the correct sign design to display a message. In overseas commands, the use of International Standard Safety Signs is encouraged and authorized.

WORDING OF SIGNS

Ensure that the wording of any sign-

- Is concise and easy to read.
- Contains enough information to be easily understood.
- Is designed for the message to be carried in a picture when appropriate.
- Is a positive rather than a negative statement when appropriate.
- Is bilingual with the second language common to the local personnel when appropriate.

SIGN INSPECTION AND MAINTENANCE

Signs should be inspected regularly and maintained in good condition. They should be kept clean, well illuminated, and legible. Replace or repair damaged or broken signs. All signs will be designed with rounded or blunt corners and with no sharp projections. Put the ends or heads of bolts or other fastening devices where they will not cause a hazard.

SELECTION OF SIGN SIZE

When choosing a sign, consider dimensions that will permit economical use of standard size material. Base the size of the sign on the following:

- Location at which the sign will be placed.
- Character of the hazard involved.
- Purpose of the sign.
- Distance from which the sign should be legible.

REQUIRED SIGN COLORS

All signs require a predominant color based on the sign's purpose. Below are the five types of signs and their predominant color.

- Danger signs: RED.
- Caution signs: YELLOW.
- Safety instruction signs: GREEN.
- Directional signs: BLACK.
- Informational signs: A variety of colors may be used, except for red, yellow, or magenta (purple).

DANGER SIGNS

Danger signs should only be used when immediate hazard exists. There will be no variations in the type or design of signs posted to warn of specific danger. All personnel will be instructed that danger signs indicate immediate danger and that special precautions are necessary.

CAUTION SIGNS

Caution signs should be used only to warn against potential hazards or to caution against unsafe practices. All personnel will be instructed that a caution sign indicates a possible hazard against which proper precautions will be taken.

DIRECTIONAL SIGNS

Directional signs should be used in sufficient numbers to indicate the way to stairways, fire escapes, exits, and other locations.

Many other safety media are available for use in military maintenance shops.

Chapter 2

PROPERTIES, IDENTIFICATION, AND HEAT TREATMENT OF METALS

GENERAL

PURPOSE

This chapter contains basic information pertaining to properties and identification of metal and heat-treating procedures used for metals. For more specific information on metal and heat-treating techniques, refer to TM 43-0106.

METAL CLASSIFICATION

All metals may be classified as ferrous or nonferrous. A ferrous metal has iron as its main element. A metal is still considered ferrous even if it contains less than 50 percent iron, as long as it contains more iron than any other one metal. A metal is nonferrous if it contains less iron than any other metal.

Ferrous

Ferrous metals include cast iron, steel, and the various steel alloys, The only difference between iron and steel is the carbon content. Cast iron contains more than 2-percent carbon, while steel contains less than 2 percent. An alloy is a substance composed of two or more elements. Therefore, all steels are an alloy of iron and carbon, but the term "alloy steel" normally refers to a steel that also contains one or more other elements. For example, if the main alloying element is tungsten, the steel is a "tungsten steel" or "tungsten alloy." If there is no alloying material, it is a "carbon steel."

Nonferrous

Nonferrous metals include a great many metals that are used mainly for metal plating or as alloying elements, such as tin, zinc, silver, and gold. However, this chapter will focus only on the metals used in the manufacture of parts, such as aluminum, magnesium, titanium, nickel, copper, and tin alloys.

PROPERTIES OF METALS

GENERAL

The internal reactions of a metal to external forces are known as mechanical properties. The mechanical properties are directly related to each other. A change in one property usually causes a change in one or more additional properties. For example, if the hardness of a metal is increased, the brittleness usually increases and the toughness usually decreases. Following is a brief explanation of the mechanical properties and how they relate to each other.

TENSILE STRENGTH

Tensile strength is the ability of a metal to resist being pulled apart by opposing forces acting in a straight line (Figure 2-1). It is expressed as the number of pounds of force required to pull apart a bar of the material 1 inch wide and 1 inch thick.

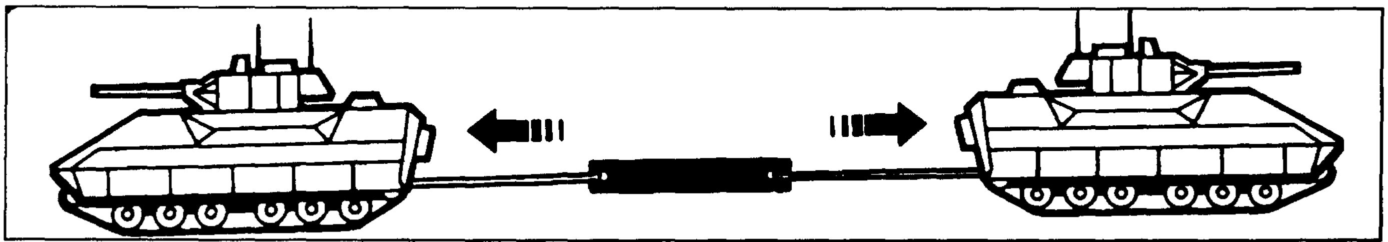


Figure 2-1. Tensile strength

SHEAR STRENGTH

Shear strength is the ability of a metal to resist being fractured by opposing forces not acting in a straight line (Figure 2-2). Shear strength can be controlled by varying the hardness of the metal.

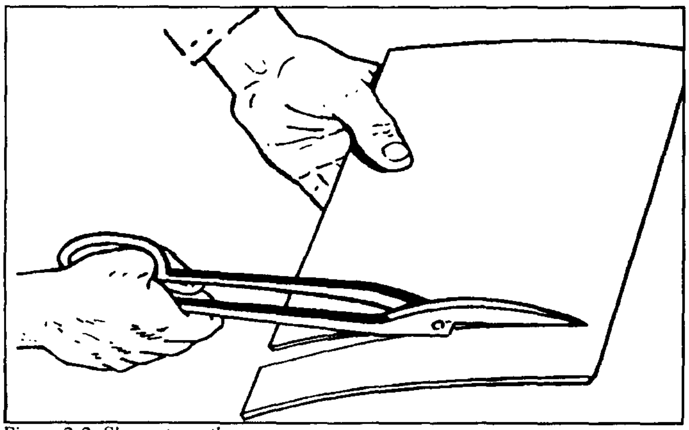


Figure 2-2. Shear strength.

COMPRESSIVE STRENGTH

Compressive strength is the ability of a metal to withstand pressures acting on a given plane (Figure 2-3).

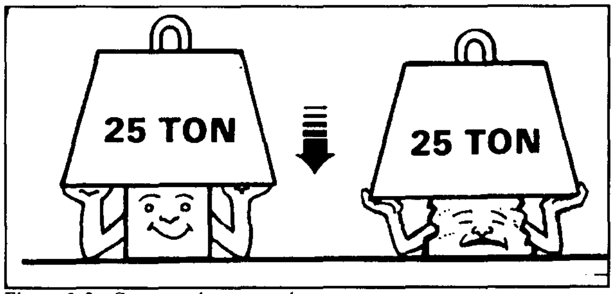


Figure 2-3. Compressive strength.

ELASTICITY

Elasticity is the ability of metal to return to its original size and shape after being stretched or pulled out of shape (Figure 2-4).

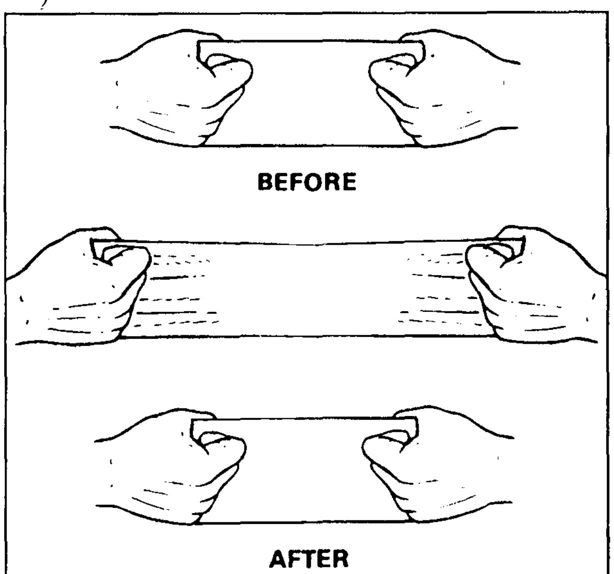


Figure 2-4. Elasticity.

DUCTILITY

Ductility is the ability of a metal to be drawn or stretched permanently without rupture or fracture (Figure 2-5). Metals that lack ductility will crack or break before bending.

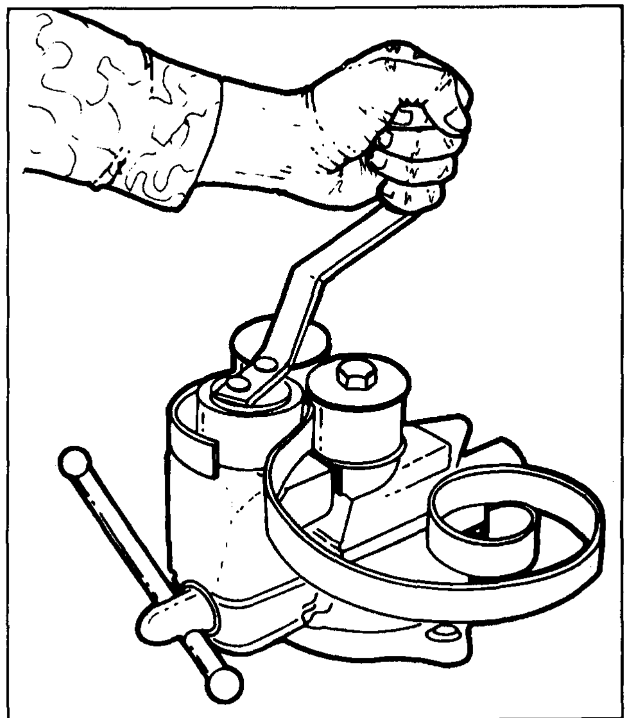


Figure 2-5. Ductility.

MALLEABILITY

Malleability is the ability of a metal to be hammered, rolled, or pressed into various shapes without rupture or fracture (Figure 2-6).

Figure 2-6. Malleability.

TOUGHNESS

Toughness is the ability of a metal to resist fracture plus the ability to resist failure after the damage has begun. A tough metal can withstand considerable stress, slowly or suddenly applied, and will deform before failure.

HARDNESS

Hardness is the ability of a metal to resist penetration and wear by another metal or material. It takes a combination of hardness and toughness to withstand heavy pounding. The hardness of a metal limits the ease with which it can be machined, since toughness decreases as hardness increases. The hardness of a metal can usually be controlled by heat treatment.

MACHINABILITY AND WELDABILITY

Machinability and weldability are the ease or difficulty with which a material can be machined or welded.

CORROSION RESISTANCE

Corrosion resistance is the resistance to eating or wearing away by air, moisture, or other agents.

HEAT AND ELECTRICAL CONDUCTIVITY

Heat and electrical conductivity is the ease with which a metal conducts or transfers heat or electricity.

BRITTLENESS

Brittleness is the tendency of a material to fracture or break with little or no deformation, bending, or twisting. Brittleness is usually not a desirable mechanical property. Normally, the harder the metal, the more brittle it is.

IDENTIFICATION OF METALS

GENERAL

Part of the metalworker's skill lies in the ability to identify various metal products brought to the shop. The metalworker must be able to identify the metal so the proper work methods can be applied. For Army equipment, drawings should be available. They must be examined in order to determine the metal to be used and its heat treatment (if required). If no drawing is available, knowledge of what the parts are going to do will serve as a guide to the type of metal to use.

TESTING OF METALS

Simple tests can be made in the shop to identify metals. Since the ability to judge metals can be developed only through personal experience, practice these tests with known metals until familiar with the reactions of each metal to each type of test.

Appearance Test

This test includes such things as the color and appearance of machined as well as unmachined surfaces.

Fracture Test

Some metals can be quickly identified by looking at the surface of the broken part or by studying the chips produced with a hammer and chisel.

Spark Test

This is a simple identification test used to observe the color, spacing, and quantity of sparks produced by grinding. It is a fast and convenient method of sorting mixed steels with known spark characteristics. This test is best conducted by holding the steel stationary and touching a high-speed portable grinder to the steel with sufficient pressure to throw a spark stream about 12 inches long. The characteristics of sparks generated by a spark grinding test are shown in Figure 2-7. These spark patterns provide general information about the type of steel, cast iron, or alloy steel. In all cases, it is best to use standard samples of metal when comparing their sparks with that of the test sample.

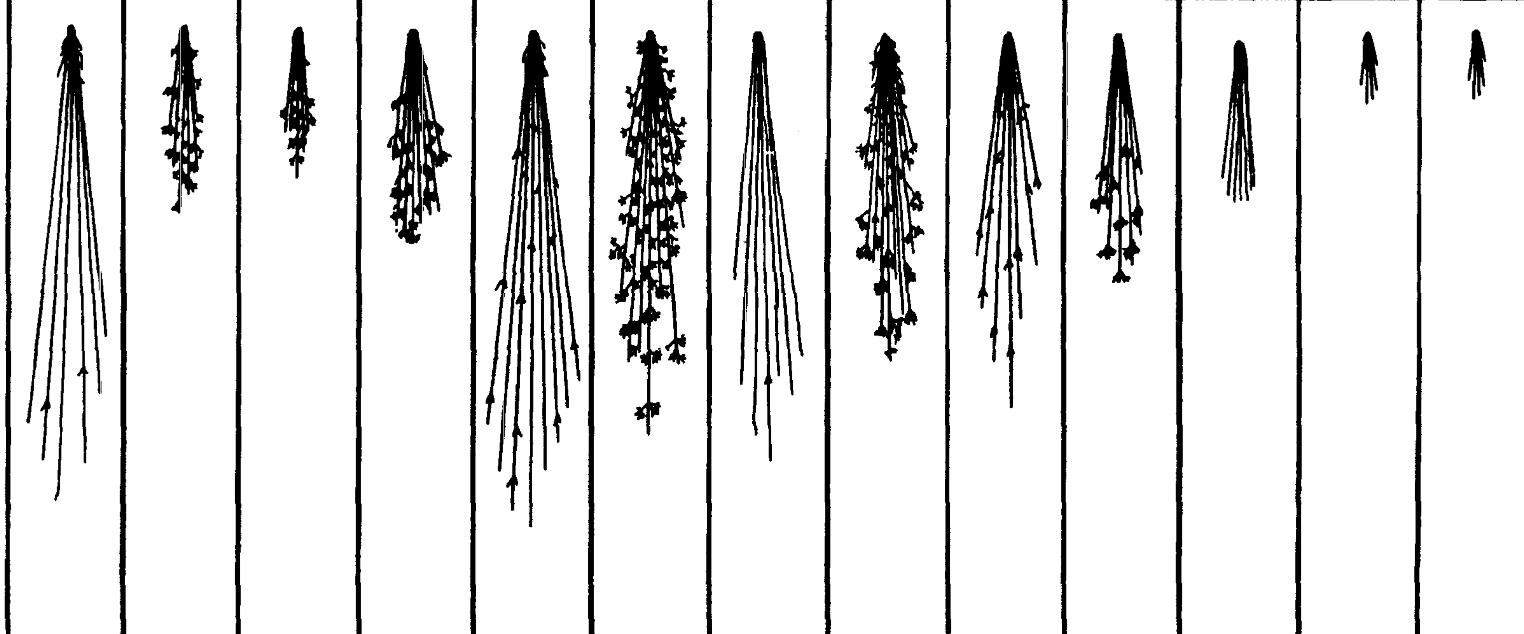
	WROUGHT IRON	GRAY CAST IRON	WHITE CAST IRON	ANNEALED MALLEABLE IRON	MACHINE STEEL (AISI 1020)	CARBON TOOL STEEL	HIGH SPEED STEEL (18-4-1)	AUSTENITIC MANGANESES STEEL	STAINLESS STEEL (TYPE410)	TUNGSTEN CHROMIUM DIE STEEL	STELLITE	CEMENTED TUNGSTEN CARBIDE	NICKEL
STREAM													
VOLUME	LARGE	SMALL	VERY SMALL	MODERATE	LARGE	MODERATLY LARGE	SMALL	MODERATELY LARGE	MODERATE	SMALL	VERY SMALL	EXTREMELY SMALL	VERY SMALL
LENGTH	LONG	SHORT	SHORT	SHORT	LONG	LONG	LONG	LONG	LONG	AVERAGE	SHORT	VERY SHORT	SHORT
COLOR CLOSE TO WHEEL	STRAW	RED	RED	RED	WHITE	WHITE	RED	WHITE	STRAW	RED	ORANGE	LIGHT ORANGE	ORANGE
STREAKS NEAR END OF STREAM	WHITE	STRAW	STRAW	STRAW	WHITE	WHITE	STRAW	WHITE	WHITE	STRAW BLUE WHITE	ORANGE	LIGHT ORANGE	ORANGE
QUANTITY OF SPURTS	VERY FEW	MANY	FEW	MANY	FEW	VERY MANY	EXTREMELY FEW	MANY	MODERATE	MANY	NONE	NONE	NONE
NATURE OF SPURTS	FORKED	FINE REPEATING			FORKED	FINE REPEATING	FORKED	FINE REPEATING	FORKED	FINE REPEATING			

Figure 2-7. Spark test.

THE ROCKWELL HARDNESS NUMBER IS DETERMINED BY THE DEPTH OF THE IMPRESSION WHILE THE BRINELL HARDNESS NUMBER IS DETERMINED BY THE AREA OF THE IMPRESSION

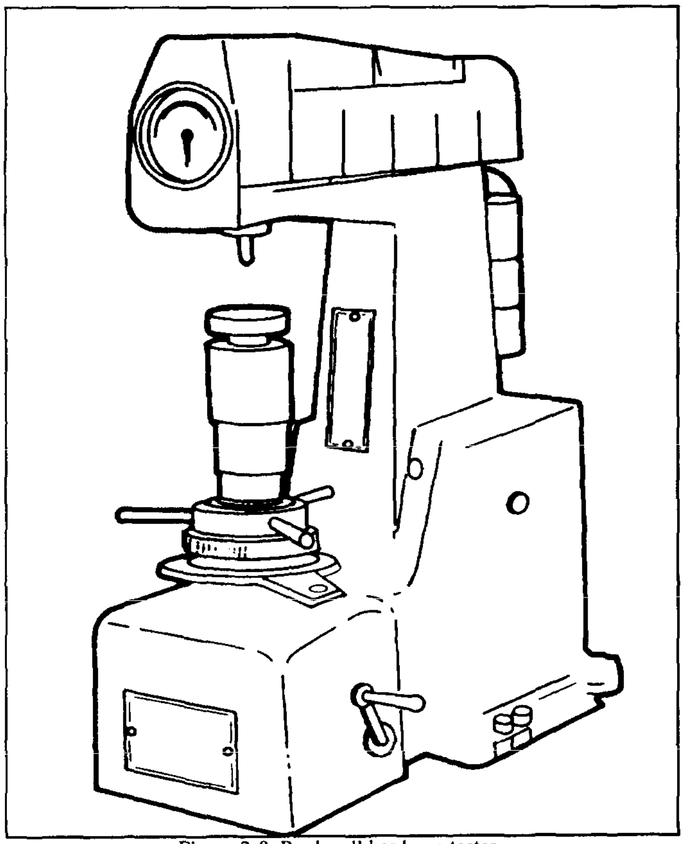


Figure 2-8. Rockwell hardness tester.

File Test

One simple way to check for hardness in a piece of metal is to file a small portion of it. If it is soft enough to be machined with regular tooling, the file will cut it. If it is too hard to machine, the file will not cut it. This method will indicate whether the material being tested is softer or harder than the file, but it will not tell exactly how soft or hard it is. The file can also be used to determine the harder of two pieces of metal; the file will cut the softer metal faster and easier. The file method should only be used in situations when the exact hardness is not required. This test has the added advantage of needing very little in the way of time, equipment, and experience.

Rockwell Hardness Test

This test determines the hardness of metals by measuring the depth of impression which can be made by a hard test point under a known load. The softer the metal, the deeper the impression. Soft metals will be indicated by low hardness numbers. Harder metals permit less of an impression to be made, resulting in higher hardness numbers. Rockwell hardness testing is accomplished by using the Rockwell hardness testing machine (Figure 2-8).

Brinell Hardness Fest

Brinell hardness testing operates on almost the same principle as the Rockwell test. The difference between the two is that the Rockwell hardness number is determined by the depth of the impression while the Brinell hardness number is determined by the area of the impression. This test forces a hardened ball, 10 mm (0.3937 *in)* in diameter, into the surface of the metal being tested, under a load of 3,000 kilograms (approximately 6,600 lb). The area of this impression determines the Brinell hardness number of the metal being tested. Softer metals result in larger impressions but have lower hardness numbers.

NUMERICAL CODES

Perhaps the best known numerical code is the Society of Automotive Engineers (SAE) code. For the metals industry, this organization pioneered in developing a uniform code based on chemical analysis. SAE specification numbers are now used less widely than in the past; however, the SAE numerical code is the basic code for ferrous metals Figure 2-9).

The SAE system is based on the use of four-or five digit numbers.

- The first number indicates the type of alloy used; for example, 1 indicates a carbon steel.
- Two indicates nickel steel.
- The second, and sometimes the third, number gives the amount of the main alloy in whole percentage numbers.
- The last two, and sometimes three, numbers give the carbon content in hundredths of 1 percent (0.01 percent).

The following examples will help you understand this system:

SAE 1045

1- Type of steel (carbon).

0- Percent of alloy (none).

45- Carbon content (0.45-percent carbon).

TYPES OF STEEL	SAE NUMBERS
CARBON STEELS	1XXX
Plain Carbon	10XX
Free Cutting, Manganese	X13XX
Free Cutting, Screw Stock	11XX
HIGH MANGANESE	T13XX
NICKEL STEELS	2XXX
.50% Nickel	20XX
1.50% Nickel	21XX
3.50% Nickel	23XX
5.00% Nickel	25XX
NICKEL-CHROMIUM STEELS	3XXX
1.25% Nickel : .60% Chromium	31XX
1.75% Nickel : 1.00% Chromium	32XX
3.50% Nickel : 1.50% Chromium	33XX
3.00% Nickel : .80% Chromium	34XX
Corrosion and Heat Resisting	30XXX
MOLYBDENUM STEELS	4XXX
Chromium-Molybdenum	41XX
Chromium-Nickel-Molybdenum	43XX
Nickel-Molybdenum	46XX & 48XX
CHROMIUM STEELS	5XXX
.60% to 1.10% Chromium	51XX
1.2% to 1.5% Chromium	52XXX
Corrision and Heat Resistant	51XXX
Chromium-Vanadium Steels	6XXX
Tungsten Steels	7XXXX & 7XXX
Silcon-Manganese Steels	9XXX

Figure 2-9. SAE numerical code.

SAE 2330

2- Type of steel (nickel).

3- Percent of alloy (3-percent nickel).

30- Carbon content (0.30-percent carbon).

SAE 71650

7- Type of steel (tungsten).

16- Percent of alloy (16-percent tungsten).

50- Carbon content (0,50-percent carbon).

SAE 50100

5- Type of steel (chromium).

0- Percent of alloy (less than l-percent chromium).

100- Carbon content (1-percent carbon).

AA Code

A system similar to the SAE classifications for steel and alloys has been developed by the Aluminum Association (AA) for wrought aluminum and aluminum alloys.

This identification system of aluminum, as shown in Figure 2-10, consists of a four-digit number which indicates the type of alloy. control over impurities, and the specific alloy. The first number indicates the type of alloy. For example, 2 is copper, 3 is manganese, 4 is silicone, and so forth. The second number indicates the control that has been used. The last two numbers usually indicate an assigned composition. Thus, AA-2024 means:

2 - Type of alloy (copper).

O - Control of impurities.

24 - Exact composition (AA number 24).

Aluminum alloys vary greatly in their hardness and physical condition. These differences are called "temper," Letter symbols represent the different tempers, In addition to a letter, one or more numbers are sometimes used to indicate further differences. The temper designation is separated from the basic four-digit identification number by a dash; for example, 2024-T6. In this case there is an aluminum alloy, 2024, with a T6 temper (solution heat treated and then artificially aged). Figure 2-11 shows the numerals 2 through 10 that have been assigned in the AA system to indicate specific sequences of annealing, heat treating, cold working, or aging.

MAJOR ALLOYING ELEMENTS

ALUMINUM AT LEAST 99% PURE	1XXX
COPPER	2XXX
MANGANESE	3XXX
SILICON	4XXX
MAGNESIUM	5XXX
MAGNESIUM AND SILICON	6XXX
ZINC	7XXX
OTHER ELEMENTS	8XXX
UNUSED SERIES	9XXX

Figure 2-10. Aluminum alloy groups.

METHODS OF MARKING

Stenciling

A stencil and white or black paint, whichever shows up better on the metal being marked, should be used when the size of the metal piece permits. The federal or military specification numbers should be stenciled on the metal in vertically or hoizontally aligned rows. The distance between the vertical rows should not exceed 36 inches, and the distance between the horizontal rows should not exceed 10 inches.

Stamping

Stamping the specification number into the metal should be used when it is impossible to use the stencil method. It is usually necessary to cut or eliminate the marked portion of the metal prior to using the material for work stock. Therefore, the marking should be located where waste will be held to a minimum. Gothic style numerals and letters should be used; the height may be 1/16 inch, 1/8 inch, or 1/4 inch, depending upon the size of the material being marked.

GENERAL

TEMPER DESIGNATION	
Symbol	**Designation**
—F	As fabricated.
—O	Annealed, recrystallized (wrought products only).
—H	Strain hardened.
—H1	Plus one or more digits. Strain hardened only.
—H2	Plus one or more digits. Strain hardened and then partially annealed.
—H3	Plus one or more digits. Strain hardened and stabilized.
—W	Solution heat treated—unstable temper. This designation is specified only when the period of natural aging is indicated.
—T	Treated to produce stable tempers other than —F, —O, or —H.
—T2	Annealed (cast products only).
—T3	Solution heat-treated and then cold worked.
—T4	Solution heat-treated.
—T5	Artificially aged only.
—T6	Solution heat-treated and then artifically aged.
—T7	Solution heat-treated and then stabilized.
—T8	Solution heat-treated cold-worked and then artifically aged.
—T9	Solution heat-treated, artificially aged and then cold-worked.
—T10	Artifically-aged and then cold worked.

Figure 2-11. Temper designation of aluminum.

FERROUS METALS

Ferrous metals are those that contain iron as the base metal. The properties of ferrous metals may be changed by adding various alloying elements. The chemical and mechanical properties need to be combined to produce a metal to serve a specific purpose. The basic ferrous metal form is pig iron. Pig iron is produced in a blast furnace that is charged with an iron ore, coke, and limestone. The four principal iron ores are hematite, limonite, magnetite and faconite.

CAST IRON

Cast iron is a metal that is widely used. It is a hard, brittle metal that has good wear resistance. Cast iron contains 2 to 4 percent carbon. White cast iron is very hard and is used mostly where abrasion and wear resistance is required. White cast iron may be made into malleable iron by heating it; then cooling it very slowly over a long period of time. Malleable iron is stronger and tougher than white cast iron; however, it is much more expensive to produce. Gray iron is another form of cast iron. It is used mostly for castings because of its ability to flow easily into complex shapes.

WROUGHT IRON

Wrought iron is an iron that has had most of its carbon removed. It is tough; however, it can be bent or twisted very easily. Wrought iron is used mostly in ornamental ironwork, such as fences and handrails, because it is welded or painted easily and it rusts very slowly.

STEEL

Steel is an alloy of iron and carbon or other alloying elements. When the alloying element is carbon, the steel is referred to as carbon steel. Carbon steels are classified by the percentage of carbon in "points" or hundredths of 1 percent they contain.

Low Carbon Steel

(Carbon content up to 0.30 percent or 30 points).

This steel is soft and ductile and can be rolled, punched, sheared, and worked when either hot or cold. It is easily machined and can be readily welded by all methods. It does not harden to any great amount; however, it can be easily case- or surface-hardened.

Medium Carbon Steel

(Carbon content from 0.30 to 0.50 percent or 30 to 50 points).

This steel may be heat-treated after fabrication. It is used for general machining and forging of parts that require surface hardness and strength. It is made in bar form in the cold-rolled or the normalized and annealed condition. During welding, the weld zone will become hardened if cooled rapidly and must be stress-relieved after welding.

High Carbon Steel

(Carbon content from 0.50 to 1.05% or 50 to 105 points)

This steel is used in the manufacture of drills, taps, dies, springs, and other machine tools and hand tools that are heat-treated after fabrication to develop the hard structure necessary to withstand high shear stress and wear. It is manufactured in bar, sheet, and wire forms, and in the annealed or normalized condition in order to be suitable for machining before heat treatment. This steel is difficult to weld because of the hardening effect of heat at the welding joint.

Tool Steel

(carbon content from 0.90 to 1.70 percent or 90 to 170 points)

This steel is used in the manufacture of chisels, shear blades, cutters, large taps, woodturning tools, blacksmith's tools, razors, and other similar parts where high hardness is required to maintain a sharp cutting edge. It is difficult to weld due to the high carbon content.

High-Speed Steel

High-speed steel is a self-hardening steel alloy that can withstand high temperatures without becoming soft. High-speed steel is ideal for cutting tools because of its ability to take deeper cuts at higher speeds than tools made from carbon steel.

Tungsten Carbide

Tungsten carbide is the hardest man-made metal. It is almost as hard as a diamond. The metal is molded from tungsten and carbon powders under heat and pressure. Tools made from this metal can cut other metals many times faster than high-speed steel tools.

Alloy Steels

Steel is manufactured to meet a wide variety of specifications for hardness, toughness, machinability, and so forth. Manufacturers use various alloying elements to obtain these characteristics. When elements other than carbon, such as chromium, manganese, molybdenum, nickel, tungsten, and vanadium are used. The resulting metals are called alloy steels. Figure 2-12 shows some of the general characteristics obtained by the use of various alloying elements.

NONFERROUS METALS

There are many metals that do not have iron as their base metal. These metals, known as nonferrous metals, offer specific properties or combinations of properties that make them ideal for tasks where ferrous metals are not suitable. Nonferrous metals are often used with iron base metals in the finished product.

ALUMINUM

Aluminum and its alloys are produced and used in many shapes and forms. The common forms are castings, sheet, plate, bar, rod, channels, and forgings. Aluminum alloys have many desirable qualities. They are lighter than most other metals and do not rust or corrode under most conditions. Aluminum can be cast-forged, machined, and welded easily.

MAGNESIUM

Magnesium alloys are produced and used in many shapes and forms, for example, castings, bars, rods, tubing, sheets and plates, and forgings. Their inherent strength, light weight, and shock and vibration resistance are factors which make their use advantageous. The weight for an equal volume of magnesium is approximately two-thirds of that for aluminum and one-fifth of that for steel. Magnesium has excellent machining qualities; however, care must be taken when machining because the chips are highly flammable. Magnesium fires bum so hot that they cannot be extinguished by conventional fire extinguishers.

COPPER

Copper is a reddish metal, very ductile and malleable, and has high electrical and heat conductivity. Copper can be forged, cast, and cold worked. It also can be welded, but its machinability is only fair. The principal use of commercially pure copper is in the electrical industry where it is made into wire or other such conductors. It is also used in the manufacture of nonferrous alloys such as brass, bronze, and monel metal. Typical copper products are sheet roofing, cartridge cases, bushings, wire, bearings, and statues.

BRASS AND BRONZE

Brass, an alloy of copper and zinc (60 to 68 percent copper and 32 to 40 percent zinc), has a low melting point and high heat conductivity. There are several types of brass such as naval, red, admiralty, yellow, and commercial. All differ in copper and zinc content. All may be alloyed with other elements such as lead, tin, manganese, or iron, and all have good machinability and can be welded. Bronze is an alloy of copper and tin and may contain lead, zinc, nickel, manganese, or phosphorous. It has high strength, is rust or corrosion resistant, has good machinability, and can be welded.

TYPES OF STEEL	SAE NUMBERS (GENERAL SERIES)	CHARACTERISTICS RESULTING FROM THE ALLOYING ELEMENTS ADDED
CARBON STEELS	1000	Surface Hardness and Strength
NICKEL STEELS	2000	Toughness
CHROME-NICKEL STEELS	3000	Toughness and Depth Hardness
MOLYBDENUM STEELS	4000	Eliminates Brittleness and Increases Depth Hardness
CHROME-MOLYBDENUM STEELS	4100	High Strength and Toughness
CHROMIUM STEELS	5000	Corrosion Resistance and Hardness
CHROME-VANADIUM	6000	Depth Hardness and toughness at Sub-zero Temperature
TUNGSTEN STEELS	7000	Hardness at High Temperatures
CHROME-NICKEL-MOLYBDENUM STEELS	8000	Toughness and Strength (General Purpose Steel)
SILICONE-MANGANESE STEELS	9000	Depth Hardness and Toughness Under Impact

Figure 2-12. General characteristics of common alloys.

LEAD

Lead is used mainly in the manufacture of electrical equipment such as lead-coated power and telephone cables and storage batteries. Zinc alloys are used in the manufacture of lead weights, bearings, gaskets, seals, bullets, and shot. Many types of chemical compounds are produced from lead. Among these are lead carbonate (paint pigment) and tetraethyl lead (antiknock gasoline). Lead is also used for X-ray protection (radiation shields). Lead has more fields of application than any other metal. It can be cast, cold worked, welded, and machined. Lead has low strength with heavy weight.

TIN

The major use of tin is in coating steel. It is the best container for preserving perishable food. Tin, in the form of foil, is often used in wrapping food products. A second major use of tin is as an alloying element. Tin is alloyed with copper to produce bronze, with lead to produce solder, and with antimony and lead to form babbitt. Tin can be die cast, cold worked, machined, and soldered; however, it cannot be welded.

NICKEL

Nickel is used in making alloys of both ferrous and nonferrous metals. Chemical and food processing equipment, electrical resistance heating elements, ornamental trim, and parts that must withstand elevated temperatures are all produced from nickel containing metal. Alloyed with chromium, it is used to make stainless steel. Nickel alloys are readily welded by either gas or arc methods and can be machined, forged, cast, and easily formed.

COBALT-CHROMIUM-TUNGSTEN MOLYBDENUM WEAR-RESISTANT ALLOYS

These alloys feature a wear resistance which makes them ideal for metal-cutting operations. Their ability to retain hardness even at red-heat temperatures also makes them especially useful for cutting tools. Common cutting tools will lose their edge at high heat, whereas this alloy group is actually tougher at red heat than it is when cold; as a result, higher speeds and feeds may be used when machining with tools made with these alloys.

PRECIOUS METALS

These include silver, gold, platinum, palladium, iridium, osmium, rhodium, and ruthenium, and their alloys. These alloys are produced under technical and legal requirements. Gold alloys used for jewelry are described in karats. The karat is the content of gold expressed in twenty-fourths. An 18-karat gold alloy would contain 18/24 gold (75 percent by weight). Other than jewelry, there are many industrial uses for precious metals.

HEAT TREATMENT OF METALS

Heat treatment is any one of a number of controlled heating and cooling operations used to bring about a desired change in the physical properties of a metal. Its purpose is to improve the structural and physical properties for some particular use or for future work of the metal. There are five basic heat treating processes: hardening, case hardening, annealing, normalizing, and tempering. Although each of these processes bring about different results in metal, all of them involve three basic steps: heating, soaking, and cooling.

HEATING

Heating is the first step in a heat-treating process. Many alloys change structure when they are heated to specific temperatures. The structure of an alloy at room temperature can be either a mechanical mixture, a solid solution, or a combination solid solution and mechanical mixture.

A mechanical mixture can be compared to concrete. Just as the.sand and gravel are visible and held in place by the cement. The elements and compounds in a mechanical mixture are clearly visible and are held together by a matrix of base metal. A solid solution is when two or more metals are absorbed, one into the other, and form a solution. When an alloy is in the form of a solid solution, the elements and compounds forming the metal are absorbed into each other in much the same way that salt is dissolved in a glass of water. The separate elements forming the metal cannot be identified even under a microscope. A metal in the form of a mechanical mixture at room temperature often goes into a solid solution or a partial solution when it is heated. Changing the chemical composition in this way brings about certain predictable changes in grain size and structure. This leads to the second step in the heat treating process: soaking.

SOAKING

Once a metal part has been heated to the temperature at which desired changes in its structure will take place, it must remain at that temperature until the entire part has been evenly heated throughout. This is known as soaking. The more mass the part has, the longer it must be soaked.

COOLING

After the part has been properly soaked, the third step is to cool it. Here again, the structure may change from one chemical composition to another, it may stay the same, or it may revert to its original form. For example, a metal that is a solid solution after heating may stay the same during cooling, change to a mechanical mixture, or change to a combination of the two, depending on the type of metal and the rate of cooling. All of these changes are predictable. For that reason, many metals can be made to conform to specific structures in order to increase their hardness, toughness, ductility, tensile strength, and so forth.

HEAT TREATMENT OF FERROUS METALS

All heat-treating operations involve the heating and cooling of metals, The common forms of heat treatment for ferrous metals are hardening, tempering, annealing, normalizing, and case hardening.

HARDENING

A ferrous metal is normally hardened by heating the metal to the required temperature and then cooling it rapidly by plunging the hot metal into a quenching medium, such as oil, water, or brine. Most steels must be cooled rapidly to harden them. The hardening process increases the hardness and strength of metal, but also increases its brittleness.

TEMPERING

Steel is usually harder than necessary and too brittle for practical use after being hardened. Severe internal stresses are set up during the rapid cooling of the metal. Steel is tempered after being hardened to relieve the internal stresses and reduce its brittleness. Tempering consists of heating the metal to a specified temperature and then permitting the metal to cool. The rate of cooling usually has no effect on the metal structure during tempering. Therefore, the metal is usually permitted to cool in still air. Temperatures used for tempering are normally much lower than the hardening temperatures. The higher the tempering temperature used, the softer the metal becomes. High-speed steel is one of the few metals that becomes harder instead of softer after it is tempered.

ANNEALING

Metals are annealed to relieve internal stresses, soften them, make them more ductile, and refine their grain structures. Metal is annealed by heating it to a prescribed temperature, holding it at that temperature for the required time, and then cooling it back to room temperature. The rate at which metal is cooled from the annealing temperature varies greatly. Steel must be cooled very slowly to produce maximum softness, This can be done by burying the hot part in sand, ashes, or some other substance that does not conduct heat readily (packing), or by shutting off the furnace and allowing the furnace and part to cool together (furnace cooling).

NORMALIZING

Ferrous metals are normalized to relieve the internal stresses produced by machining, forging, or welding. Normalized steels are harder and stronger than annealed steels. Steel is much tougher in the normalized condition than in any other condition. Parts that will be subjected to impact and parts that require maximum toughness and resistance to external stresses are usually normalized. Normalizing prior to hardening is beneficial in obtaining the desired hardness, provided the hardening operation is performed correctly. Low carbon steels do not usually require normalizing, but no harmful effects result if these steels are normalized. Normalizing is achieved by heating the metal to a specified temperature (which is higher than either the hardening or annealing temperatures), soaking the metal until it is uniformly heated, and cooling it in still air.

CASE HARDENING

Case hardening is an ideal heat treatment for parts which require a wear-resistant surface and a tough core, such as gears, cams, cylinder sleeves, and so forth. The most common case-hardening processes are carburizing and nitriding. During the case-hardening process, a low-carbon steel (either straight carbon steel or low-carbon alloy steel) is heated to a specific temperature in the presence of a material (solid, liquid, or gas) which decomposes and deposits more carbon into the surface of a steel. Then, when the part is cooled rapidly, the outer surface or case becomes hard, leaving the, inside of the piece soft but very tough.

HEAT TREATMENT OF NONFERROUS METALS

Two types of heat-treating operations can be performed on nonferrous metals. They are annealing and solution heat treating.

ANNEALING

Most nonferrous metals can be annealed. The annealing process consists of heating the metal to a specific temperature, soaking, and cooling to room temperature. The temperature and method of cooling depend on the type of metal. Annealing is often accomplished after various cold working operations because many nonferrous metals become hard and brittle after cold working. Also, annealing is used to remove the effects of solution heat treatment so that machining or working qualities can be improved.

SOLUTION HEAT TREATMENT

The tensile strength of many nonferrous alloys can be increased by causing the materials within the alloy to go into a solid solution and then controlling the rate and extent of return to an altered mechanical mixture. This operation is called solution heat treatment. After an alloy has been heated to a specified temperature, it is "quenched" or cooled rapidly, which traps the materials in the solid solution attained during the heating process. From this point, the process varies greatly depending on the metal. To be sure the materials in the alloy do not revert to their original configuration after a period of time, a process of aging or precipitation hardening must follow. In this process the materials in the alloy are allowed to change or to precipitate out of the solid solution.

This process occurs under controlled conditions so that the resultant grain structure will produce a greater tensile strength in the metal than in its original condition. Depending on the alloy, this precipitation process can also consist of simply aging the alloy at room temperature for a specified time and then air-cooling it; this is called artificial aging.

Aluminum alloys can be obtained in various conditions of heat treatment called temper designations. Figure 2-11, on page 2-9, shows the various temper designations and the process to which they apply. The term "strain-hardened" refers to aging or hardening that has been brought about by coldworking the alloy. "Stabilizing" refers to a particular aging process that freezes or stops the internal changes that normally would take place in the alloy at room temperature. Magnesium alloys can be subjected to all of the nonferrous heat treatments, but the different alloys within the series require different temperatures and times for the various processes. Copper alloys are generally hardened by annealing. The nickel alloys can also be annealed and certain types can be hardened by heat treatment. Likewise, titanium may be annealed (mostly relieve machining or cold-working stresses) but is not noticeably affected by heat treatment.

Chapter 3

PORTABLE MACHINE TOOLS

The portable machine tools identified and described in this chapter are intended for use by maintenance personnel in a shop or field environment. These lightweight, transportable machine tools, can quickly and easily be moved to the workplace to accomplish machining operations. The accuracy of work performed by portable machine tools is dependent upon the user's skill and experience.

Portable machine tools are powered by self-contained electric motors or compressed air (pneumatic) from an outside source. They are classified as either cutting took (straight and angle hand drills, metal sawing machines, and metal cutting shears) or finishing tools (sanders, grinders, and polishers).

SAFETY PRECAUTIONS

GENERAL

Portable machine tools require special safety precautions while being used. These are in addition to those safety precautions described in Chapter 1.

PNEUMATIC AND ELECTRIC TOOL SAFETY

Here are some safety precautions to follow:

- Never use electric equipment (such as drills, sanders, and saws) in wet or damp conditions.
- Properly ground all electric tools prior to use.
- Do not use electric tools near flammable liquids or gases.
- Inspect all pneumatic hose lines and connections prior to use.
- Keep constant watch on air pressure to stay within specified limits.
- Keep all equipment in proper working order, and use the equipment according to the manufacturer's instructions.
- Remove chuck keys from drills prior to use.
- Hold tools firmly and maintain good balance.
- Secure the work in a holding device, not in your hands.
- Wear eye protection while operating these machines.
- Ensure that all lock buttons or switches are off before plugging the machine tool into the power source.
- Never leave a portable pneumatic hammer with a chisel, star drill, rivet set, or other tool in its nozzle.

ELECTRIC EXTENSION CORDS

Use the right wire gage for the length of the cord. As the length of the extension cord increases, heavier gage wire must be used. Lengthening extension cords by connecting several small gage cords together causes a serious drop in voltage. This results in the cord overheating. Extension cords that overheat will bum away the insulation, creating a potential electric shock hazard and fire hazard. See Table 3-1, Appendix A, for proper gage and length of extension cords.

PORTABLE DRILLS

PURPOSE AND TYPES

The portable drill is a hand-supported, power-driven machine tool that rotates twist drills, reamers, counterbores, and similar cutting tools. The portable drill may be electrically powered by means of an internal electric motor (Figure 3-1) or may be pneumatically powered (Figure 3-2). Portable drills are rated by the maximum size hole that can be drilled in steel without overtaxing the motor or drill.

Therefore, a 1/4-inch-capacity drill is capable of drilling a 1/4-inch diameter hole or smaller in steel. Portable electric and pneumatic drills rated at 1/4 to 1/2-inch maximum capacities are usually equipped with geared drill chucks for mounting straight, round shank twist drills or other similar tools by using a chuck key (Figure 3-3). Heavier portable drills (Figure 3-4) having a 3/4- to 1 1/4-inch capacity use taper shank chucks to mount drills and other similar tools.

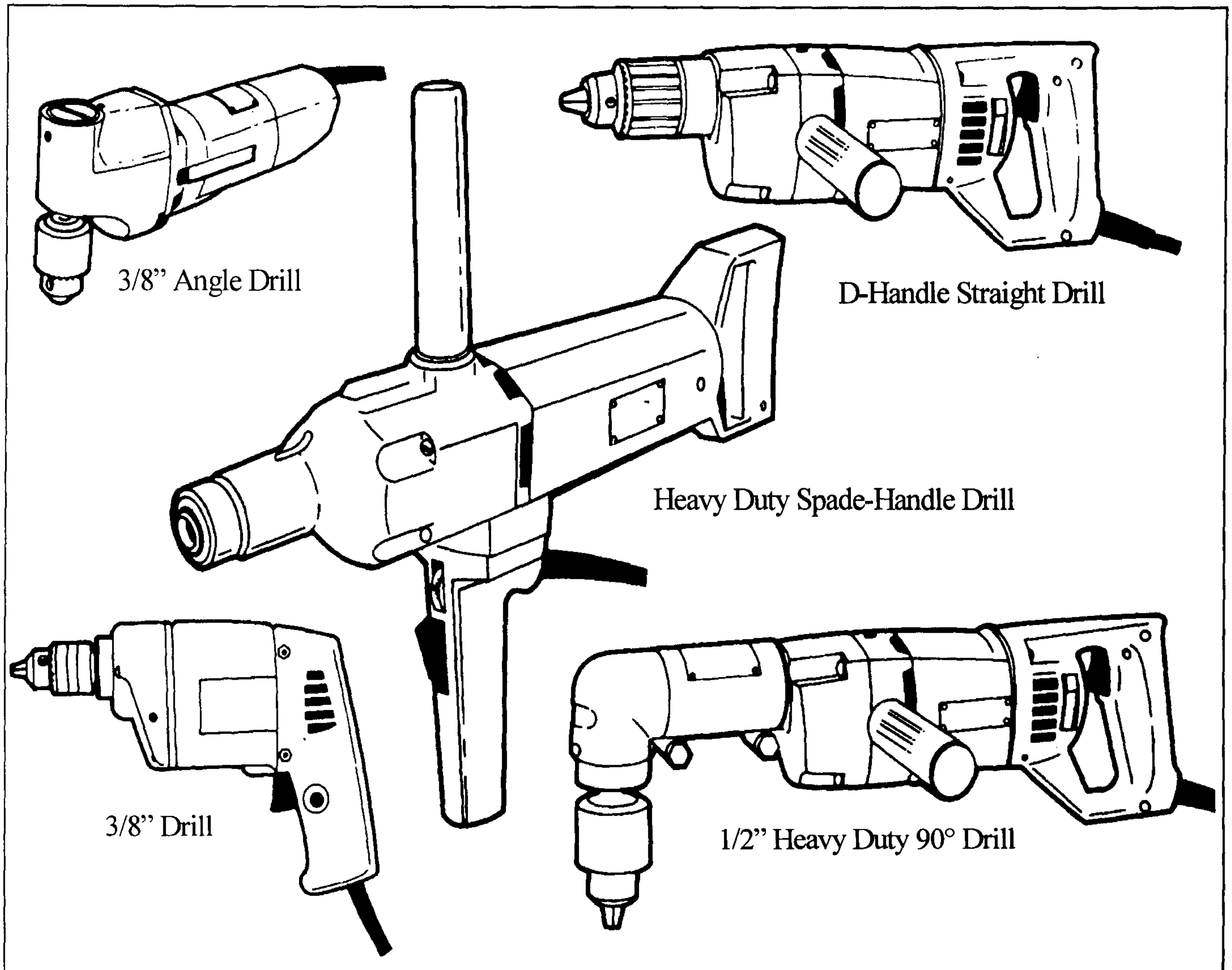


Figure 3-1. Portable electric hand drills.

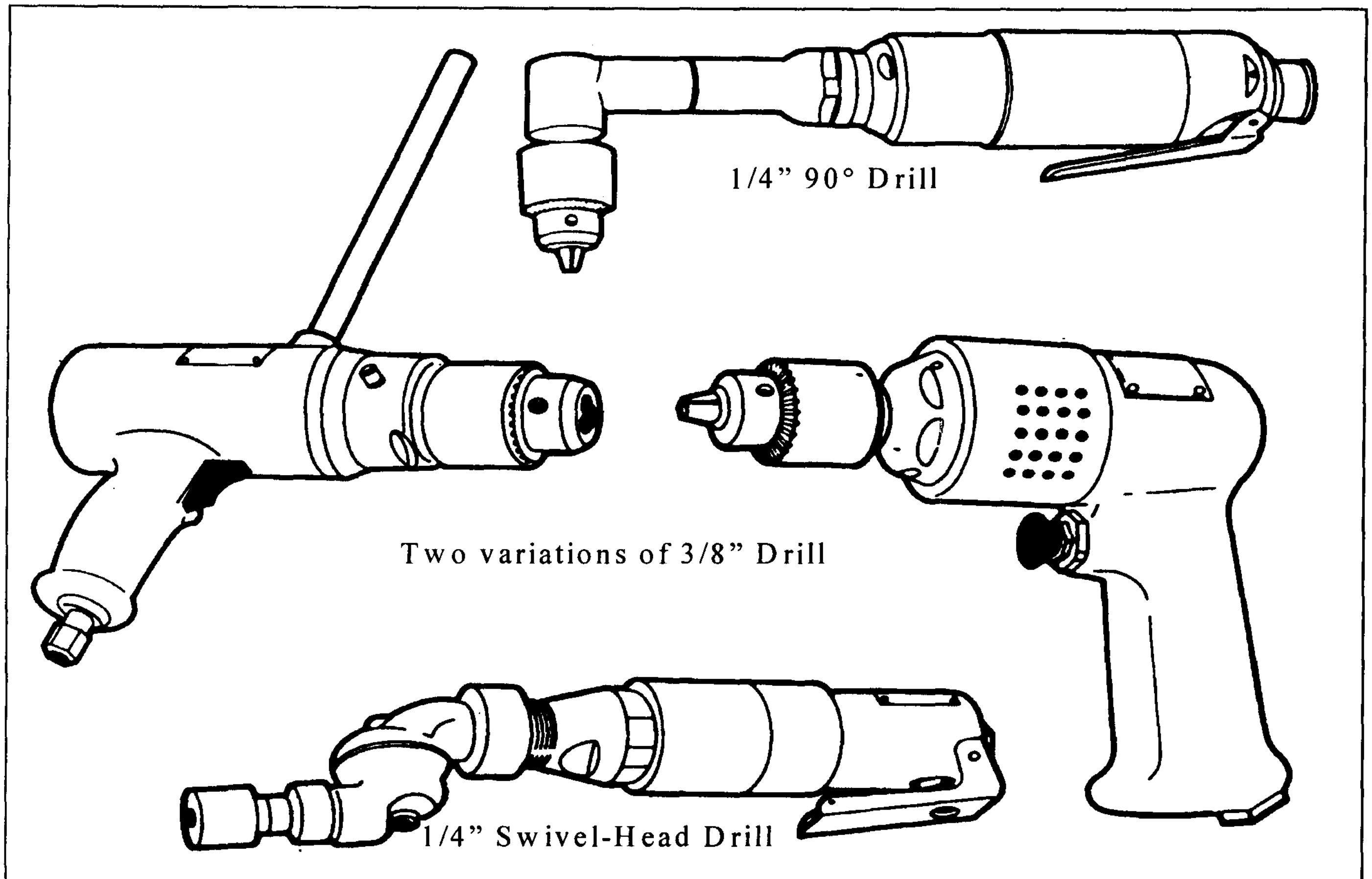


Figure 3-2. Portable pneumatic hand drills.

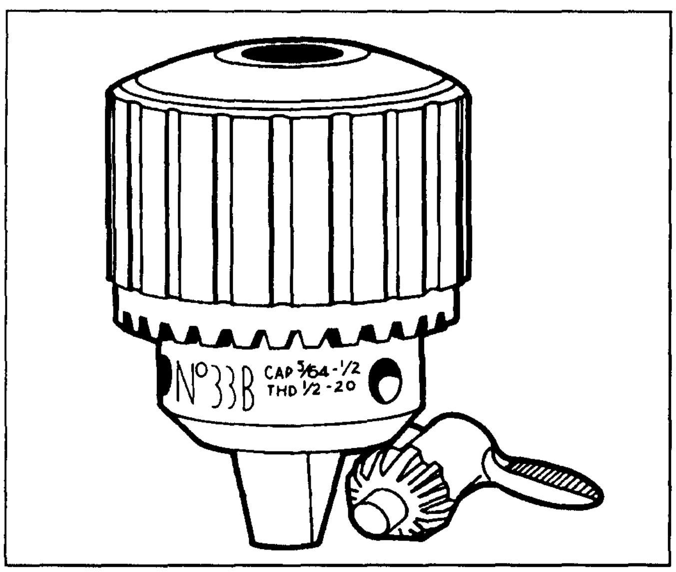


Figure 3-3. Geared drill chuck and chuck key.

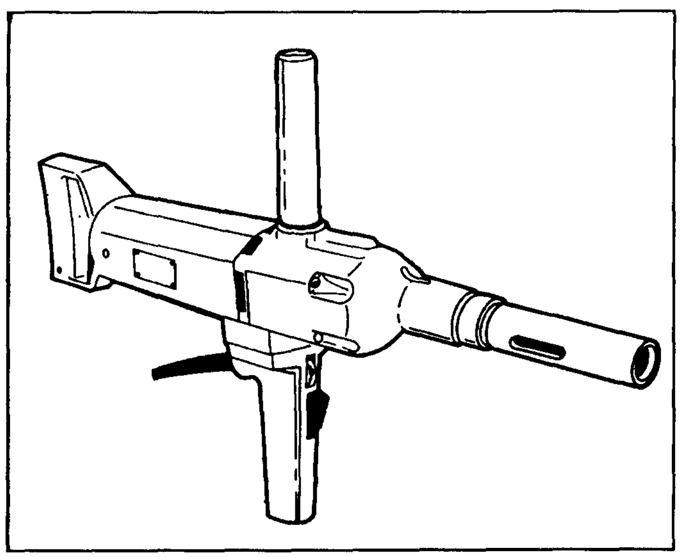


Figure 3-4. 1-inch capacity portable electric drill.

Portable drills have many different characteristics (Figure 3-5) depending on how the job is to be done. They may be set for one speed or they maybe variable speed drills. A variable speed drill is an excellent tool for use as a power screwdriver. Portable drills may be equipped with a reversing switch to allow a screwdriver attachment to reverse bolts and screws out of holes. Special 90° angle portable drills (Figure 3-8) are available for drilling in confined spaces where a standard size drill will not have sufficient clearance. For corners and tight spots, a 360° angle portable pneumatic drill (Figure 3-2) is available which can be swiveled to any desired angle and locked into position. Most portable drills have a lock button near the on-off switch which allows for continuous operation without holding the trigger. Side handles and rear spade handles (Figure 3-5) can be attached to most drills to stabilize drilling and to allow for better control. Special devices. such as a vertical stand (Figure 3-6) or feed screw (Figure 3-7), can be used on some of the portable drills to make a job easier or more proficient.

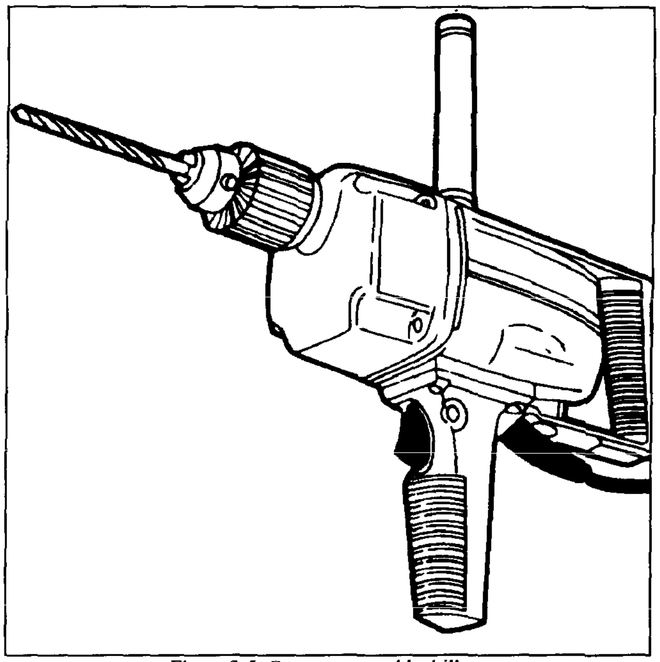


Figure 3-5. Common portable drill.

The size, type. and power capacity of portable drills selected depends on the job to be performed. Before attempting a drilling job, check the capabilities of the portable drill with the manufacturer's instruction manual.

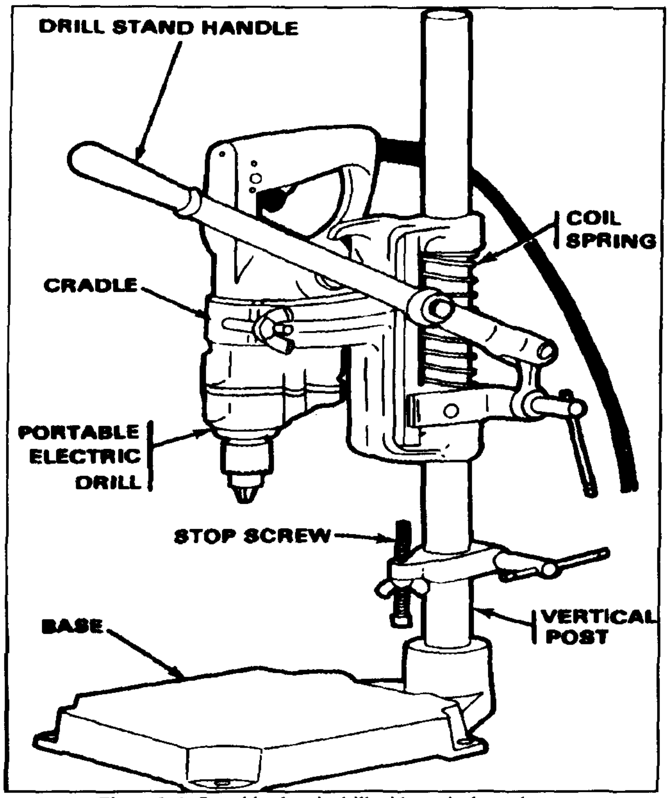


Figure 3-6. Portable electric drill with vertical stand.

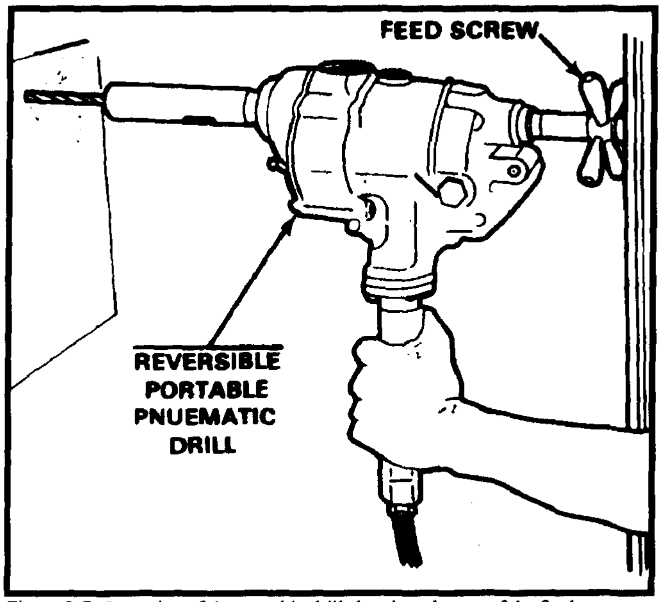


Figure 3-7. Operation of the portable drill showing the use of the feed screw.

DRILLING OPERATIONS

Operation of the portable electric and pneumatic drills differs from recommended operating procedures for the upright drilling machine. The portable drill is hand supported for most operations, and the cutting speed of the drill is fixed or dependent upon the operator to control. When hand supported, the drill must be carefully aligned with the workpiece (Figure 3-9) and this alignment must be maintained throughout the drilling operation. Care must be taken not to lose control of the portable drill and allow it to be wrenched from the operator's hands. The larger portable drills (Figure 3-10) can be very dangerous if not held firmly by the operator. If the cutting speed is fixed, the operator must learn to control the feed of the portable drill by applying sufficient pressure for the drill to cut, but not too much pressure as to cause overheating of the twist drill or stalling of the portable drill motor.

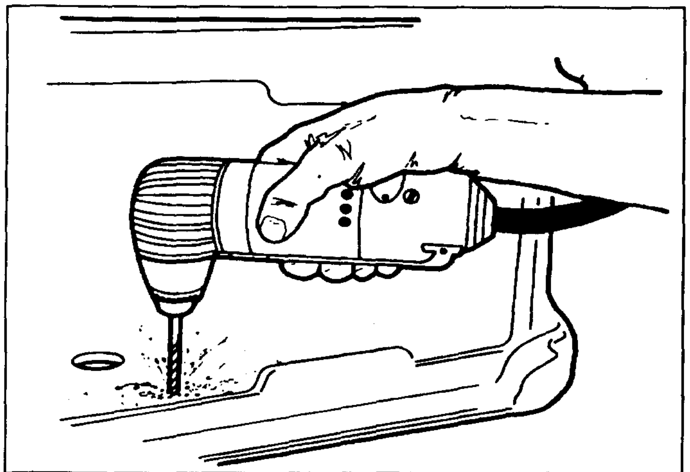


Figure 3-8. Hand drilling operation in confined space using the 90° angle drill.

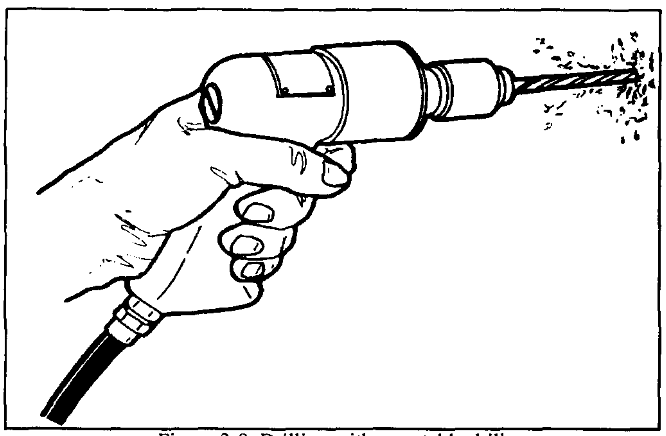


Figure 3-9. Drilling with a portable drill.

When metal is to be drilled with the portable drill, the workpiece must be prepared by locating the center position of the potential hole and marking the location with a center punch. When a large drill is to be used, it will be necessary first to drill a pilot hole slightly larger in diameter than the thickness of the larger drill's web, which will allow for the drag caused by the larger drill's chisel edge (Figure 3- 11).

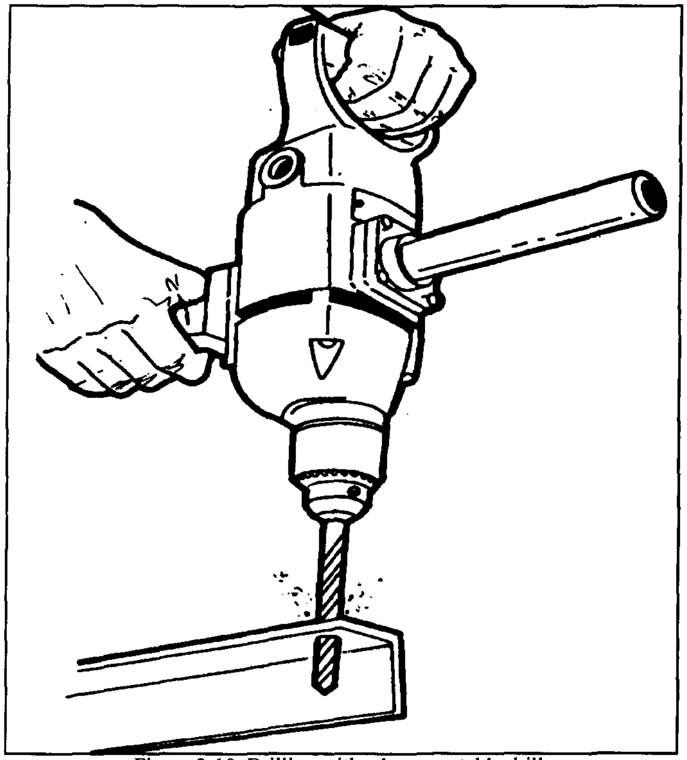


Figure 3-10. Drilling with a large portable drill.

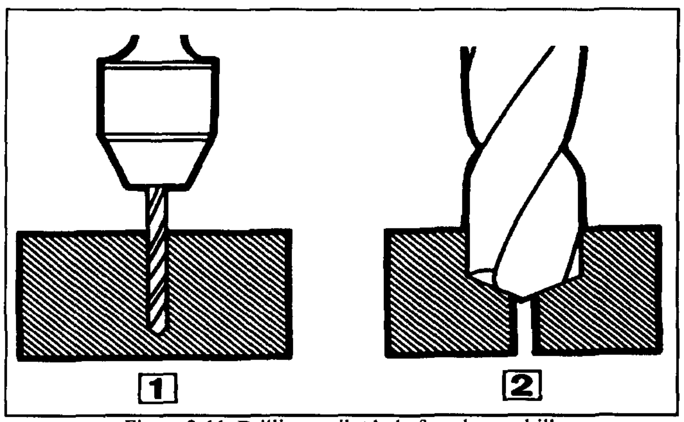


Figure 3-11. Drilling a pilot hole for a larger drill.

Portable pneumatic drills require special attention to lubricate their internal moving parts. Each drill may be made slightly different, so refer to the pertinent lubrication order or manufacturer's instruction manual before drilling.

For drilling by hand, the workpiece must be mounted securely. Thin workplaces should be backed up with a thicker piece of wood or metal to prevent the drill from snagging in the workpiece. Do not attempt to hold any workpiece by hand or serious injury could result.

Select a twist drill of the proper size for the hole to be drilled. Ensure that the twist drill selected has the right type of shank for the type of chuck mounted on the portable drill. Taper shank drills cannot be mounted in a drill with a geared chuck. Check each twist drill for sharp cutting edges prior to use.

After securing the twist drill in the proper chuck, connect the portable drill to its power source. Position the portable drill perpendicular to the workpiece and center the chisel point of the drill in the center-punched hole of the workpiece. Apply firm but not too heavy pressure upon the portable drill, pull the trigger or throttle button to start the drill.

Apply a few drops of cutting oil to the twist drill and hole (Figure 3-12) to improve the cutting action and prevent overheating of the twist drill. For long drilling operations, stop the drill and allow it to cool; then apply additional cutting oil to the drilling area. The lock button can be engaged for lengthy cutting operations.

Continue drilling the hole while applying enough pressure to produce a clean chip, but not so much pressure as to cause the motor to strain or the drill to bind. The drill must be held firmly at all times to prevent the drill from being wrenched from the hands of the operator if the flutes of the drill should snag on a metal burr in the hole.

As the twist drill nears the back wall of the workpiece, release the lock button so that the drill can be stopped immediately if required. Decrease the feed pressure as the drill breaks through, and cautiously feed the drill through the wall of the workpiece. If the drill should snag on a burr, stop drilling immediately and withdraw from the hole. Carefully feed the drill back into the hole while the drill is turning to cut through the burr.

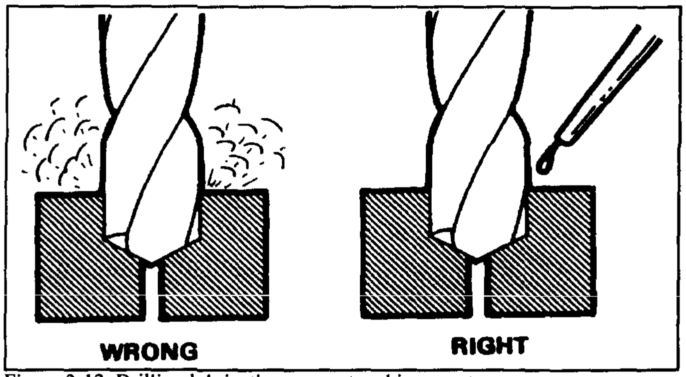


Figure 3-12. Drilling lubrication, correct and incorrect.

When a portable drill is mounted to a vertical stand, the operating procedure is identical to that used for the upright drilling machine. Use the lock button while drilling and use the hand lever to drill to the required depth.

Portable drilling operations can be difficult to an inexperienced operator. It is difficult to keep the twist drill perpendicular to the workpiece during drilling, and it is hard to drill to a desired depth accurately. If help is available, use the buddy system to keep the drill aligned while drilling. To drill to depth, mark the twist drill with a light colored marking pen or a strip of tape and keep a close watch on the drill as it cuts. Another way to drill to depth accurately using the portable drill is to use a jig, such as a piece of metal pipe or tubing cut to length, to indicate when the drill has reached the desired depth.

PORTABLE GRINDERS

PURPOSE AND TYPES

The portable grinder is a lightweight, hand-operated machine tool. It can be powered electrically or pneumatically, depending on the model selected. The portable grinder is used in the field or maintenance shop to grind excess metal from welds, remove rust, and for special finishing operations around the work area. Since this tool is hand operated, the quality of the work depends upon the ability and experience of the operator.

A small portable chuck type grinder may be known as a die grinder and is available with a number of accessories.

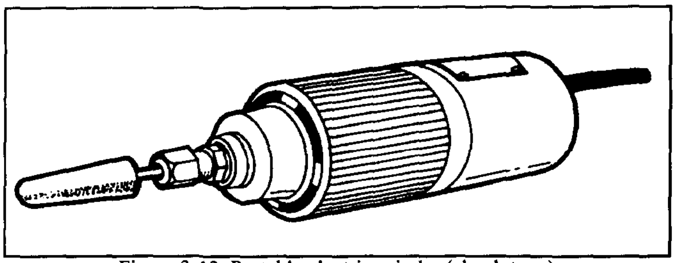


Figure 3-13. Portable electric grinder (chuck type).

These accessories include rotary files, small circular saws, wire brushes, assorted grinding wheels, and small sanding and polishing disks. These accessories are mounted to straight shank arbors which fit into the collet chuck of the grinder. Special reduction collets are provided so that smaller diameter arbors or shanks can be mounted in the chuck. Operations performed with this portable grinder include shaping and smoothing intricate dies and castings, removing burrs from edges and surfaces, cleaning and repairing threaded parts, repairing keyways and splines, grinding bevels, countersinking holes. and repairing scored and mutilated surfaces.

The portable grinder (wheel type) (Figure 3-14) can be electric or pneumatic and is designed for heavy-duty portable grinding operations. It is capable of mounting and rotating 6-inch-diameter grinding abrasive wheels and 6-inch-diameter wire brushes and polishing wheels. This grinder is used as a hand grinder for removing rust, corrosion, and sharp burrs from large workpieces (Figure 3-15).

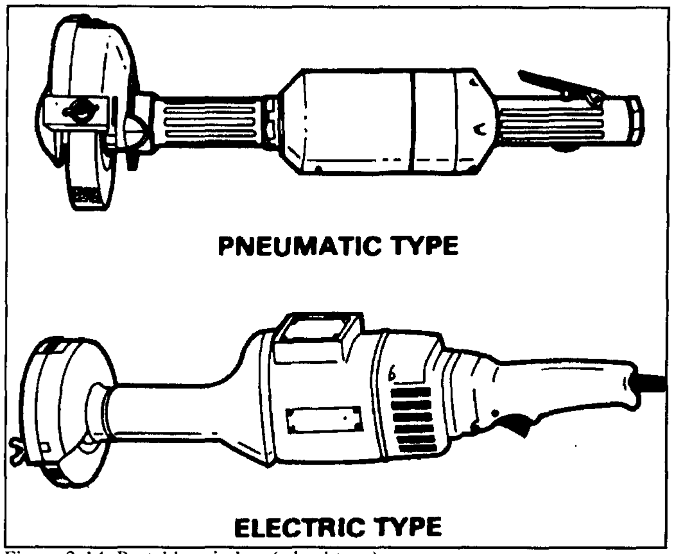


Figure 3-14 Portable grinders (wheel type).

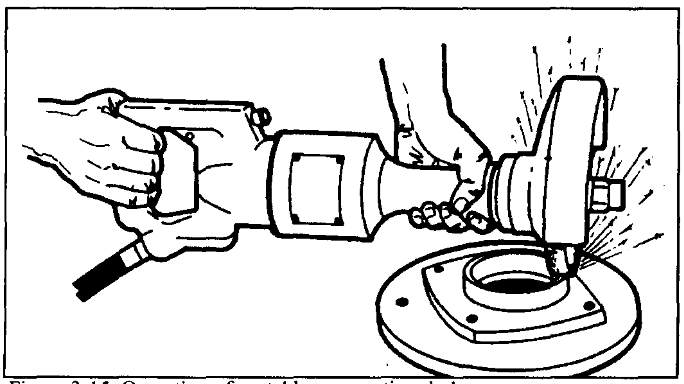


Figure 3-15. Operation of portable pneumatic grinder.

Most portable grinders come with a grinder stand (Figure 3-16). Mounted on this stand, the grinder can be used to sharpen twist drills and cutter bits in the machine shop. Most grinders also come equipped with a wheel guard that should remain in place at all times to protect the operator from flying sparks and waste material. The portable grinder is designed so that the face of the grinding wheel is used; never use the side of the wheel or serious injury or damage could occur (Figure 3-17).

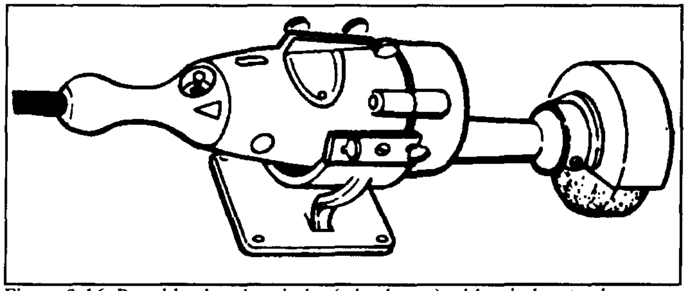


Figure 3-16. Portable electric grinder (wheel type) with grinder stand.

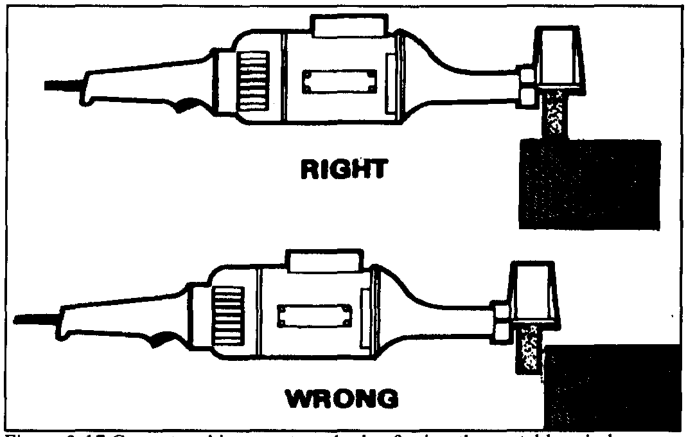


Figure 3-17 Correct and incorrect methods of using the portable grinder (wheel type).

The angle grinder (disk type) (Figure 3-18) can be electric or pneumatic, and is designed for heavy duty grinding operations. The angle grinder consists of a depressed center abrasive grinding disk with wheel guard attached to the basic portable motor assembly (Figure 3-19). Care must be taken to check the wheel for cracks and to ensure that the wheel guard stays in place while operating.

OPERATIONS WITH PORTABLE GRINDERS

Before operating any portable grinder, check the grinding wheel for cracks and check that the arbor hole is the proper size for the grinder to be used. When operating these grinders, keep a light pressure on the work to avoid damaging the wheel or overheating the workpiece.

Both the small and the larger portable grinders operate at a high speed, so avoid letting the wheel rest on one spot for too long. This could cause the work to burn or the wheel to crack and explode. Always check the manufacturer's instruction. manual before operation to ensure the grinding wheel's maximum rated speed is rated higher than the maximum speed of the grinder.

When grinding, buffing, or polishing with any portable grinder, always keep a firm grip on the tool to avoid injury or damage to equipment

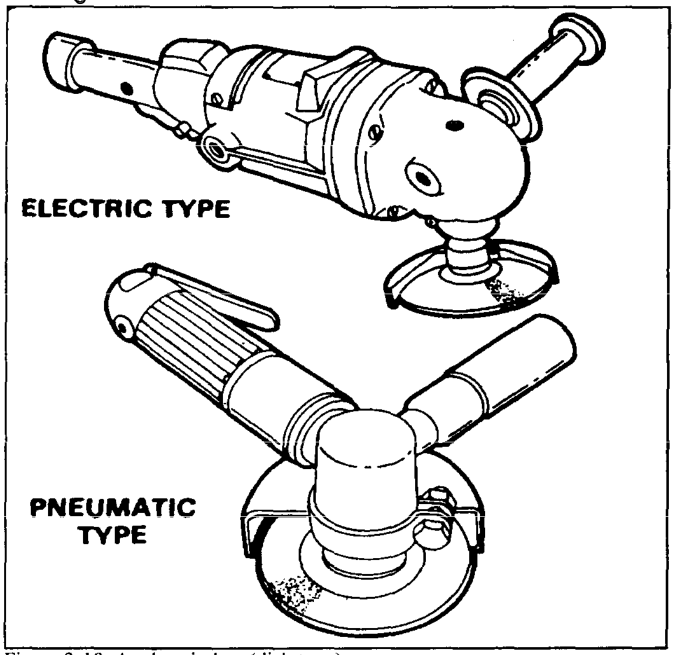


Figure 3-18. Angle grinders (disk type).

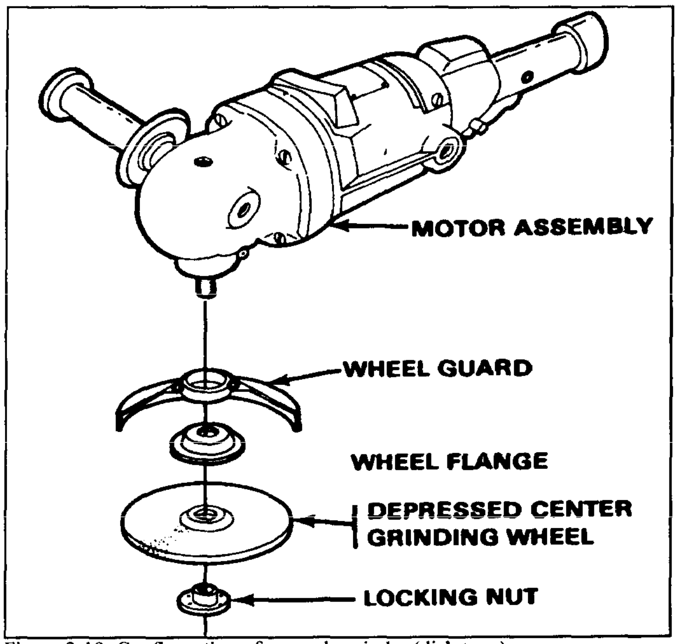


Figure 3-19. Configuration of an angle grinder (disk type).

PORTABLE SANDERS AND POLISHERS

PURPOSE AND TYPES

Portable sanders and polishers are used for surface finishing of materials such as metal, wood, ceramics, and plastics. Both tools are Lightweight and fairly easy cooperate. They can be powered electrically or pneumatically and can be light-duty or heavy duty.

Portable sanders are used to remove paint, rust, corrosion, and imperfections from the surface of workplaces to produce a smooth surface for finishing. Field and machine shop maintenance personnel use the disk-type portable sander (Figure 3-20). The disk-type portable sander has a high-speed motor that rotates an abrasive disk, wire wheel, or a grinding wheel to prepare a surface for finishing. For sanding, a disk of abrasive paper is mounted with a flexible backing pad on the motor spindle (Figure 3-21). The basic motor unit is similar to the motor unit used for angle grinding, but with sanding there is no need for a wheel guard. On some models the motor spindle can be locked by depressing a lock button to install or remove the sanding disks. A side handle on the motor housing is used to support the sander during operation. This handle can be removed and screwed into the opposite side of the motor housing for left-handed operation. Pneumatic sanders have an advantage over electric sanders because they are lighter in weight and easier to handle which usually produces a better finished product.

NOTE: Portable sanders are not intended for use as portable abrasive cutoff saws. The torque for cut off sawing will ruin the soft gearing in the sander motor unit.

Various abrasive disks are used in the operation of the portable electric sander. These disks consist of different abrasive grains that have been bonded or glued onto a cloth or paper disk (see Table 3-2) in Appendix A..

The backing material that supports the abrasive disk is made of a tough vulcanized rubber or fiber that can withstand

hard use and constant flexing. Normally, the abrasive grain used on the disk is aluminum oxide, and the bonding agent is glue or special resin. Abrasive disks come in open-coat or closed-coat types, depending on the work to be performed. The closed-coat disk has the abrasive grains bonded close together, while the open-coat disk has the abrasive grains spaced further apart. Open-coat abrasive disks are used for sanding soft materials that could possibly load up a closed-coat disk, for example, wood sanding, removing paint and rust, and plastic. Closed-coat abrasive disks are used for sanding metal, finishing ceramics, and for smoothing rougher sanded areas.

Most portable sanders come with an instruction manual and those accessories that the manufacturer recommends for its use. These accessories can include a sanding setup which includes a flexible rubber backing plate, several types of sanding disks, and the hardware to secure the disk to the motor assembly. Other accessories may include flexible grinding disks with wheel guards, wire wheels, and odd-shaped grinding cups with the appropriate wheel guard. Only use accessories approved by the manufacturer to avoid injury or damage to equipment.

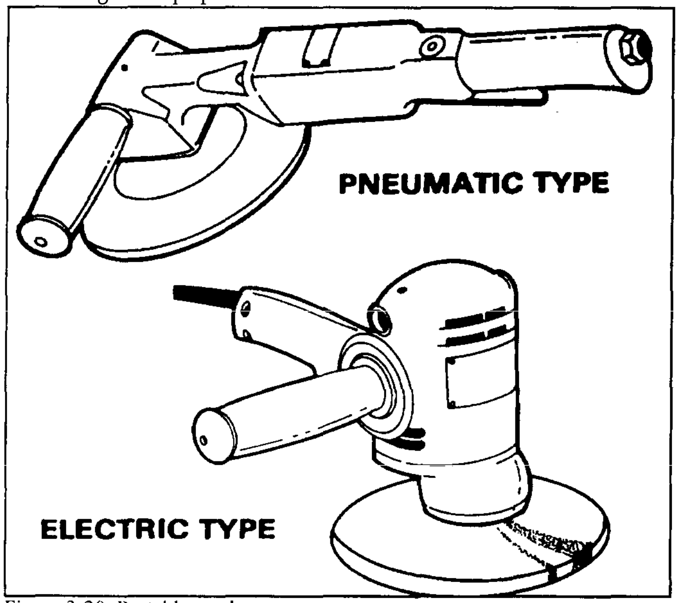


Figure 3-20. Portable sanders.

The portable polisher (Figure 3-22) is used to produce a super finish or shine to the workpiece surface. Polishing or buffing a surface is desirable at times to increase smoothness and make the surface easier to clean. By polishing a surface, a workpiece can also be made more wear resistant. Portable polishers are generally more powerful than portable sanders

Since they encounter a greater frictional resistance when in operation, portable polishers operate at slower speeds than portable sanders so as not to mar the finished surface. Pneumatic portable polishers are lighter in weight than electric models and may make fewer buffing marks on the finish. In order to improve the surface quality of a workpiece through polishing, it is necessary to use a soft bonnet or cover over the sander backing pad.

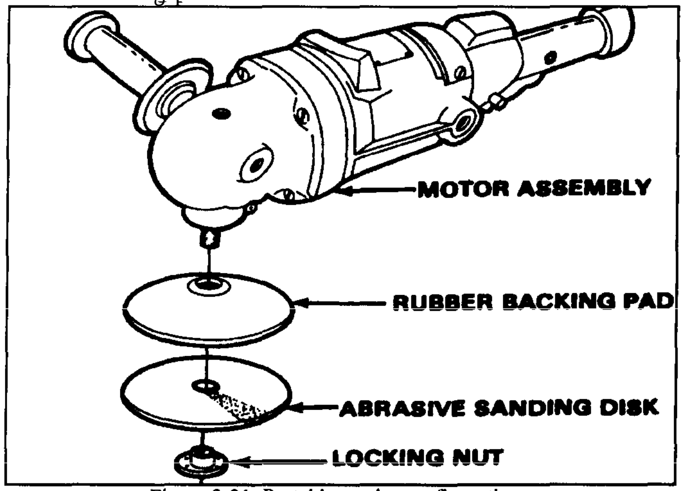


Figure 3-21. Portable sander configurations.

Lamb's wool polishing bonnets are recommended with a soft rubber cushion pad separating the bonnet and the backing pad. Polishing compound, which is a mild abrasive, is used to help polish the surface. A left- or right-handed side handle is attached to the motor housing to help control the polisher during operations.

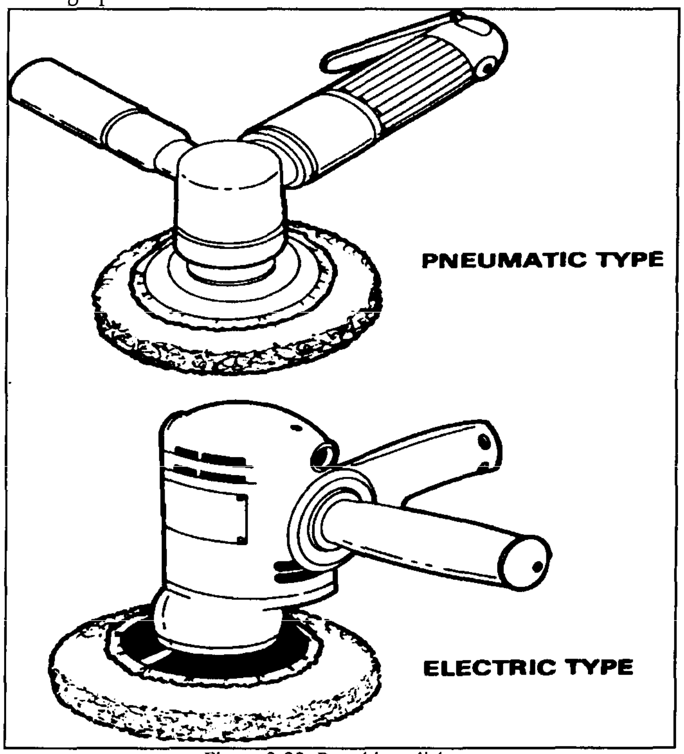


Figure 3-22. Portable polishers.

OPERATIONS WITH THE PORTABLE SANDER AND POLISHER

Operating the portable sander is difficult due to the rotating force of the disk, so the quality of the work depends mostly on the experience of the machine operator. Hold the portable sander so that the abrasive disk forms an angle of approximately 15° to the workpiece surface (Figure 3-23). Apply just enough pressure against the sander to bend the sanding pad and abrasive disk so that about 2 inches of the disk contact the surface. Move the sander from side to side, overlapping each path with the next. If the sander cuts irregularly or is hard to control, the sander is most likely at an angle less than the required 15° to the workpiece. If the sander gouges or leaves rough edges, the angle formed by the sander is most likely too great. When the sander is operating, keep it moving back and forth across the workpiece or lift it free to avoid damaging the surface.

The portable polisher looks like the portable sander but it is built with a slower speed and high torque needed for polishing. Polishing is performed by placing the spinning lamb's wool polishing bonnet lightly against the workpiece and moving the polisher lightly back and forth while maintaining a light pressure on the workpiece. Avoid pressing down too hard, or the surface could get damaged. Use separate polishing bonnets for different polishing abrasives, glazes, or waxes. Reapply polishing compound as needed to keep a smooth finish.

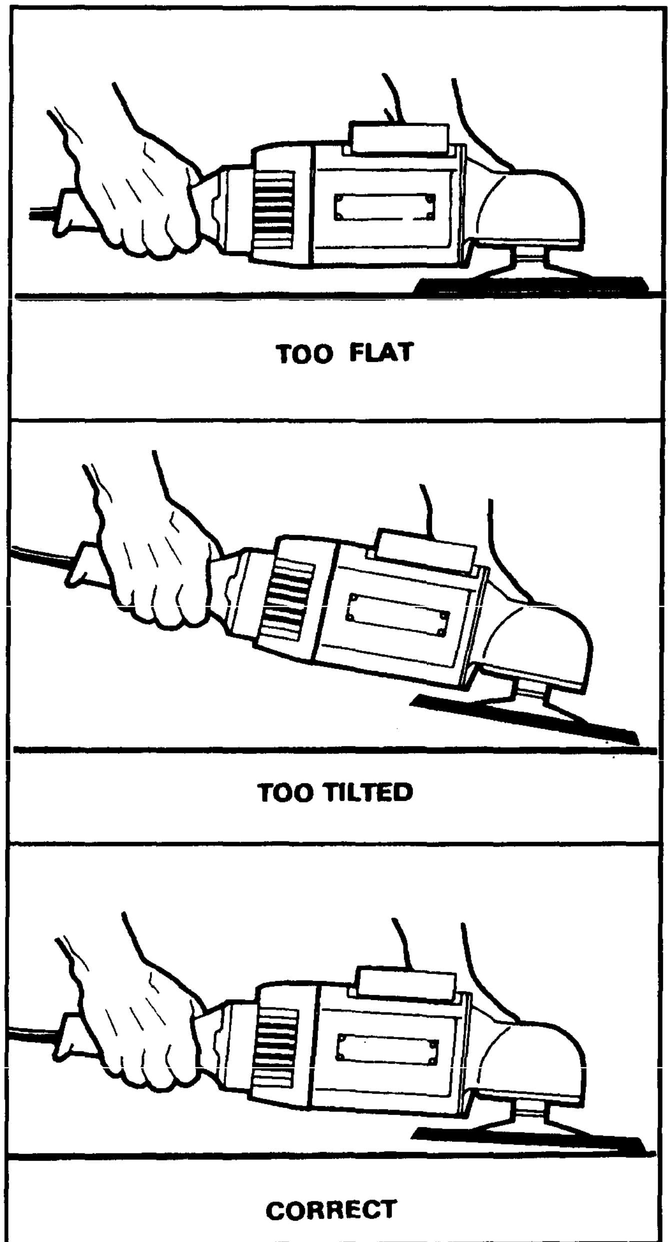


Figure 3-23. Correct and incorrect methods of using the electric sander.

PORTABLE METAL SAWING MACHINES

PURPOSE AND TYPES

The portable metal sawing machines described in this section are those lightweight and easily transportable saws that are used in a field or normal machine shop by maintenance personnel. These saws can be used to cut stock that is too big or too long to move to a maintenance shop to be cut. The following portable sawing machines are described in this section: the portable hacksawing machine, the portable band sawing machine, and the portable reciprocating saw. Two of these saws are operated by hand, so the quality of work depends upon the experience and skill of the operator. Portable metal sawing machines can be used in the maintenance shop to cut wood, steel, plastics, electrical conduit, tubing, pipes, and shop stock, and for auto body work.

THE PORTABLE HACKSAWING MACHINE

The portable hacksawing machine (Figure 3-24) is not designed to be hand-held, but to lock onto the workpiece with a self-contained vise. This saw has a built-in electric motor that causes a power hacksaw blade to reciprocate at a fixed speed of 115 strokes per minute. The machine is capable of cutting solid steel 3 inches square and at an angle to 45°. This saw can be used in a horizontal, angular, or vertical position, having an adjustable counterbalance to compensate for operating the sawing machine in a vertical position. A 10-inch power hacksaw blade is used with this machine, producing a 4-inch stroke. A tension screw permits increasing or decreasing the blade pressure with each cut. The portable hacksawing machine will support itself when fastened very securely to a stationary workpiece, using the self-contained vise.

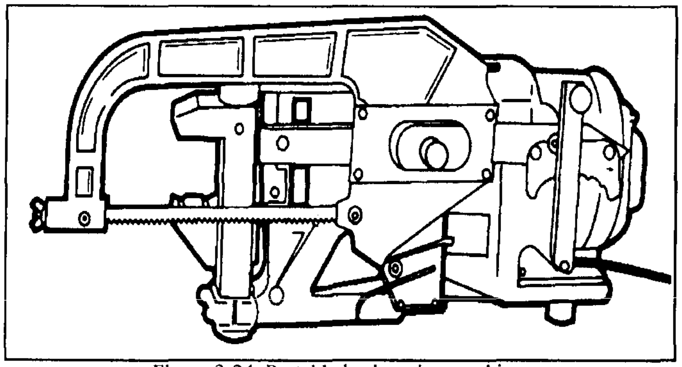


Figure 3-24. Portable hacksawing machine.

To operate the portable hacksawing machine, insert a power hacksaw blade of 18, 24, or 32 teeth per inch, depending on the material to be cut. Then, check the adjustment of the tension screw and the adjustment of the counterbalance lever. Turning the tension screw clockwise will increase the amount of lift the hacksaw blade makes on each return stroke and will increase the downward pressure of the blade on each cutting stroke. Counterclockwise rotation of the screw will decrease the lift and pressure. This control should be adjusted to cause the hacksaw blade to lift 1/8 inch on each return stroke to provide maximum cutting speed and efficiency. The counter balance lever controls the downward pressure exerted upon the hacksaw blade by the weight of the saw frame. By moving the counterbalance lever to the left, the pressure is decreased. Moving the lever to the right increases the pressure. Mount the workpiece squarely or angularly in the vise, depending on the type of cut desired. Start the sawing machine and observe the cutting action. If the machine strains, the blade pressure may be too heavy.

If the machine cuts very slowly, increase the pressure. Continuously check the power hacksaw blade for sharpness. If the blade is dull, it should be replaced. When the machine cuts completely through the material, the saw frame will fall and trip the motor switch, stopping the saw.

When the sawing machine is used in the vertical position, the counterbalance lever must be positioned in the farthest right notch of the guide bar ratchet to compensate for the lack of gravitational pressure normally applied to the blade by the saw frame. This practice should be attempted only if the workpiece can be clamped very securely in the vise and cannot be wrenched loose during vertical sawing, or damage to personnel or equipment could occur .

THE PORTABLE BAND SAWING MACHINE

The portable band sawing machine (Figure 3-25) or portable band saw is a lightweight, hand-held unit powered by an electric motor. The saw motor and gears rotate a solid steel band saw blade around two large wheel pulleys and through several saw blade guides at such an angle to give clearance to the workpiece being cut. The portable band saw can cut steel round stock to 3 3/8 inch diameter or steel rectangular stock 3 3/8-inch thick by 4 1/8 inch wide. The portable metal band sawing blades are 44 7/8 inches long and can have from 6 to 24 teeth per inch, providing a wide range of cutting capabilities (see Table 3-3 in Appendix A). Single-speed band saw models are designed for softer metals, such as brass, aluminum, and mild steel. Two-speed and variable speed models can be switched to a low speed to cut harder metals, such as stainless steel or tungsten. The band saw blade is completely enclosed, using the motor housing as a blade guard, except for the exposed part of the blade that does the sawing. A hand grip and trigger switch are provided on one end of the saw and a knob grip is on the other end to provide for maximum control while sawing.

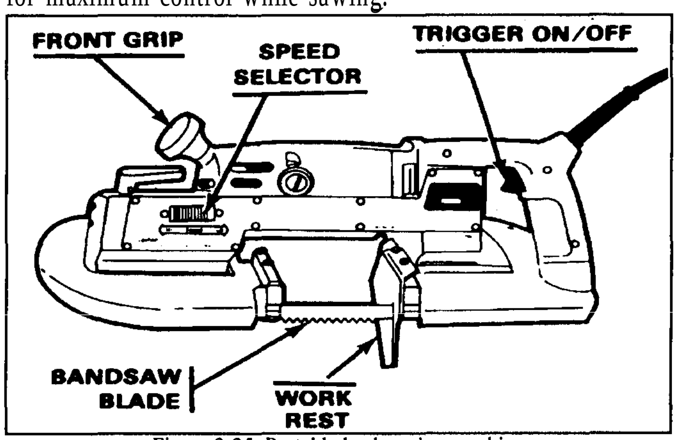


Figure 3-25. Portable hacksawing machine.

To start sawing, make sure that the material to be cut is held very securely in the vise to avoid excessive vibration. Select the appropriate blade for the material to be cut and mount the blade securely into the portable band saw in accordance with the manufacturer's instructions. Take hold of the front knob grip handle and rear hand grip handle and squeeze the trigger switch to start the saw blade in motion. Set the speed appropriately if operating a two-speed or variable-speed model. Gently lower the portable band saw onto the workpiece, being careful to use the weight of the machine as pressure to cut. If the operator uses additional pressure on the workpiece, the saw blade will slow down and reduce the cutting efficiency. Hold the machine steady and the saw blade straight to avoid twisting or breaking the blade. At the completion of the cut, do not allow the saw to fall onto the workpiece. Maintain hand control of the machine, release the trigger switch, and allow the blade to stop before setting down the saw. Never use a liquid coolant with the portable band sawing machine as this could damage the saw guide bearings or rubber pulleys. Lubricate and service each saw as specified in the manufacturer's instructions.

THE PORTABLE RECIPROCATING SAW

The portable reciprocating saw (Figure 3-26) is a hand-held lightweight machine tool that can be electrically or pneumatically powered, depending on the model selected. The saw motor and gearing cause a single knife-like blade to move rapidly in and out, sawing across a workpiece as hand pressure is applied. The saw may be a one-speed model or two speed model. The one-speed model operates at high speed only and is used for cutting soft materials like wood or sheet rock. The two-speed models have a switch that can move the speed from high speed to low speed, so that harder materials, such as metal pipes and steel sheets, can be cut.

The portable reciprocating saw, with the proper blade installed, can cut through steel stock up to 1 inch square or steel pipe up to 4 inches in diameter. An enclosed hand grip handle with trigger switch is provided at one end of the saw and another hand grip is toward the front of the saw, near the blade, to provide for maximum control while sawing. The blade freely protrudes from an angled work rest that is attached to the motor housing. There is no blade guard, so care must be exercised at all times.

To start sawing, ensure the material to be cut is held securely to avoid vibration that could break the saw blade. Select the right blade for the material to be cut and mount the blade into the blade clamp according to the manufacturer's instructions. Check the speed setting, get a firm grip on both handles, and squeeze the trigger switch. Guide the saw so that the work rest is against the workpiece and lower the saw until the blade starts cutting into the workpiece. Keep a firm grip through the saw cut and control the saw to avoid twisting or breaking the blade. After the cut is completed, maintain control of the saw and release the trigger switch. Allow the blade to come to a complete stop before laying the tool down. Periodically lubricate and service the portable reciprocating saw according to the manufacturer's instructions.

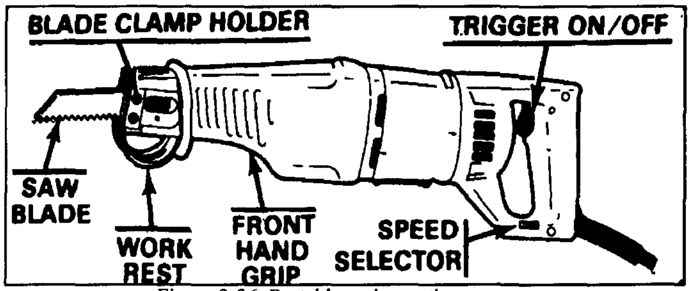


Figure 3-26. Portable reciprocating saw.

PORTABLE METAL CUTTING SHEARS PURPOSE AND TYPES

PURPOSE AND TYPES

The portable metal cutting shears are lightweight, hand-held power tools used to cut through sheet metal. These shears are capable of continuous cutting along a straight or irregular line on a workpiece. Field and machine shop maintenance personnel use the portable metal cutting shears for sheet metal trimming, auto body work, duct work, aircraft structural repair, and cutting template patterns. These tools can be powered by an electric motor or air depending on the model selected.

There are two basic types of portable metal cutting shears: the heavy-duty type with the upper movable blade (single-cut) (Figure 3-27), and the light-duty type with the scissor action blade (doublecut) (Figure 3-28). Both types of shears work well, but there are slight differences in the operation and capabilities of each. Since these are hand controlled tools, the quality of work performed depends upon the experience and skill of the operator.

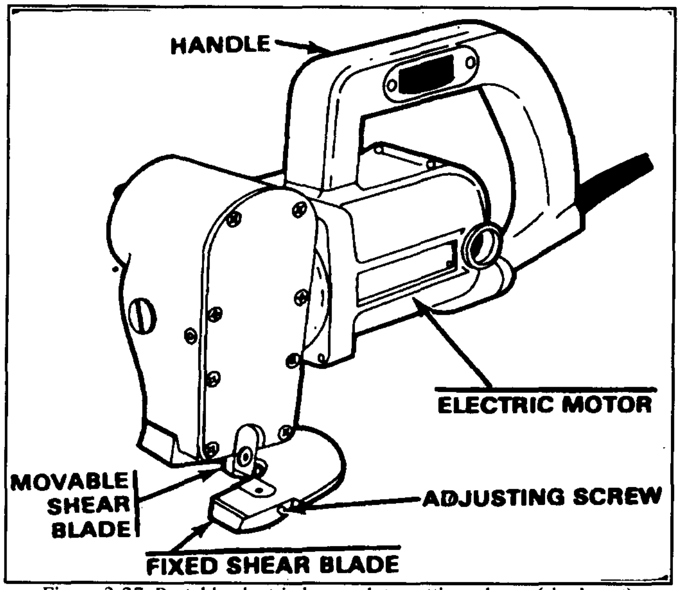


Figure 3-27. Portable electric heavy-duty cutting shears (single cut).

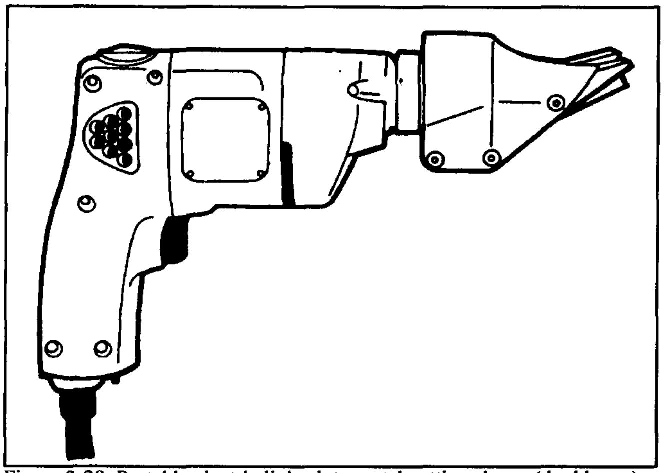


Figure 3-28. Portable electric light-duty metal cutting shears (double cut).

The heavy-duty portable metal cutting shears have an upper, movable shear blade that moves up and down very rapidly over a fixed lower blade so that a continuous single-cut action occurs. The single-cutting action of these shears can cause the sheet metal being cut to warp or bend, so these shears are not recommended for making precision templates or very flat sheet metal pieces. Some models of the very heavy-duty portable metal cutting shears can cut mild sheet steel up to #6 gage or about 3/16-inch, but most maintenance shops use the normal heavy-duty shears capable of cutting up to #12 gage (about 7/64-inch) or thinner. Softer metals can be slightly thicker than the rating for sheet metal and still be cut successfully. The heavy-duty type shear has a blade clearance adjustment so that the best cutting action can be obtained for each type and thickness of metal.

The light-duty portable metal cutting shears operate with a scissor-like motion that makes a double cut by removing a strip of metal about 1/4 inch wide which produces a distortion-free piece (Figure 3-29). These shears are used for thin sheet metal, such as #18 gage (about 3/64-inch) or thinner. A hole about 3/8 inch in diameter is needed to gain access for inside cutting. The rapidly reciprocating blade enables these shears to cut intricate patterns, make models, trim gaskets, and cut out templates from different sheet metal materials. These light-duty type of shears are lighter in weight and much easier to handle than the larger heavy-duty type. The cutting blade clearance is set at the factory, so the only adjustment is to sharpen the blades if the cutting action becomes difficult.

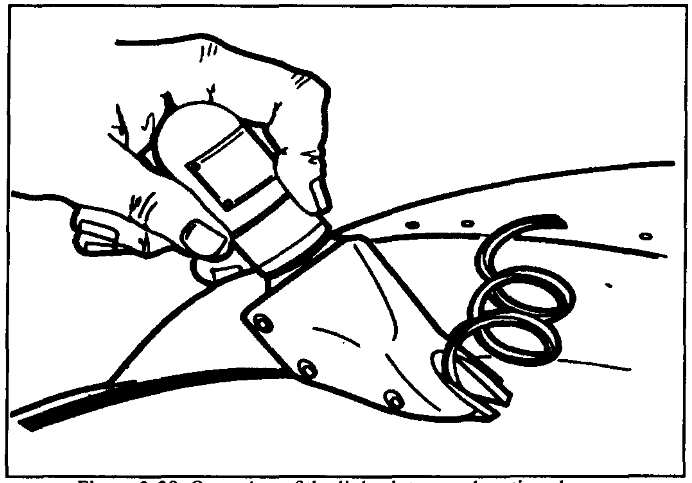


Figure 3-29. Operation of the light-duty metal cutting shears.

OPERATION OF THE PORTABLE METAL CUTTING SHEARS

Successful operation of the portable metal cutting shears depends upon two important factors: sharp shear blades and proper shear blade clearance. The shear blades are easily taken out and sharpened or replaced as needed. Each model is slightly different, so follow the manufacturer's instructions on sharpening or changing the shear blades. When sharpening the shear blades, grind only the top and bottom edges. Never grind the sides of the blades.

If the metal being cut twists or jams beneath the blades, the most likely cause is excessive blade clearance. If the shears bind or stall when cutting through the metal, or if the blades tend to double shear and produce a burred edge, then the blade clearance is probably too small. Sharpen or replace the shear blades if the cutting action becomes slowed or stops, or if the workpiece edges become burred.

Before starting to cut, scribe a line on the workpiece. Holding the portable metal cutting shears in one hand, start cutting from the edge of the sheet metal while keeping the scribed line alongside the reciprocating blade. Only a light forward pressure is required to guide the shears through the metal. Any irregular contours can be followed quickly and easily because one blade is always visible to the operator. If the shear blades are sharp and the clearance for the blades is correct, a clean, smooth cutting action should occur.

PORTABLE COOLANT ATTACHMENT

PURPOSE

The portable coolant attachment is a device for supplying coolants and cutting oils for cutting operations with machine tools when continuous application of a coolant or cutting oil is required. The portable coolant attachment consists of a container to hold the coolant or cutting oil, a pump to force the coolant through a flexible hose directed at the cutting tool and workpiece, and a pan arrangement beneath the machine tool to catch the coolant or cutting oil, filter it, and return it to the container.

The portable coolant attachment (Figure 3-30) is self-contained and powered by an electric motor. The coolant container and catch pans are attached to the bed or frame of the machine tool beneath the work area, and a flexible metal hose is positioned where the stream of coolant or cutting oil from the pump will flood the workpiece and cutting tool at their point of contact. The pans beneath the workpiece catch the coolant as it splashes from the workpiece and strain the coolant as it flows back to the container for recirculation. Coolant can be controlled by a valve at the base of the flexible hose. A pipe plug is provided at the base of the container to drain the coolant from the container after use. The portable coolant attachment moves easily from one machine to another to provide various machines with cooling capabilities.

COOLANT ATTACHMENT OPERATION

The portable coolant attachment serves the needs of a machine shop in a field or regular maintenance facility. It provides coolant for lathes, mills, drilling machines, grinders, sawing machines, and other machine tools. The attachment should be set up under the area of the machine tool that does the cutting action and needs to be cooled. The drip or catch pans should be arranged horizontally to catch the coolant as it drips from the workpiece. Position the flexible hose so that it directs a stream of coolant to the point of contact between the cutting tool and the workpiece.

The portable coolant attachment is a device for supplying coolants and cutting oils for cutting operations with machine tools when continuous application of a coolant or cutting oil is required. The portable coolant attachment consists of a container to hold the coolant or cutting oil, a pump to force the coolant through a flexible hose directed at the cutting tool and workpiece, and a pan arrangement beneath the machine tool to catch the coolant or cutting oil, filter it, and return it to the container.

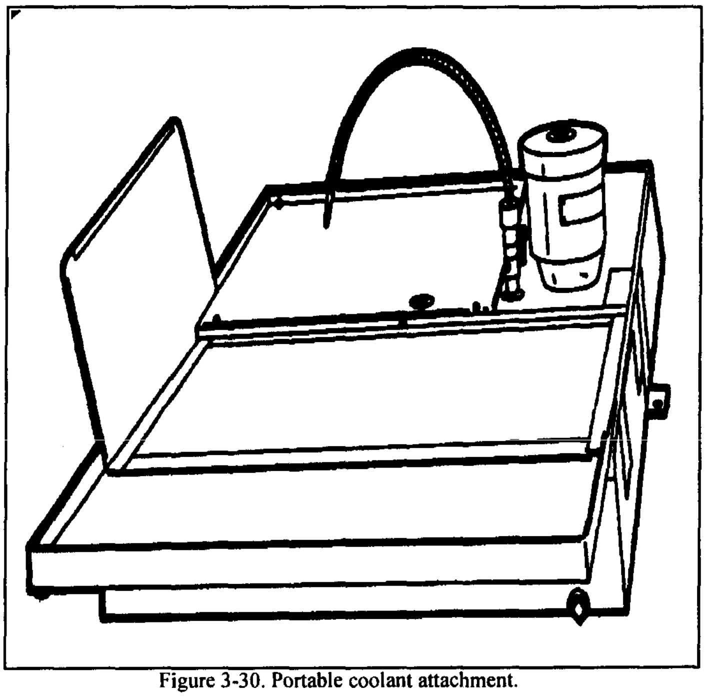


Figure 3-30. Portable coolant attachment.

If the cutting tool moves along the workpiece, clip the hose end to the cutting tool carriage so that the hose will move with the tool.

The material to be machined will determine whether to use a coolant or a cutting oil. Fill the container of the portable coolant attachment with the selected coolant or cutting oil. Start the pump motor of the attachment before starting the machine tool to check the flow of coolant over the workpiece being machined, and adjust the stream flow as necessary. Start the machine tool and perform the cutting operation. At the conclusion of the operation, stop the pump motor. Drain the coolant or cutting oil from the container by removing the plug at the bottom of the container. Clean out the container, pump, and hose before using a different type of coolant.

Chapter 4

DRILLING MACHINES

GENERAL INFORMATION

PURPOSE

This chapter contains basic information pertaining to drilling machines. A drilling machine comes in many shapes and sizes, from small hand-held power drills to bench mounted and finally floor-mounted models. They can perform operations other than drilling, such as countersinking, counterboring, reaming, and tapping large or small holes. Because the drilling machines can perform all of these operations, this chapter will also cover the types of drill bits, took, and shop formulas for setting up each operation.

Safety plays a critical part in any operation involving power equipment. This chapter will cover procedures for servicing, maintaining, and setting up the work, proper methods of selecting tools, and work holding devices to get the job done safely without causing damage to the equipment, yourself, or someone nearby.

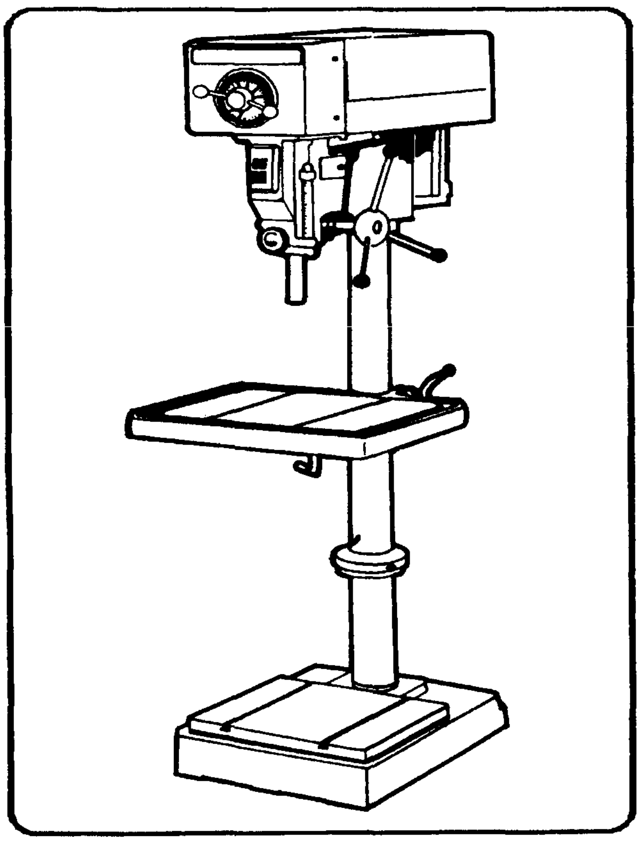


Figure 4-1. Upright drilling machine.

USES

A drilling machine, called a drill press, is used to cut holes into or through metal, wood, or other materials (Figure 4-1). Drilling machines use a drilling tool that has cutting edges at its point. This cutting tool is held in the drill press by a chuck or Morse taper and is rotated and fed into the work at variable speeds. Drilling machines may be used to perform other operations. They can perform countersinking, boring, counterboring, spot facing, reaming, and tapping (Figure 4-2). Drill press operators must know how to set up the work, set speed and feed, and provide for coolant to get an acceptable finished product. The size or capacity of the drilling machine is usually determined by the largest piece of stock that can be center-drilled (Figure 4-3). For instance, a 15-inch drilling machine can center-drill a 30-inch-diameter piece of stock. Other ways to determine the size of the drill press are by the largest hole that can be drilled, the distance between the spindle and column, and the vertical distance between the worktable and spindle.

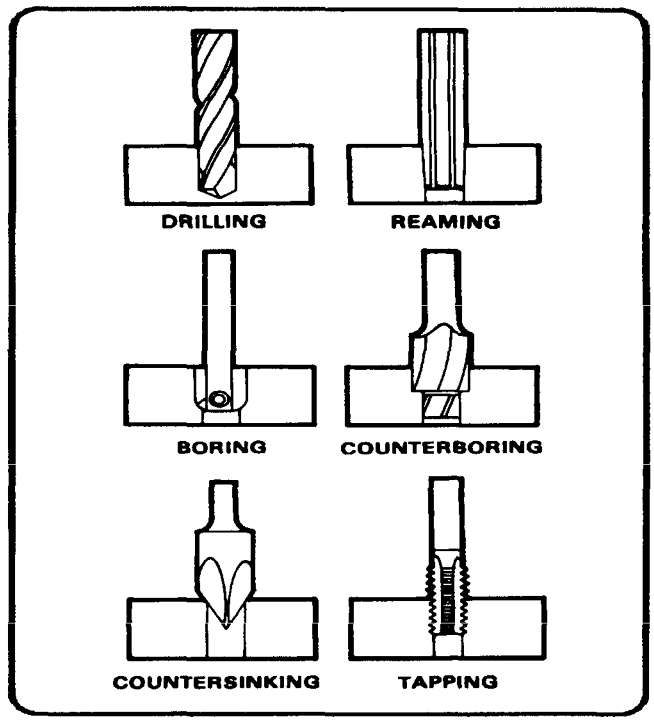
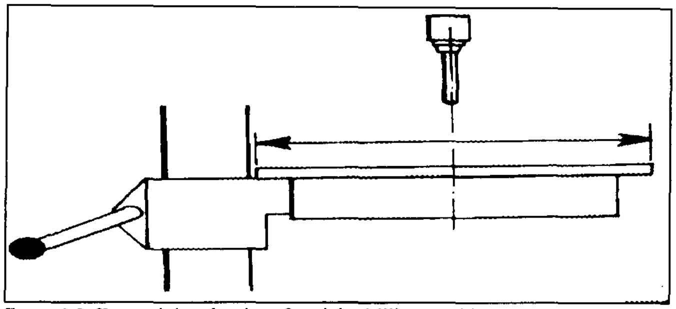


Figure 4-2. Operations of the upright drilling machine.



Fgure 4-3. Determining the size of upright drilling machines.

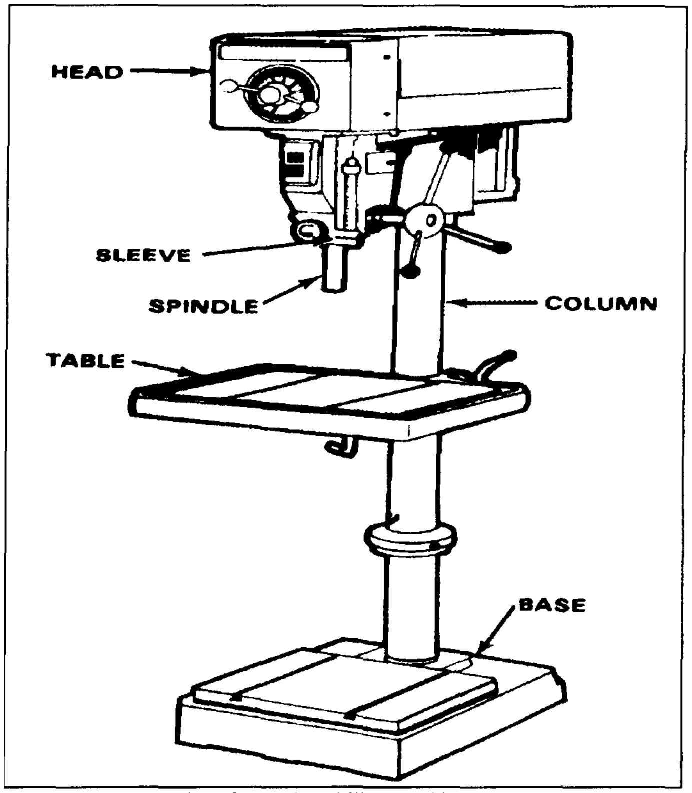


Figure 4-4. Construction of an upright drilling machine.

CHARACTERISTICS

All drilling machines have the following construction characteristics (Figure 4-4): a spindle. sleeve or quill. column, head, worktable, and base.

- The spindle holds the drill or cutting tools and revolves in a fixed position in a sleeve. In most drilling machines, the spindle is vertical and the work is supported on a horizontal table.
- The sleeve or quill assembly does not revolve but may slide in its bearing in a direction parallel to its axis. When the sleeve carrying the spindle with a cutting tool is lowered, the cutting tool is fed into the work: and when it is moved upward, the cutting tool is withdrawn from the work. Feed pressure applied to the sleeve by hand or power causes the revolving drill to cut its way into the work a few thousandths of an inch per revolution.
- The column of most drill presses is circular and built rugged and solid. The column supports the head and the sleeve or quill assembly.
- The head of the drill press is composed of the sleeve, spindle, electric motor, and feed mechanism. The head is bolted to the column.
- The worktable is supported on an arm mounted to the column. The worktable can be adjusted vertically to accommodate different heights of work. or it may be swung completely out of the way. It may be tilted up to 90° in either direction, to allow for long pieces to be end or angled drilled.
- The base of the drilling machine supports the entire machine and when bolted to the floor, provides for vibration-free operation and best machining accuracy. The top of the base is similar to a worktable and maybe equipped with T-slots for mounting work too large for the table.

CARE OF DRILLING MACHINES

Lubrication

Lubrication is important because of the heat and friction generated by the moving parts. Follow the manufacturer's manual for proper lubrication methods. Clean each machine after use. Clean T-slots. grooves. and dirt from belts and pulleys. Remove chips to avoid damage to moving parts. Wipe all spindles and sleeves free of grit to avoid damaging the precision fit. Put a light coat of oil on all unpainted surfaces to prevent rust. Operate all machines with care to avoid overworking the electric motor.

Special Care

Operations under adverse conditions require special care. If machines are operated under extremely dusty conditions. operate at the slowest speeds to avoid rapid abrasive wear on the moving parts and lubricate the machines more often. Under extreme cold conditions, start the machines at a slow speed and allow the parts and lubricants to warm up before increasing the speeds. Metal becomes very brittle in extreme cold. so do not strike the machines with hard tools. Extreme heat may cause the motor to overheat. so use intermittent. or on and off, operations to keep the motor running cool.

TYPES OF DRILLING MACHINES

There are two types of drilling machines used by maintenance personnel for repairing and fabricating needed parts: hand-feed or power-feed. Other types of drilling machines, such as the radial drill press. numerically controlled drilling machine. multiple spindle drilling machine, gang drilling machine, and turret drill press, are all variations of the basic hand and power-feed drilling machines. They are designed for high-speed production and industrial shops.

Drilling depth is controlled by a depth-stop mechanism located on the side of the spindle. The operator of the machine must use a sense of feel while feeding the cutting tool into the work. The operator must pay attention and be alert. to when the drill breaks through the work, because of the tendency of the drill to grab or snag the workpiece, wrenching it free of its holding device. Due to the high speed of these machines, operations that require drilling speeds less than 450 revolutions per minute cannot be performed.

Reaming, counterboring, and counter-sinking may require slower speeds than drilling and may not be able to be performed for all materials on these machines.

Hand-Feed

The hand-feed drilling machines (Figure 4-5) are the simplest and most common type of drilling machines in use today. These are light duty machines that are hand-fed by the operator, using a feed handle. so that the operator is able to "feel" the action of the cutting tool as it cuts through the workpiece. These drilling machines can be bench or floor-mounted. They are driven by an electric motor that turns a drive belt on a motor pulley that connects to the spindle pulley. Hand-feed machines are essentially high-speed machines and are used on small workplaces that require holes 1/2 inch or smaller. Normally, the head can be moved up and down on the column by loosening the locking bolts. which allows the drilling machine to drill different heights of work.

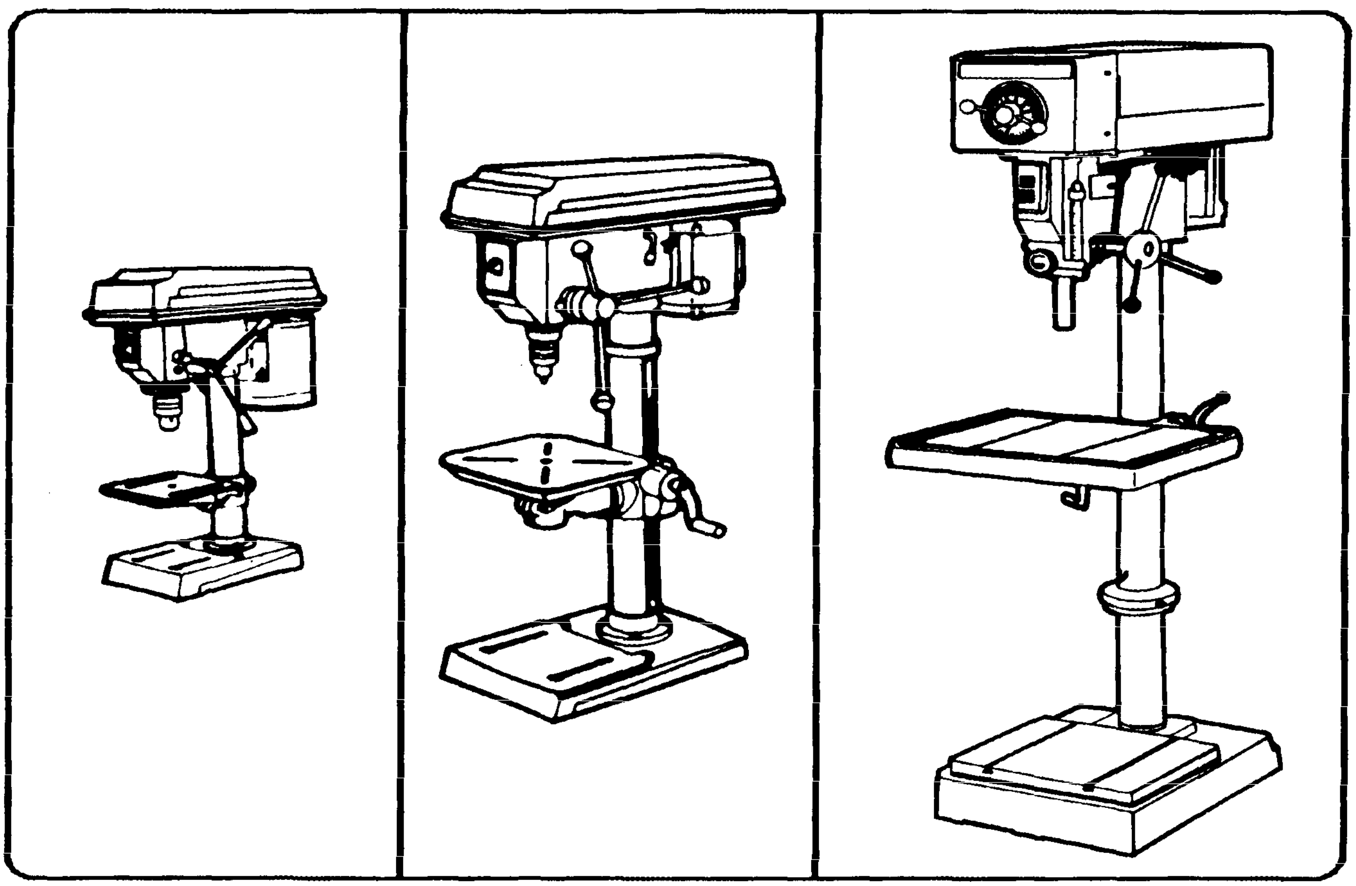


Figure 4-5. Hand-feed drilling machine.

Power-Feed

The power-feed drilling machines (Figure 4-6) are usually larger and heavier than the hand-feed. They are equipped with the ability to feed the cutting tool into the work automatically, at a preset depth of cut per revolution of the spindle, usually in thousandths of an inch per revolution.

These machines are used in maintenance shops for medium-duty work, or work that uses large drills that require power feeds. The power-feed capability is needed for drills or cutting took that are over 1/2 inch in diameter, because they require more force to cut than that which can be provided by using hand pressure. The speeds available on power-feed machines can vary from about 50 RPM to about 1,800 RPM. The slower speeds allow for special operations, such as counterboring, countersinking, and reaming.

The sizes of these machines generally range from 17-inch to a 22-inch center-drilling capacity, and are usually floor mounted. They can handle drills up to 2 inches in diameter, which mount into tapered Morse sockets. Larger workplaces are usually clamped directly to the table or base using T-bolts and clamps, while small workplaces are held in a vise. A depth-stop mechanism is located on the head, near the spindle, to aid in drilling to a precise depth.

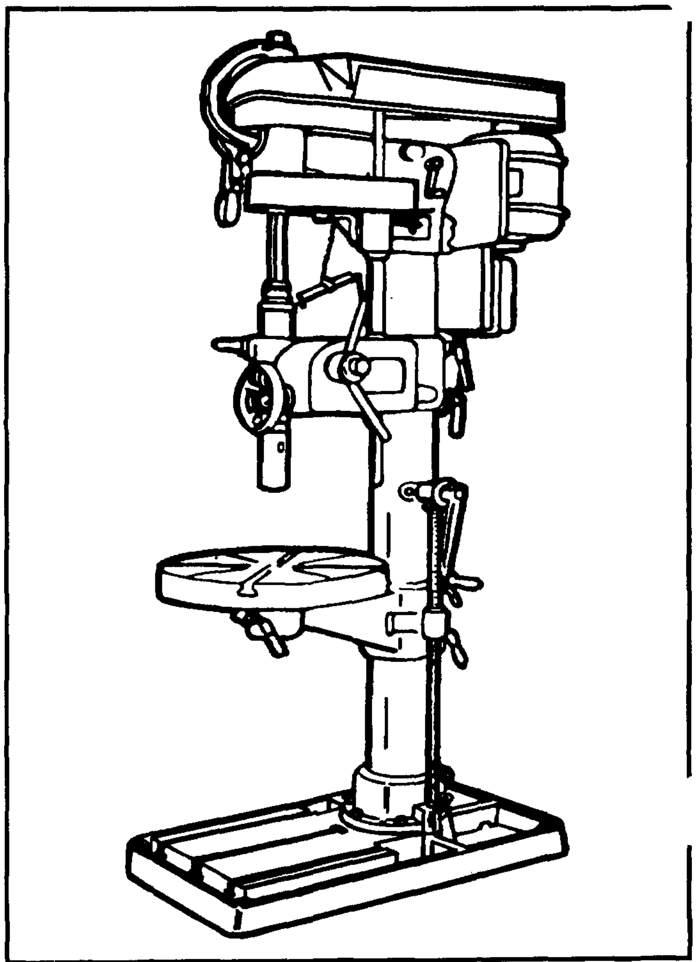


Figure 4-6. Power-feed drilling machine.

SAFETY PRECAUTIONS

GENERAL

Drilling machines have some special safety precautions that are in addition to those listed in Chapter 1.

DRILLING MACHINE SAFETY

Drilling machines are one of the most dangerous hand operated pieces of equipment in the shop area. Following safety procedures during drilling operations will help eliminate accidents, loss of time, and materials. Listed below are safety procedures common to most types of drilling machines found in the machine shop.

- Do not support the workplaces by hand. Use a holding device to prevent the workpiece from being tom from the operator's hand.
- Never make any adjustments while the machine is operating.
- Never clean away chips with your hand. Use a brush.
- Keep all loose clothing away from turning tools.
- Make sure that the cutting tools are running straight before starting the operation.

- Never place tools or equipment on the drilling tables.
- Keep all guards in place while operating.
- Ease up on the feed as the drill breaks through the work to avoid damaged tools or workplaces.
- Remove all chuck keys and wrenches before operating.
- Always wear eye protection while operating any drilling machines.

TOOLS AND EQUIPMENT

TWIST DRILLS

Twist drills are the most common cutting tools used with drilling machines. Twist drills are designed to make round holes quickly and accurately in all materials. They are called twist drills mainly because of the helical flutes or grooves that wind around the body from the point to the neck of the drill and appear to be twisted (Figure 4-7). Twist drills are simply constructed but designed very tough to withstand the high torque of turning, the downward pressure on the drill, and the high heat generated by friction.

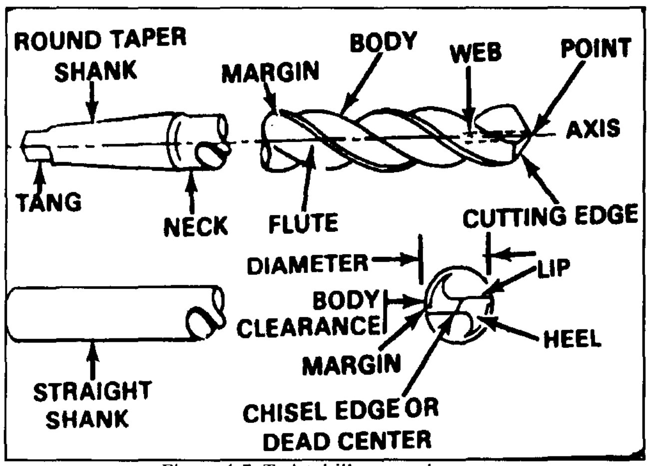


Figure 4-7. Twist drill nomenclature.

There are two common types of twist drills, high-speed steel drills, and carbide-tipped drills. The most common type used for field and maintenance shop work is the high-speed steel twist drill because of its low cost. Carbide-tipped metal drills are used in production work where the drill must remain sharp for extended periods, such as in a numerically controlled drilling machine. Other types of drills available are: carbide tipped masonry drills, solid carbide drills, TiN coated drills, parabolic drills and split point drills. Twist drills are classified as straight shank or tapered shank (Figure 4-7). Straight shank twist drills are usually l/2-inch or smaller and tit into geared drill chucks, while tapered shank drills are usually for the larger drills that need more strength which is provided by the taper socket chucks.

Common twist drill sizes range from 0.0135 (wire gage size No. 80) to 3.500 inches in diameter. Larger holes are cut by special drills that are not considered as twist drills. The standard sizes used in the United States are the wire gage numbered drills, letter drills, fractional drills, and metric drills (See Table 4-1, in Appendix A). Twist drills can also be classified by the diameter and length of the shank and by the length of the fluted portion of the twist drill.

Wire gage twist drills and letter twist drills are generally used where other than standard fractional sizes are required, such as drilling holes for tapping. In this case, the drilled hole forms the minor diameter of the thread to be cut, and the major diameter which is cut by tapping corresponds to the common fractional size of the screw. Wire gage twist drills range from the smallest to the largest size; from No 80 (0.01 35 inch) to No 1 (0.2280 inch). The larger the number, the smaller the diameter of the drill. Letter size twist drills range from A (0.234 inch) to Z (0.413 inch). As the letters progress, the diameters become larger.

Fractional drills range from 1/64 to 1 3/4 inches in l/64-inch units; from 1/32 to 2 1/4 inches in 1/32-inch units, and from 1/1 6 to 3 1/2 inches in 1/16-inch units.

Metric twist drills are ranged in three ways: miniature set, straight shank, and taper shank. Miniature metric drill sets range from 0.04 mm to 0.99 mm in units of 0.01 mm. Straight shank metric drills range from 0.05 mm to 20.0 mm in units from 0.02 mm to 0.05 mm depending on the size of the drill. Taper shank: drills range in size from 8 mm to 80 mm in units from 0.01 mm to 0.05 mm depending on the size of the drill.

The drill gage (Figure 4-8) is used to check the diameter size of a twist drill. The gage consists of a plate having a series of holes. These holes can be numbered, lettered, fractional, or metric-sized twist drills. The cutting end of the drill is placed into the hole to check the size. A micrometer can also be used to check the size of a twist drill by measuring over the margins of the drill (Figure 4-9). The smaller sizes of drills are not usually marked with the drill size or worn drills may have the drill size rubbed off, thus a drill gage or micrometer must be used to check the size.

It is important to know the parts of the twist drill for proper identification and sharpening (Figure 4-7).

The point is the entire conical shaped end of the drill containing the cutting edges and chisel edge.

The body is the part of the drill that is fluted and relieved.

The shank is the part that fits into the holding device, whether it is a straight shank or a tapered shank.

The chisel edge is the point at which the two lips meet. The chisel edge acts as a chisel when the drill is turning and cuts into the workpiece. The chisel edge must always be centered exactly on the drill's axis for accurate cutting action.

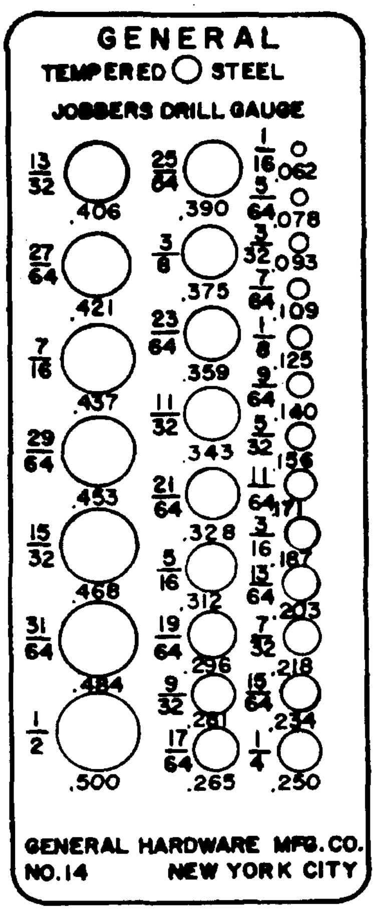


Figure 4-8. Drill gage.

The cutting edge lips cut like knives when fed and rotated into the workpiece. The lips are sharp edges formed by grinding the flutes to a conical point.

The heel is the conical shaped portion of the point in back of the cutting edge lips.

The amount of slope given to the heel in back of the drill lips is called lip clearance. This clearance is necessary to keep the heel from rubbing the bottom of the hole being drilled. Rubbing would prevent the drill from cutting.

The flute *is* the helical groove on the drill. It carries out the chips and admits coolant to the cutting edges.

The margin is the narrow surface along the flutes that determines the size of the drill and keeps the drill aligned.

The portion of the drill body that is relieved behind the margin is known as the body clearance. The diameter of this part is less than that of the margin and provides clearance so that all of the body does not rub against the side of the hole and cause friction. The body clearance also permits passage of lubricants around the drill.

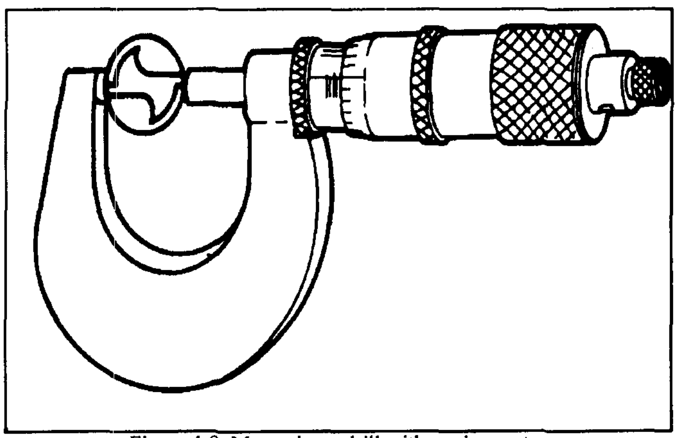


Figure 4-9. Measuring a drill with a micrometer.

The narrowed end of the tapered shank drill is called the tang. The tang fits the slot in the innermost end of the drill spindle, drill chuck, or other drill holding device and aids in driving the tool. It also prevents the drill from slipping.

The web of the drill is the metal section separating the flutes. It runs the length of the body between the flutes. The web gradually increases in thickness toward the shank, increasing the rigidity of the drill.

An imaginary line through the center of the drill from end to end is the axis. The drill must rotate evenly about the axis at all times.

SPECIAL DRILLS

Special drills are needed for some applications that a normal general purpose drill cannot accomplish quickly or accurately. Special drills can be twist drill type, straight fluted type, or special fluted. Special drills can be known by the job that they are designed for, such as aircraft length drills, which have an extended shank. Special drills are usually used in. high-speed industrial operations. Other types of special drills are: left hand drill, Silver and Deming, spotting, slow spiral, fast spiral, half round, die, flat, and core drills. The general purpose high-speed drill, which is the common twist drill used for most field and maintenance shops, can be reground and adapted for most special drilling needs.

SHARPENING TWIST DRILLS

Twist drills become dull and must be resharpened. The preferred method of resharpening a twist drill is with the drill grinding machine, but this machine is not always available in field and maintenance units, so the offhand method of drill sharpening must be used (Figure 4-10). The off hand method requires that the operator have a knowledge of the drilling geometry (Figure 4-11) and how to change drill angles as needed for any drilling job (see Table 4-2 in Appendix A).

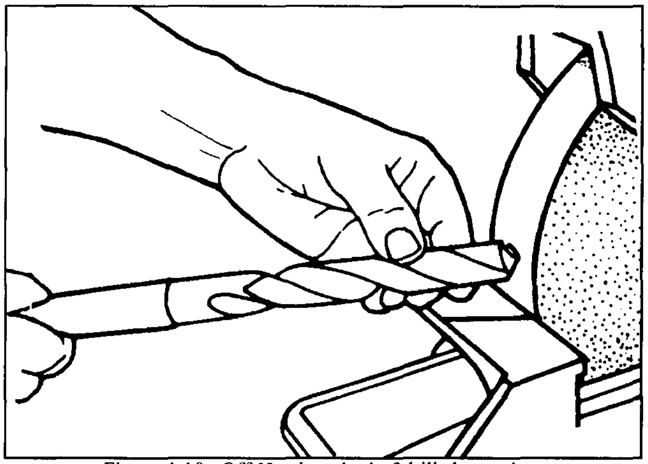


Figure 4-10. Off-Hand method of drill sharpening.

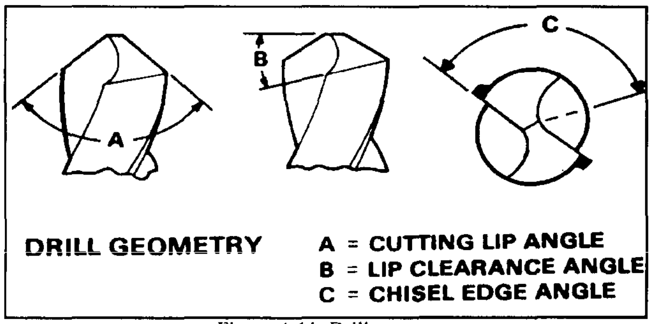


Figure 4-11. Drill geometry.

Tools needed are a utility or bench grinder with a dressed wheel and a drill point gage (Figure 4-12) or protractor head on the combination square. The drill point gage is set at 59° and adjusted along the steel rule to fit the drill to be sharpened. The cutting lips must be of the same angle, the lip clearance angle must be within a specific degree range, and the cutting lips must be of an equal length. There are several basic characteristics that all twist drills must have to cut properly. The following will cover those characteristics.

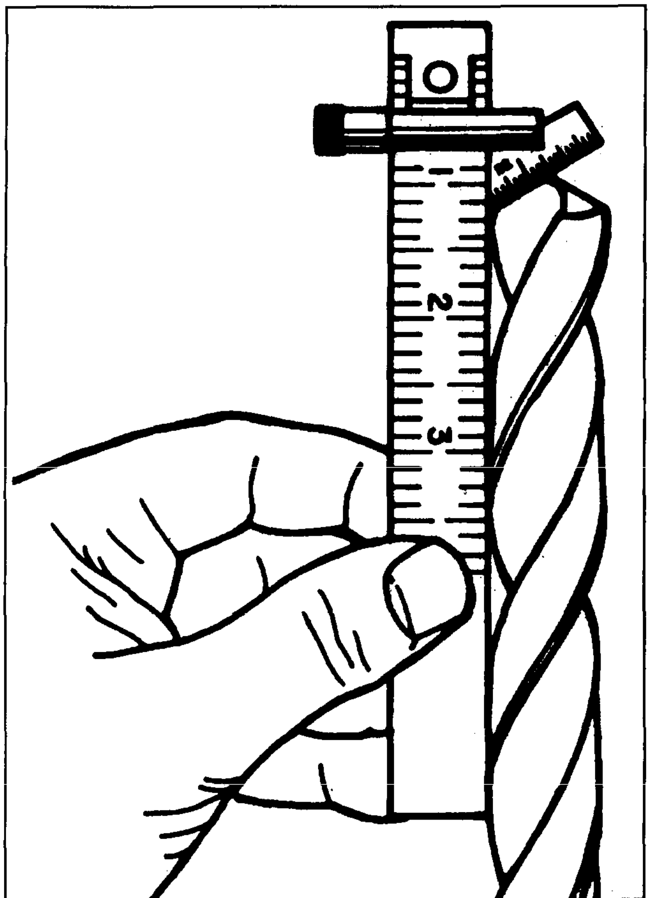


Figure 4-12. Checking the lip angle.

PRECHECK

Before sharpening a twist drill, the operator must check the condition of the drill for chipped and cracked lips or edges that must be ground off during the sharpening process. The operator must also check the references for the proper lip angle and lip clearance angle for the material to be drilled. After setting up the bench grinder for offhand drill sharpening, the operator assumes a comfortable stance in front of the grinding wheel to sharpen the twist drill. The suggested method is to grind the lip angle first, then concentrate on grinding the lip clearance angle, which will then determine the lip length. The usual lip angle is an included angle of 118° (59° x 2) (Figure 4-13), which is the lip angle of general purpose drills. Use the drill point gage frequently to check lip angle and lip length. When grinding, do not allow the drill to become overheated. Overheating will cause the drill edges to become blue which is an indication that the drill's temper has been lost. The blue area must be ground completely away to reestablish the drill's temper. If a drill becomes too hot during sharpening, the lips can crack when dipped into cold water or coolant.

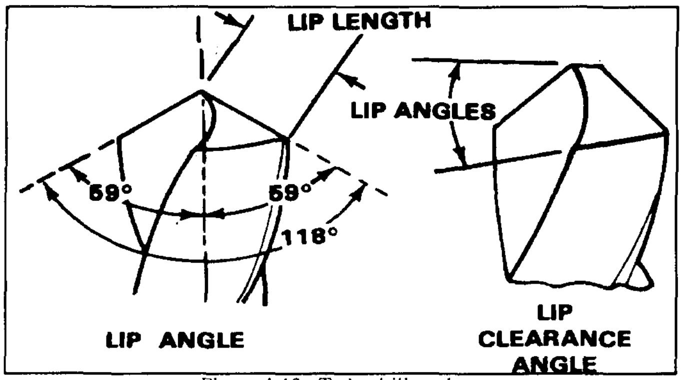


Figure 4-13. Twist drill angles.

DRILL POINT

When grinding the lip angle, use the drill point gage and grind one lip perfectly straight and at the required angle (usually 590). Then flip the drill over and grind the other lip. Once the angle is established, then the lip clearance angle and lip length can be ground. If both lips are not straight and of the same angle, then the chisel edge (Figure 4-14) will not be established. It is it important to have a sharp and centered chisel edge or the drill will not rotate exactly on its center and the hole will be oversized. If the drill point is too flat, it will not center properly on the workpiece. If the drill point is too steep, the drill will require more power and cut slowly. When the angles of the cutting lips are different, then the drill will only have one lip cutting as it revolves. The hole will be oversized and the drill will wear very rapidly.

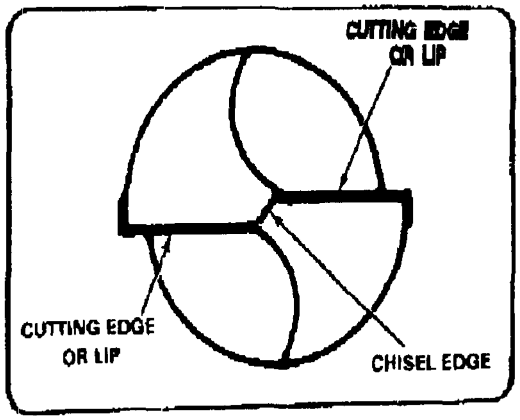


Figure 4-14. The drill point.

When both the angles and the length of the angles are incorrect, then excessive wear is put on both the drill and machine, which will result in poor workmanship (Figure 4-15).

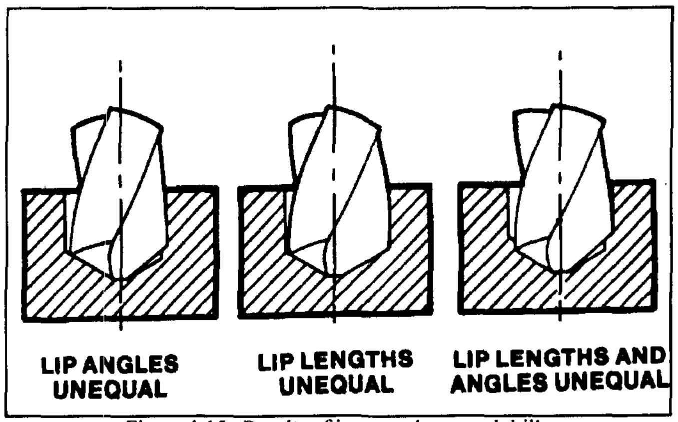


Figure 4-15. Results of improperly ground drills.

CLEARANCE ANGLE

When grinding the lip clearance angle, (Figure 4-13), relief must be given to both cutting edges allowing them to enter into the workpiece to do the cutting. General purpose drills have a clearance of 8° to 12°. The chisel edge of a correctly ground drill should be at an angle of about 45° with the line of the cutting edges. The angle of the chisel edge to the lips is a guide to the clearance (Figure 4-16). Too much clearance will cause the drill to break down because of insufficient support of the lip, and there will not be enough lip thickness to carry away the generated heat.

Too little clearance will result in the drill having little or no cutting edges, and the increased pressure required to feed it into the hole will cause the drill to break. By looking straight onto the cutting tip of the drill, the operator can see if the chisel edge is correct. If the chisel edge is correct at 45° to the

lips, then it is an indication that the lip clearance angle is correct. An incorrect chisel edge is usually produced by holding the drill at an incorrect angle to the wheel (Figure 4-17) when grinding. A good guide is to hold the drill parallel to the ground, and make slight adjustments.

RAKE ANGLE

The angle between the flute and the axis of the drill that forms the cutting edge is known as the rake angle (Figure 4-18). Generally, the rake angle is between 180 and 450, with 30° being the most common. Drills used on armor plate or other very hard materials need a reduced rake angle to increase the support behind the cutting edge. Soft materials, like brass and bronze, also use a reduced rake angle to prevent the drill from grabbing. The rake angle partially governs the tightness with which the chips curl and the amount of space they occupy. If the rake angle is too small, the lips may be too thin and break under the strain of drilling. Too large of a rake angle makes the drill chatter and vibrate excessively.

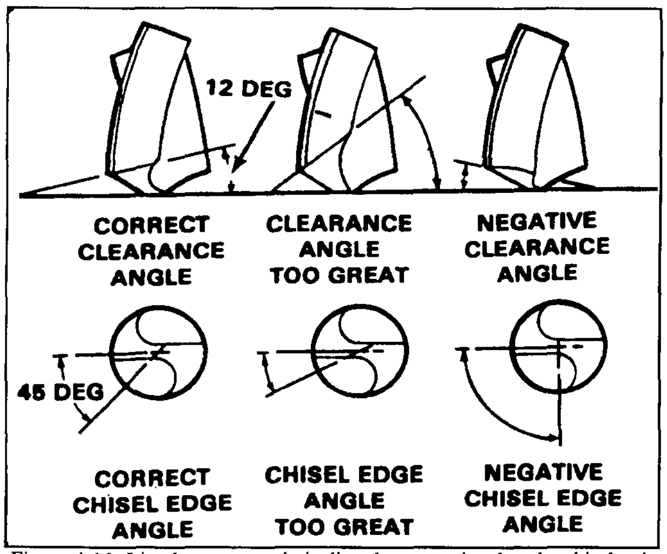


Figure 4-16. Lip clearance angle is directly proportional to the chisel point.

The web of a drill is made thicker toward the shank to strengthen the tool. In smaller size drills, the difference is not noticeable, but in larger drills, when the point is ground back by repeated sharpening, the thickness of the web becomes greater and the chisel edge of the drill becomes wider. This causes the chisel edge to scrape on the bottom of the hole and requires excessive pressure to be applied to the drill. This can be corrected by thinning the web (Figure 4-19). The point is ground thinner on a thin grinding wheel with a rounded face to fit into the flute. An equal amount of metal should be ground from each flute. The web should not be ground too thin as this may weaken the web and cause the drill to split in the middle.

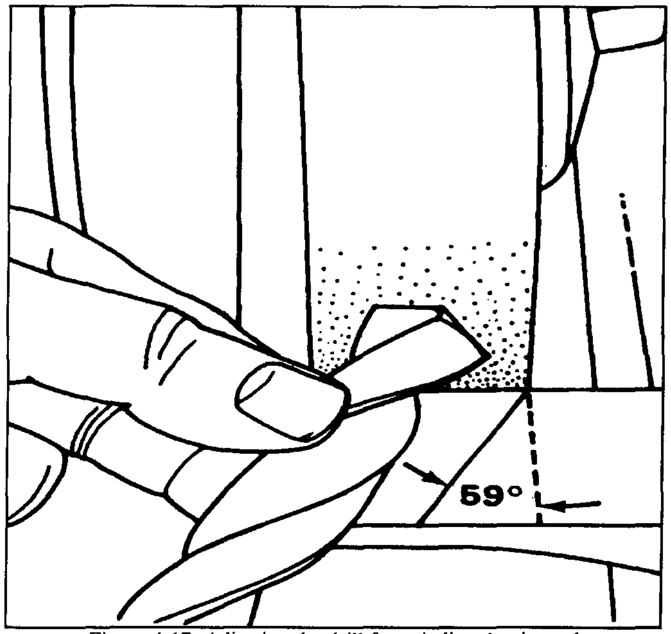


Figure 4-17. Adjusting the drill for grinding the tip angle.

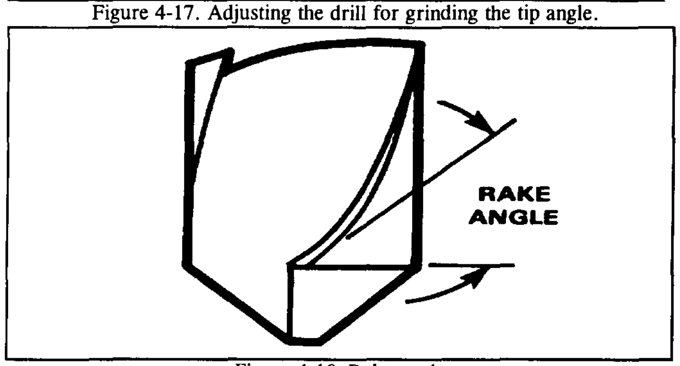


Figure 4-18. Rake angle.

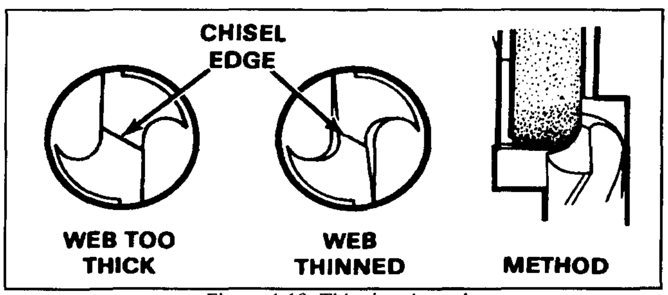


Figure 4-19. Thinning the web.

DRILL GRINDING MACHINES

Drill grinding machines (Figure 4-20) make the accurate grinding of all types and sizes of drills an easy job. Comparatively little skill is required to sharpen drills with these machines while following the operating instructions.

They are particularly valuable when a large number of the same general type of drills are to be sharpened. Two basic designs for the bench-type drill grinding machines are available. Both perform the same operations but use different drill holding devices. The capacity of these machines is stated in the horsepower of the electric motor and the sizes of drills which can be accommodated by the drill holding devices.

SINGLE WHEEL FIXTURE

One kind of bench-type drill grinding machine consists of an electric motor, a grinding abrasive wheel attached to the motor shaft, and fixtures to hold and position all types of twist drills for drill grinding. A web thinning drill grinding attachment, drill holder assembly, and swinging arm hold the drill in a fixed position for each grinding operation and permit the cutting edge lips to be ground symmetrically at the correct angle and with the correct clearance to ensure long life and efficient cutting. Collets and bushings are supplied with the drill grinding machine to hold a wide range of different sized drills. The grinding machine has a diamond set in the wheel-dressing arm to dress the grinding wheel as necessary.

DOUBLE WHEEL SWING ARM

Another kind of bench type drill grinding machine is equipped with two grinding abrasive wheels, one at each end of the motor shaft. One wheel is beveled for thinning the web of the drill at the point. The other wheel is used for lip grinding. The grinder includes a wheel holder assembly for mounting the drill and providing a means for bringing the drill into contact with the grinding wheel at the correct angle and feed to obtain proper clearance angles. A thinning drill point rest is mounted forward of the beveled grinding abrasive wheel to rest and guide the drill during web thinning operations. A wheel dresser is provided to dress the grinding wheel as necessary.

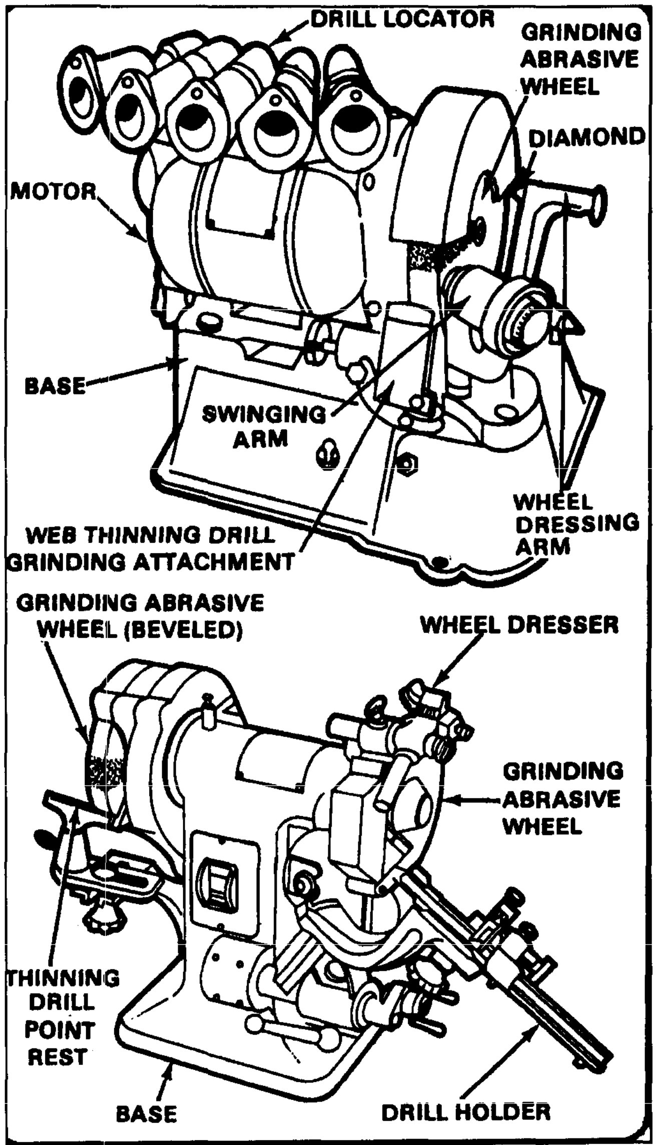


Figure 4-20. Drill grinding machines

OTHER TYPES OF CUTTERS

Drilling machines use cutters, that are not drills, to produce special holes. Below are listed the most common types.

COUNTERSINKS

Countersinks (Figure 4-21) are special angled cutters used to countersink holes for flathead screws so they are flush with the surface when mounted. The most common countersinks are cone shaped with angles of 82°. Cone angles of 60°, 90°,100°,110°, and 120° are for special needs.

COUNTERBORES

Counterbores (Figure 4-21) are special cutters that use a pilot to guide the cutting action to enlarge a portion of a hole. Common uses are for enlarging a hole to make a bolt head fit flush with the surface.

COMBINED COUNTERSINK AND CENTER DRILL

This special drilling tool (Figure 4-21) is used to start holes accurately. These tools are mainly used to center drill and countersink the end of round stock in a lathe machine.

REAMERS

Reamers (Figure 4-21) are cutting tools that are used to enlarge a drilled hole by a few thousandths of an inch for a precise fit.

BORING TOOLS

Boring tools (Figure 4-21) are not usually considered with drilling, but they can be used to bore a hole using the power-feed drilling machines. These tools consist of an arbor with a tool bit attached that cuts a preset sized hole according to the distance that the tool bit protrudes from the arbor.

FIELD EXPEDIENT CUTTERS

Under battlefield conditions, the exact tools may not be available for each job. Simple flat drills can be made quickly from a high-speed steel lathe tool bit or a drill blank. If a grinder is available, then a crude drill can be ground that has a point and two flat edges, which could produce a hole if enough pressure is applied and the workpiece is machinable.

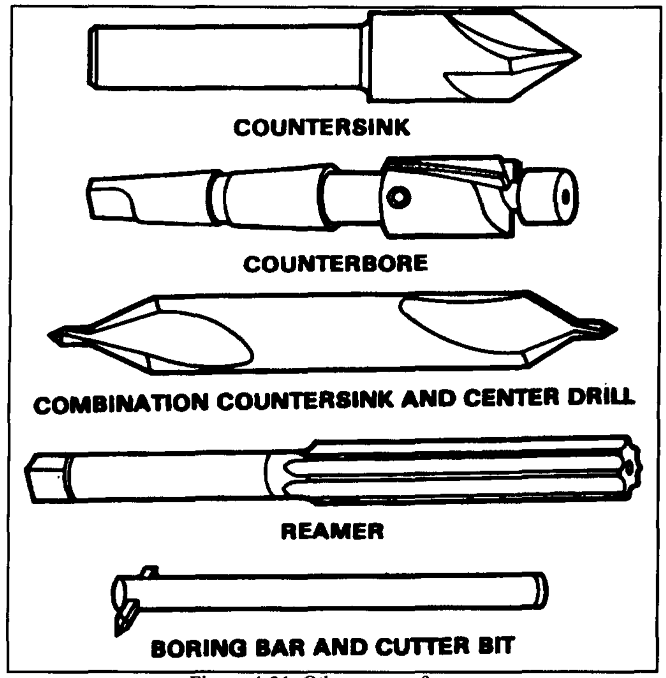


Figure 4-21. Other types of cutters.

TAP AND DIE WORK

Hand tapping and hand die work can be done on a drilling machine. The drill chuck is used to align the tap or die.

DRILL HOLDING DEVICES

The revolving vertical spindle of the drilling machine holds and drives the cutting tool. In order to use various sizes and shapes of drills in various machines three types of drill holding devices, which fit the spindle of the drilling machines, are used: the geared drill chuck, the drill sleeve, and the drill socket (Figure 4-22). The larger drilling machines have a spindle that has a standard Morse taper at the bottom end. There are three types of drill holding devices: the geared drill chuck, the drill sleeve, and the drill socket.

GEARED DRILL CHUCKS

Drills with straight shanks are held in geared drill chucks which have three adjustable jaws to clamp onto the drill. Smaller size drills are made with straight shanks because of the extra cost of providing these sizes if tapered. Geared drill chucks come in various sizes, with the 3/8 or 1/2-inch capacity chuck being the most common. The shank of the chuck is set into the spindle of the drilling machine by inserting the chuck's shank into the spindle's internal taper and seating the shank into the taper with a light blow with a soft hammer. Both the internal and external taper surfaces must be clean and free of chips for the shank to seat and lock properly. The drill is locked into the chuck by using the chuck key to simultaneously tighten the three chuck jaws. Geared drill chucks can also come with a morse tapered shank and may have a different method of attaching They may screw on, have a Jarno taper, or a Jacob's back taper.

DRILL SOCKETS AND DRILL SLEEVES

Morse taper shank drills come in several sizes, thus, adapters must be used for mounting them into various drilling machine spindles. Drill sleeves and drill sockets are designed to add to or subtract from the Morse taper for fitting a drill into the chuck spindle. For example, it is common for a 3/4 inch twist

drill to have a Morse taper of size #2, #3, or #4. It is also common for a drilling machine spindle to have a Morse taper of size #3 or #4, and it can be adapted for many other Morse taper sizes, depending on the size of the drill.

A drill too small for the machine spindle may be fitted into a socket or sleeve which has a taper hole of the proper size to hold the drill and a taper shank of the proper size to fit the drill spindle. Sometimes, more than one socket or sleeve is needed to build up the shank to tit into the drilling machine spindle. Sockets and sleeves may be obtained in a number of different sizes and hole shank taper combinations. Sockets, sleeves, and taper shank drills are mounted into the aligning slots of the spindle and lightly tapped with a sotf hammer to seat in place.

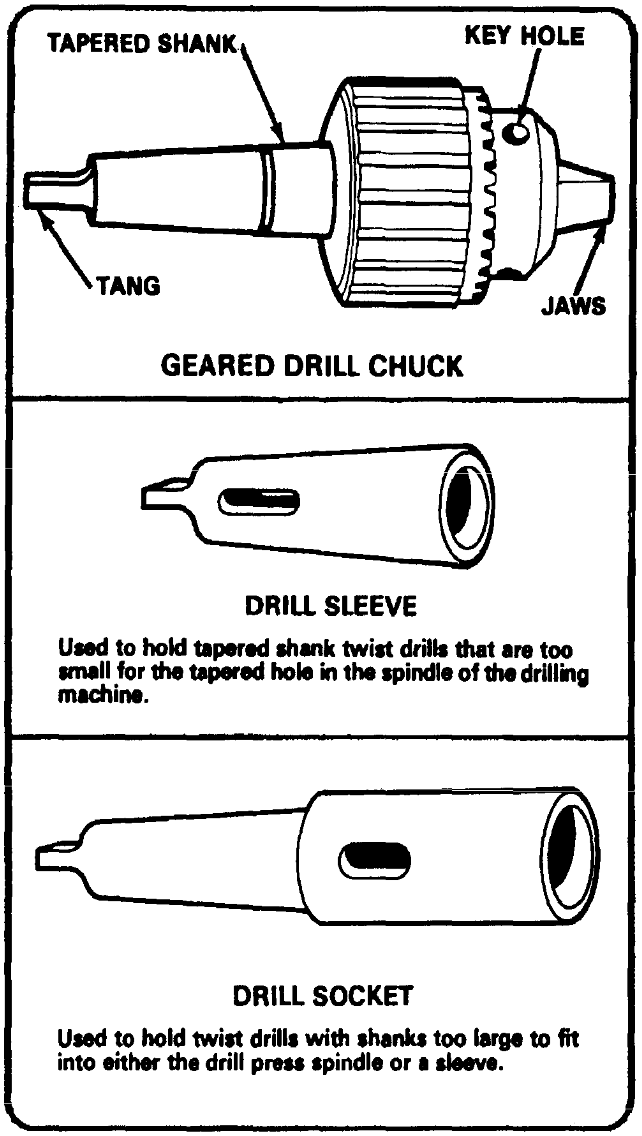


Figure 4-22 .Drill holding devices.

DRILL DRIFTS

Drill drifts are flat, tapered keys with one rounded edge that are designed to fit into a spindle chuck's slot to force a tapered shank drill loose. The rounded top of the small end of the drill drift is designed to face upward while inserting the drift into the slot. There are two types of drill drifts, the standard type and the safety type (Figure 4-23). The standard drift must be inserted into the chuck's slot and then struck with a soft hammer to jar the taper shank drill loose. The drill will fall quickly if not held by the hand and could break or cause injury. The safety drill drift has a sliding hammer weight on the drift itself to allow for a free hand to stay constantly on the drill as it comes loose.

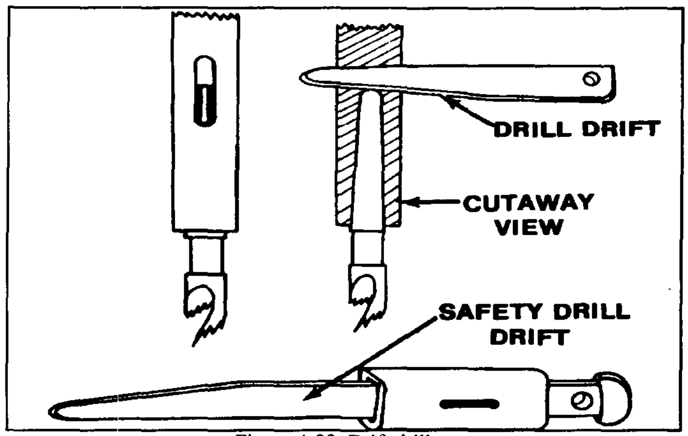


Figure 4-23. Drift drills.

WORK HOLDING AND DRILLING DEVICES

Work holding devices are used to hold the work steady for an accurate hole to be drilled, and so a safe drilling operation can be accomplished. Drilling support devices are used to keep the workpiece above the worktable or vise surface and to keep the workpiece aligned for drilling. Some devices are fairly simple and are used for drilling operations that do not require a perfect hole. Other devices are very intricate and designed for more accurate drilling. Many work holding devices are used with one another to produce the most stable work setup for drilling.

MACHINE TABLE VISES

A machine table vise is equipped with jaws which clamp against the workpiece, holding it secure. The vise can be bolted to the drilling table or the tail can be swung around to lay against the column to hold itself steady. Below are listed many types of special purpose machine table vises available to machine operators.

- The standard machine table vise is the simplest of all vises. It is equipped with two precision ground jaws for holding onto the work and a lead screw to tighten the one movable jaw to the work (Figure 4-24).

- The swivel vise is a machine vise that has an adjustable base that can swivel through 360° on a horizontal plane (Figure 4-24).

- The angle vise is very similar to the table vise. except this vise can be tilted to 90°. to be perpendicular to the work table (Figure 4-24).

- Many other vises are available. They include the compound vise. universal vise, magnetic vise, and contour vise.

STEP BLOCKS

These holding devices are built like stairs to allow for height adjustments in mounting drilling jobs and are used with strap clamps and long T-slot bolts (Figure 4-25).

CLAMPS

Clamps are small, portable vises or plates which bear against the workpiece and holding devices to steady the job. Clamps are made in numerous shapes to meet various work-holding needs. Common types of clamps are the C-clamp, the parallel clamp, the machine strap clamp, the bent-tail machine clamp, the U-clamp, and the finger machine clamp (Figure 4-25).

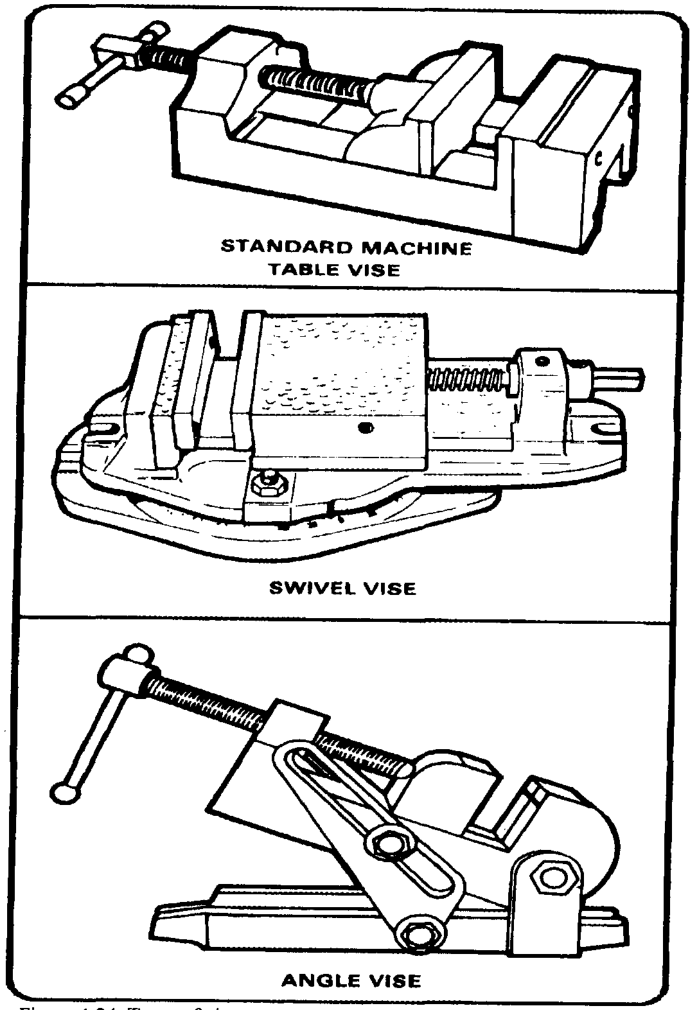


Figure 4-24. Types of vises.

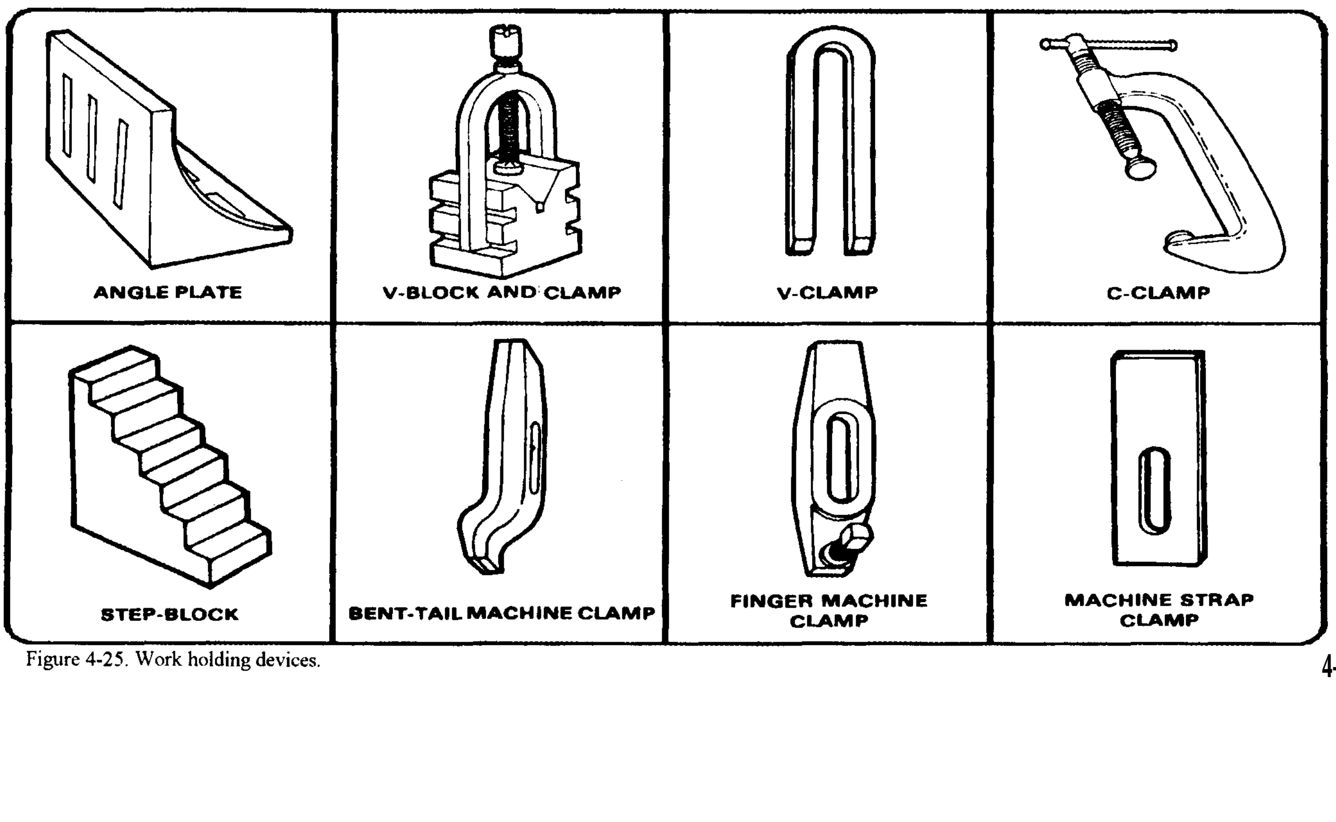


Figure 4-25. Work holding devices.

V-BLOCKS

V-blocks are precision made blocks with special slots made to anchor clamps that hold workplaces. The V-slot of the block is designed to hold round workplaces. The V-block and clamp set is usually used to hold and drill round stock.

ANGLE PLATES

Angle plates are made in a 900 angle with slots and bolt holes for securing work to the table or to other work holding devices (Figure 4-25).

T-SLOT BOLTS

These specially made bolts have a Tshaped head that is designed to slide into the T-slots of the drilling machine's worktable. A heavy duty washer and nut are used with the T-bolt to secure the work.

JIGS

Drill jigs are devices designed for production drilling jobs. The workplaces are clamped into the jig so that the holes will be drilled in the same location on each piece. The jig may guide the drill through a steel bushing to locate the holes accurately.

DRILLING SUPPORT DEVICES

These devices are important to keep the workpiece parallel while being supported above the worktable or vise surface and to keep the drill from cutting into the holding device or worktable. The following two devices are the most common used.

- Blocks are used with clamps to aid in securing and supporting the work. These blocks are usually precision ground of hard steel for long life.
- Parallels are precision ground rectangular bars are used to keep the workpiece parallel with the worktable when the workpiece must be raised above the worktable surface, such as when drilling completely through a workpiece (Figure 4-26). Parallels come in matched sets and can be solid or adjustable as needed.

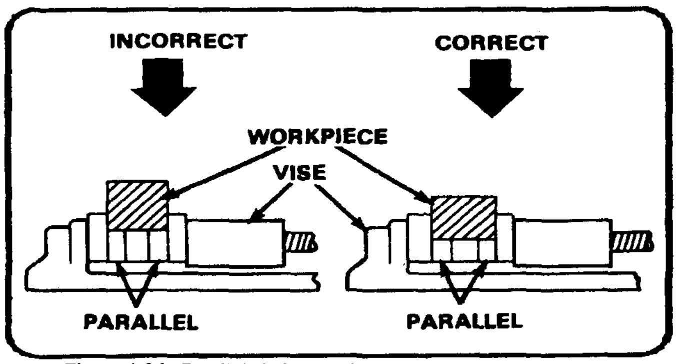


Figure 4-26. Parallels being used to support a workpiece.

CUTTING FLUIDS

Cutting fluids, lubricants, and coolants are used in drilling work to lubricate the chip being formed for easier removal, to help dissipate the high heat caused by friction, to wash away the chips, to improve the finish, and to permit greater cutting speeds for best efficiency. In drilling work, the cutting fluid can be sprayed, dripped, or machine pumped onto the work and cutting too! to cool the action and provide for maximum tool life. Drilling, reaming, and tapping of various materials can be improved by using the proper cutting fluids (see Table 4-3 in Appendix A). Cutting fluids can be produced from animal, vegetable, or mineral oils. Some cutting fluids are very versatile and can be used for any operation, while other cutting fluids are specially designed for only one particular metal.

LAYING OUT AND MOUNTING WORK

LAYING OUT WORK

Laying out work for drilling consists of locating and marking the exact centers of the holes to be drilled. The accuracy of the finished workpiece depends, in most part, on the accuracy of the layout. If the work does not require extreme accuracy, then laying out may be a simple operation, such as scribing two intersecting lines and center punching for drilling (Figure 4-27). For a precise layout, to within a few thousandths of an inch, precision layout procedures must be followed. Precision tools, such as a surface plate, surface gage, calipers, and sharp scribes must be used. The workpiece should be cleaned and deburred before applying layout dye.

LAYING OUT HOLE CENTERS

The position of the center of the hole to be drilled is marked by scribing two or more lines which intersect at the hole center. This intersecting point is then marked lightly with a prick punch and hammer. Check to see that the punch mark is exactly at the center of the intersection; use a magnifying glass if necessary. Use a pair of dividers, set to the radius of the hole to be drilled, to scribe a circle on the workpiece. The prick punch is then used to mark small indentations, known as "witness marks," on the circumference (Figure 4-27). This completes marking the circle. If a check is needed, have another circle scribed outside of the original circle, which can be checked for alignment after drilling (Figure 4-27).

Center-Punching the Layout

When all scribing is finished, enlarge the prick punch mark with a center punch to aid the center drilling process. Enlarging the mark with a center punch allows the center drill point to enter the workpiece easier and cut smoother.

Layout of Multiple Holes

When more than one hole must be drilled, lay out the holes along a common reference line, then put in the intersecting lines and scribe the circles. Throughout the layout process, avoid making the layout lines too heavy. Use lines as thin as possible, and avoid any scratches or other marks on the surface to be drilled.

MOUNTING WORKPIECES

Before attempting to use a drilling machine, some provision must be made for holding the workpiece rigidly and securely in place. The workpiece should always be firmly fastened to the table or base to produce holes that are located accurately. Use work holding devices to hold the workpiece (Figures 4-24 and 4-25). The two best methods to mount workplaces are explained below.

Vise Mounting

Most hand-feed drilling machines have no means of clamping or bolting workplaces to the table or base. The workpiece must be secured tightly in a machine table vise and swung around so that the tail of the vise contacts the column of the drill press. The hole must be centered by hand so that the center drill point is directly over the centerpunched mark. Other larger drilling machines have slotted tables and bases so that the work and work holding devices can be bolted or clamped firmly. All work should be securely clamped or set against a stop for all drilling to avoid letting the drill grab and damage the workpiece or injure the machine operator.

Table or Base Mounting

When a workpiece is table or base mounted (Figure 4-28), the strap clamps must be as parallel to the table or base as possible. All bolts and strap clamps should be as short as possible for rigidity and to provide for drilling clearance (Figure 4-29).

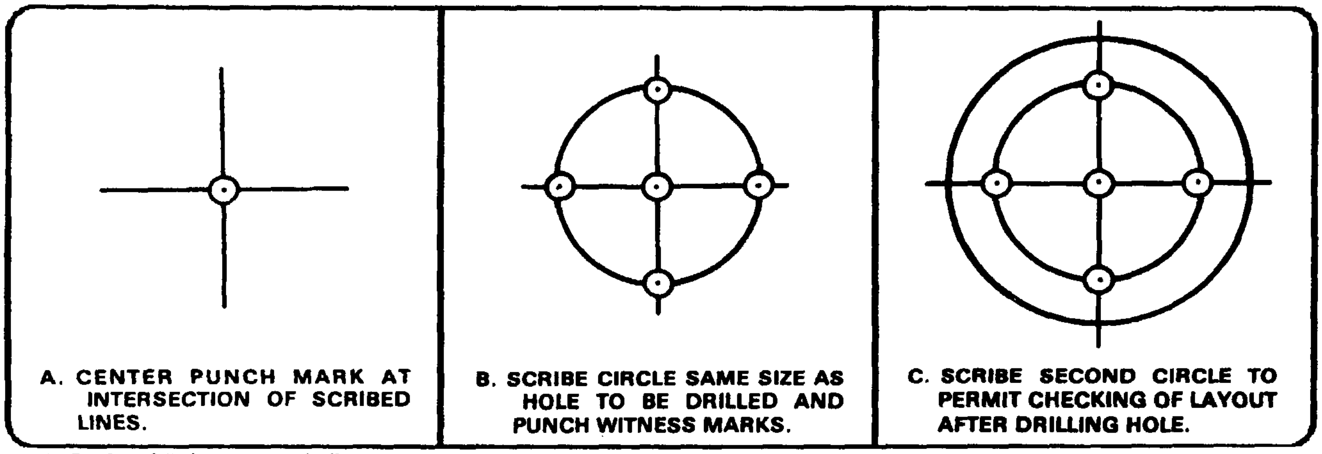


Figure 4-27. Use of "witnessess marks."

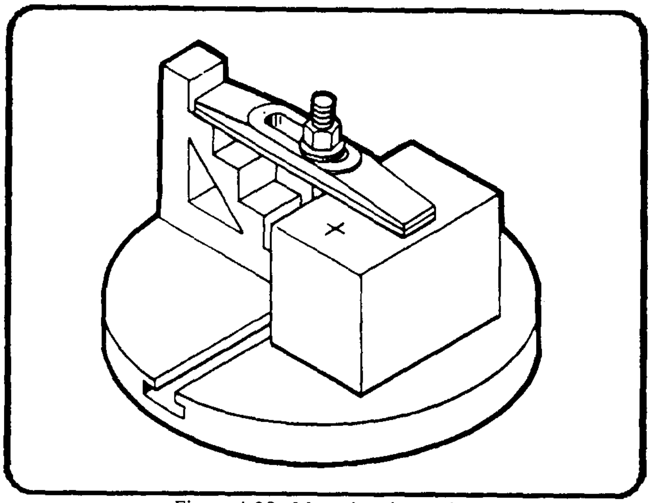


Figure 4-28. Mounting the work.

Parallel bars should be set close together to keep from bending the work. Washers and nuts should be in excellent condition. The slots and ways of the table, base, or vise must be free of all dirt and chips. All work holding devices should be free of burrs and wiped clean of oil and grease. Work holding devices should be the right size for the job. Devices that are too big or too small for the job are dangerous and must be avoided.

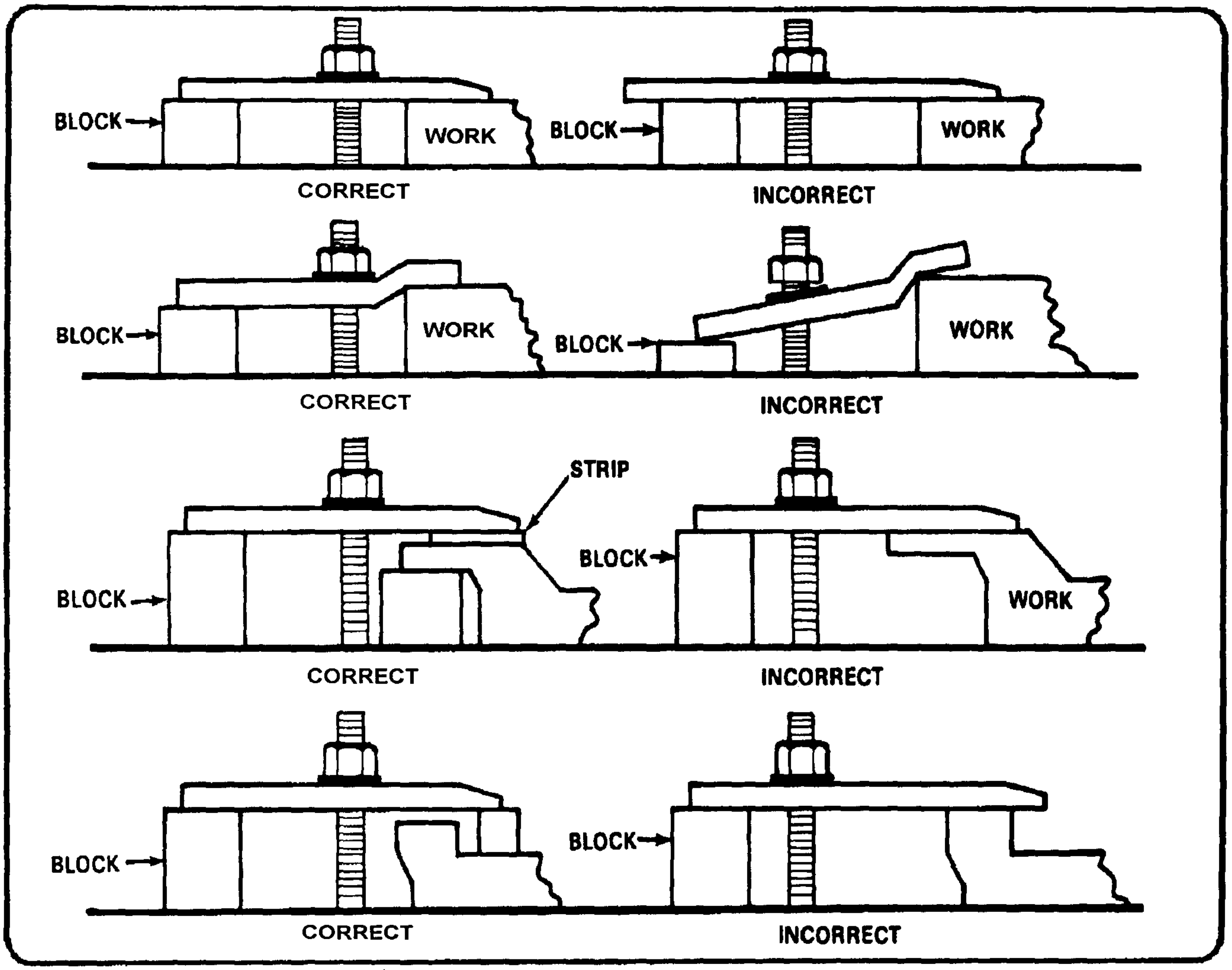


Figure 4-29. Correct and incorrect clamp applications.

GENERAL DRILLING OPERATIONS

THE DRILLING PROCESS

After a workpiece is laid out and properly mounted, the drilling process can begin. The drilling process, or complete operation, involves selecting the proper twist drill or cutter for the job, properly installing the drill into the machine spindle, setting the speed and feed, starting the hole on center, and drilling the hole to specifications within the prescribed tolerance. Tolerance is the allowable deviation from standard size. The drilling process must have some provisions for tolerance because of the oversizing that naturally occurs in drilling. Drilled holes are always slightly oversized, or slightly larger than the diameter of the drill's original designation. For instance, a l/4-inch twist drill will produce a hole that may be several thousandths of an inch larger than l/4-inch.

Oversizing is due to several factors that affect the drilling process: the actual size of the twist drill, the accuracy of the drill point, the accuracy of the machine chuck and sleeve, the accuracy and rigidity of the drilling machine spindle, the rigidity of the entire drilling machine, and the rigidity of the workpiece and setup. Field and maintenance shop drilling operations allow for some tolerance, but oversizing must be kept to the minimum by the machine operator.

Selecting the Drill

Selecting the proper twist drill means getting the right tool for the job (see Table 4-2 in Appendix A). The material to be drilled, the size of that material, and the size of the drilled hole must all be considered when selecting the drill. Also, the drill must have the proper lip angles and lip clearances for the job. The drill must be clean and free of any burrs or chips. The shank of the drill must also be clean and free of burrs to fit into the chuck. Most drills wear on the outer edges and on the chisel point, so these areas must be checked, and resharpened if needed, before drilling can begin. If the twist drill appears to be excessively worn, replace it.

Installing the Drill

Before installing the drill into the drilling machine spindle, clean the spindle socket and drill shank of all dirt, chips, and burrs. Use a small tile inside the socket to remove any tough burrs. Slip the tang of the drill or geared drill chuck into the sleeve and align the tang into the keyway slot (Figure 4-30).

Tap the end of the drill lightly with a soft hammer to seat firmly. Another method used to seat the drill into the sleeve is to place a block of wood on the machine table and force the drill down onto the block.

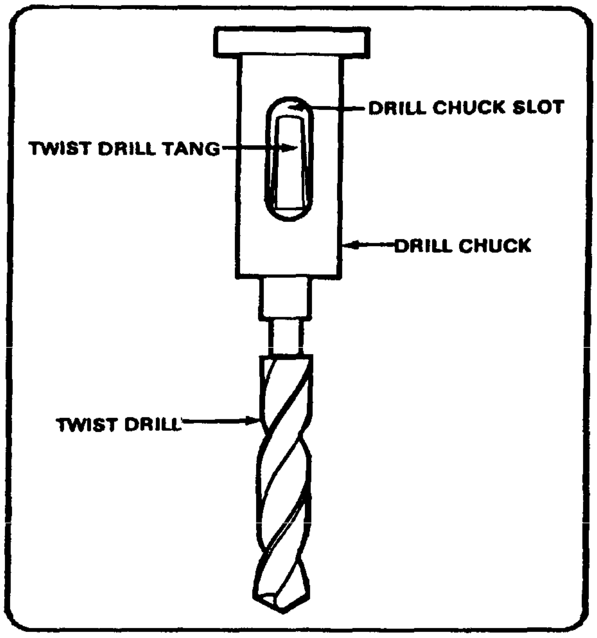


Figure 4-30. Installing a taper shank drill.

Selecting Drill Speed

Speed refers to the revolutions per minute (RPM) of the drilling machine spindle. For drilling, the spindle should rotate at a set speed that is selected for the material being drilled. Correct speeds are essential for satisfactory drilling. The speed at which a drill turns and cuts is called the peripheral speed. Peripheral speed is the speed of a drill at its circumference expressed in surface feet per minute (SFPM). This speed is related to the distance a drill would travel if rolled on its side. For example, a peripheral speed of 30 feet per minute means the drill would roll 30 feet in 1 minute if rolled on its side.

It has been determined through experience and experiment that various metals machine best at certain speeds; this best speed for any given metal is what is known as its cutting speed (CS) (see Table 4-2) in Appendix A. If the cutting speed of a material is known, then a simple formula can be used to find the recommended RPM of the twist drill.

The slower of the two recommended speeds is used for the following formulas due to the varying conditions that may exist, such as the rigidity of the setup, the size of the drilling machine, and the quality of finish.

$$\mathbf{RPM} = \frac{\mathbf{CSx4}}{\mathbf{D}}$$

Where RPM = drill speed in revolutions per minute.

CS = Recommended cutting speed in surface feet per minute.

4 = A constant in all calculations for RPM (except metric).

D = The diameter of the drill itself.

For example, if a 1/2-inch (0.500-inch) twist drill is to cut aluminum, the formula would be setup as follows:

$$\mathbf{RPM} = \frac{\mathbf{200\ X\ 4}}{\mathbf{.500}} = \frac{\mathbf{800}}{\mathbf{.500}} = \mathbf{1600\ RPM}$$

Thus, the drilling machine would be set up to drill as close to 1,600 RPM as possible. It is best to use the machine speed that is closest to the recommended RPM. When using the metric system of measurement, a different formula must be used to find RPM:

$$\mathbf{RPM} = \frac{\mathbf{CS\ (m)\ x\ 320}}{\mathbf{D\ (mm)}}$$

Where RPM = Drill speed in revolutions per minute.

CS = Recommended cutting speed in surface meters per minute.

320 = A constant for all metric RPM calculations.

D = Diameter of the twist drill in millimeters.

For example, if a 15-mm twist drill is to cut medium-carbon steel, with a recommended cutting speed of 21.4 meters per minute, the formula would be set up as follows:

$$\mathbf{RPM} = \frac{\mathbf{21.4\ x320}}{\mathbf{15}} = \frac{\mathbf{6848}}{\mathbf{15}}$$

$$\mathbf{RPM} = \frac{\mathbf{21.4\ x320}}{\mathbf{5}} = \frac{\mathbf{6.848}}{\mathbf{15}} = \mathbf{456.533\ RPM}\ \mathbf{or\ 457\ RPM}$$

Round this RPM up or down to the nearest machine speed.

The speeds on these tables are just recommendations and can be adjusted lower if needed, or to higher speeds if conditions permit.

SELECTING DRILL FEED

Feed is the distance a drill travels into the workpiece during each revolution of the spindle. It is expressed in thousandths of an inch or in millimeters. Hand-feed drilling machines have the feed regulated by the hand pressure of the operator; thus, the skill of the operator will determine the best feeds for drilling. Power feed drilling machines have the ability to feed the drill into the work at a preset depth of cut per spindle revolution, so the best feeding rate can be determined (see Table 4-4 in Appendix A).

The selection of the best feed depends upon the size of the drill, the material to be drilled, and the condition of the drilling machine. Feed should increase as the size of the drill increases. After starting the drill into the workpiece by hand, a lever on the power-feed drilling machine can be activated, which will then feed the drill into the work until stopped or disengaged. Too much feed will cause the drill to split; too little feed will cause chatter, dull the drill, and possibly harden the workpiece so it becomes more difficult to drill. Drills 1/2 inch or smaller can generally be hand-fed, while the larger drills require more downward torque and should be power-fed.

ALIGNING AND STARTING HOLES

To start a twist drill into the workpiece, the point of the drill must be aligned with the center-punched mark on the workpiece. Some drilling operations may not require a precise alignment of the drill to the work, so alignment can be done by lining up the drill by hand and eye alone. If a greater precision in centering alignment is required, than more preparation is needed before starting to drill.

STARTING HOLES WITH CENTER DRILL

The best method to align and start a hole is to use the combination countersink and drill, known as the center drill (Figure 4-31). Set the drilling machine speed for the diameter of the tip of the center drill, start the machine, and gently lower the center drill into contact with the work, using hand and eye coordination. The revolving center drill will find the center punched mark on the workpiece and properly align the hole for drilling. The depth of the center-drilled hole should be no deeper than two third the length of the tapered portion of the center drill.

DRAWING A DRILL BACK ON CENTER

Often, the drill will not be on center, sometimes due to a poorly made center-punched mark or a hard spot on the metal. To draw the twist drill back to the position desired (Figure 4-3 1), a sharp chisel is used to make one or more nicks or grooves on the side toward which the drill is to be drawn. The chisel marks will draw the drill over because of the tendency of the drill to follow the line of least resistance. After the chisel mark is made, the drill is again hand-fed into the work and checked for being on center. This operation must be completed before the drill point has enlarged the hole to full diameter or the surface of the workpiece will be marred by a double hole impression.

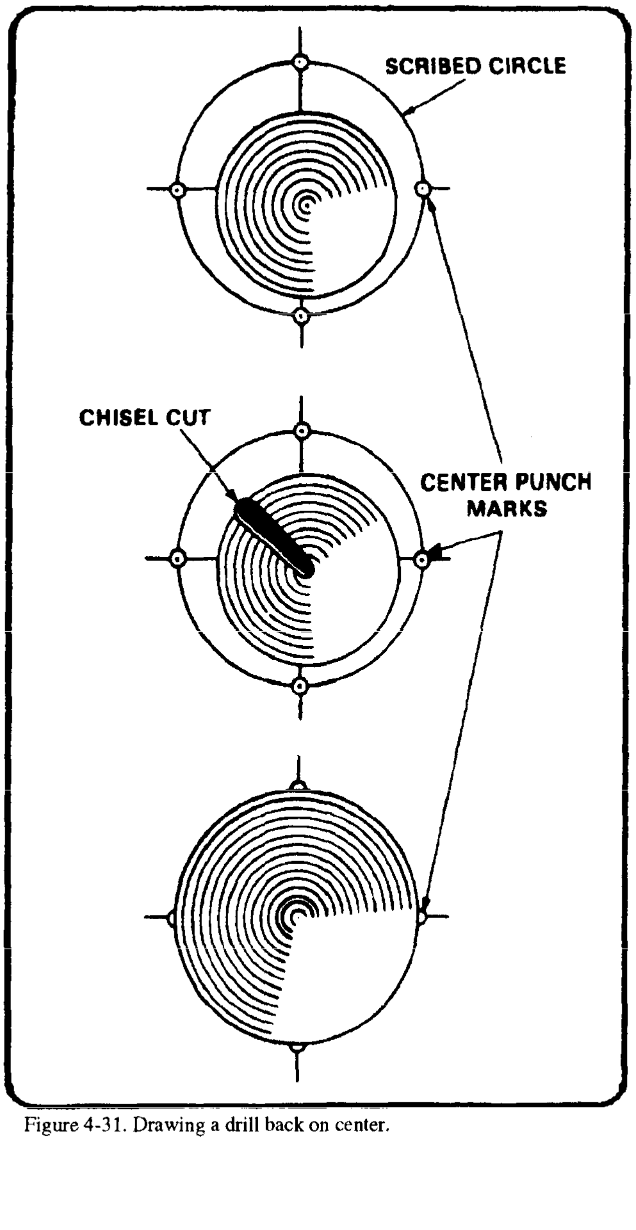


Figure 4-31. Drawing a drill back on center.

DRILLING

After the drill has been aligned and the hole started, then insert the proper size drill (Figure 4-32) and continue drilling into the workpiece (Figure 4-33), while applying cutting fluid. The cutting fluid to use will depend on what material is being machined (see Table 4-3 in Appendix A). Use the cutting fluids freely.

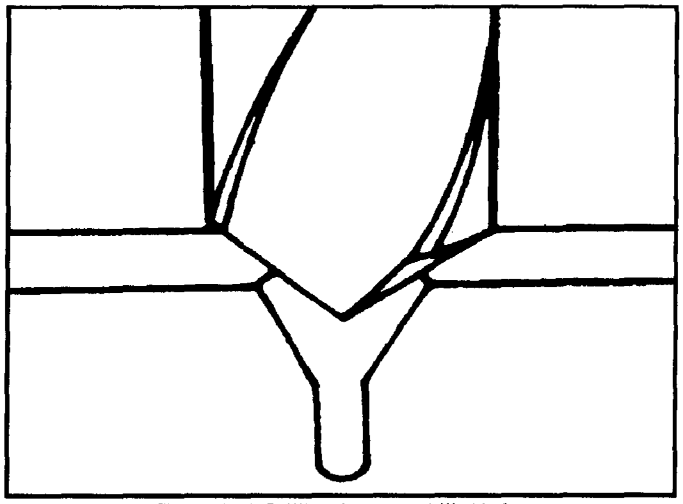


Figure 4-32. Drilling the center drilled hole.

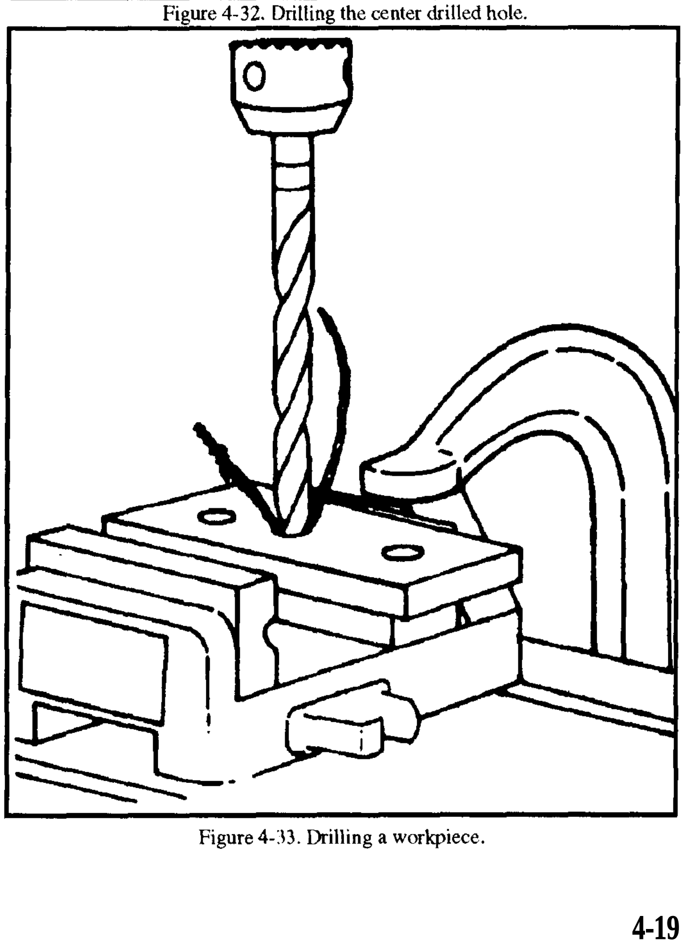


Figure 4-33. Drilling a workpiece.

Drilling Deep Holes

If the depth of the hole being drilled is greater than four times the diameter of the drill, remove the drill from the workpiece at frequent intervals to clean the chips from the flutes of the drill and the hole being drilled. A slight increasing speed and decrease in feed is often used to give the chips a greater freedom of movement. In deep hole drilling, the flutes of the smaller drills will clog up very quickly and cause the drill to drag in the hole, causing the diameter of the hole to become larger than the drill diameter. The larger drills have larger flutes which carry away chips easier.

When the depth of the hole being drilled is four times the diameter of the drill itself, remove the drill at frequent intervals and clean the chips from the flutes of the drill and from the hole being drilled.

Drilling a Pilot Hole

As the drill size increases, both the size of the web and the width of the chisel edge increase (Figure 4-34). The chisel edge of drill does not have a sharp cutting action, scraping rather than cutting occurs. In larger drills, this creates a considerable strain on the machine. To eliminate this strain when drilling a large hole, a pilot hole is drilled first (Figure 4-34) and then followed with the larger drill. A drill whose diameter is wider than the web thickness of the large drill is used for the pilot hole. This hole should be drilled accurately as the larger drill will follow the small hole.

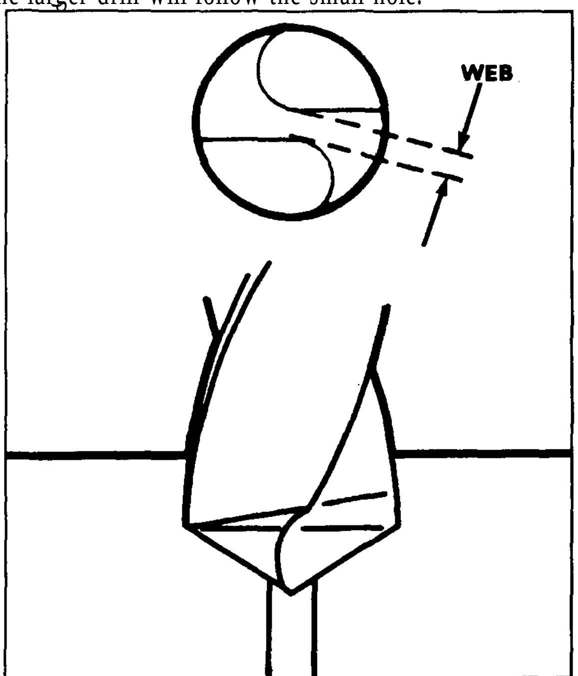


Figure 4-34. Using a pilot drill.

A pilot drill can also be used when average-sized . holes are to be drilled on small drilling machines. The small machine may not have enough power to drive the larger drill through the metal. Avoid making the pilot drilled hole much wider than the web of the larger drill. Too wide of a pilot drilled hole may cause the larger drill cutting lips to grab and snag which may cause excessive chatter or an out-of-round hole.

Drilling Thin Material

When drilling thin workpieces, such as sheet metal, place another piece of metal or wood under the workpiece to provide support and prevent bending the workpiece or ruining the hole due to the upthrust created when the drill breaks through.

If thin metal must be drilled and a support cannot be rigged under the thin metal, then a drill designed for thin metal, such as a low helix drill with zero rake angle, commonly called a sheet metal drill, must be used.

Using a Depth Stop

The depth stop mechanism on the drilling machine (Figure 4-35) should be used whenever drilling to a desired depth, and to prevent the twist drill from traveling too far after cutting through the workpiece. The depth stop is designed to be used whenever a number of holes of the same depth are to be drilled, or when drilling holes deep into the workpiece (blind holes). Make sure that drills are chucked tightly to avoid slipping and changing the depth setting. Most depth stops have away to measure the distance that the drill travels. Some may have a fractional gage on the depth stop rod, and some may have a micrometer dial located on the depth stop for very precise measurements.

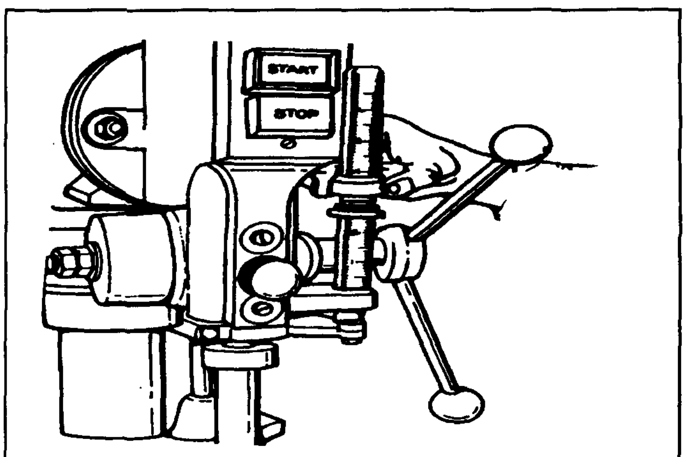


Figure 4-35. Depth stop mechanism.

Checking the Depth of Drilled Holes

To accurately check the depth of a drilled hole, the length of the sides of the hole must be measured. Do not measure from the bottom point of the hole (Figure 4-36). A thin depth gage is inserted into the hole, along the side, and the measurement taken. If the hole is too small for the gage to fit down into it then a twist drill of the same size as the hole can be inserted into the hole upside down, then removed and measured with a rule. Clean all chips and coolant from the holes before attempting any depth measurement.

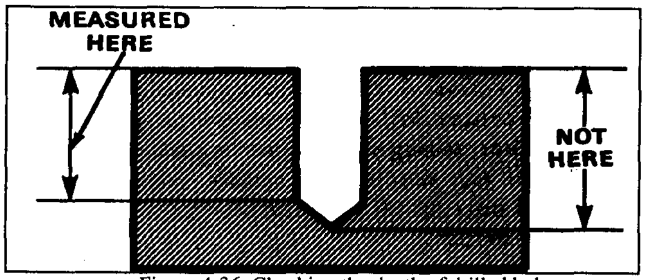


Figure 4-36. Checking the depth of drilled holes

Drilling Round Stock

When drilling shafts, rods, pipes, dowels, or other round stock, it is important to have the center punch mark aligned with the drill point (Figure 4-37). Use V-blocks to hold the round stock for center punching and drilling. Align the center of the round stock with a square or by lining the workpiece up with the twist drill point. Another method to drill round stock is to use a V-block drill jig that automatically centers the work for drilling.

Operational Checks

After the hole is drilled to specifications, always back the drill out of the hole and shut off the machine. Allowing a drill to run on in the hole will cause the hole to be oversized. At any time during the drilling process, a problem could occur. If so, it should be fixed as soon as possible to avoid any damage or injury. Operators must observe the drilling machine for any excessive vibration or wobble, overheating of the electric motor, and unusual noises coming from the machine. A high pitched squeal coming from the drill itself may indicate a dull drill. A groaning or rumbling sound may indicate that the drill is overloaded and the feed needs to be reduced. A chattering sound may indicate an off-center drill or a poorly sharpened drill. These or other noises could also be caused by internal parts of the machine. Consult the operator's manual and correct all problems before attempting to continue drilling.

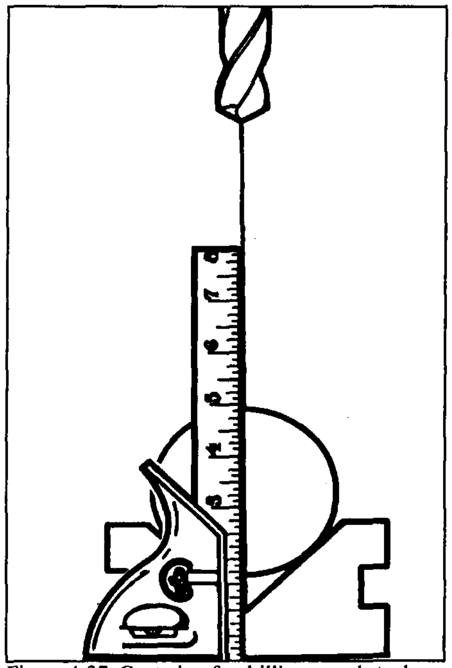


Figure 4-37. Centering for drilling round stock.

SPECIAL OPERATIONS ON DRILLING MACHINES

COUNTERSINKING

Countersinking is the tapering or beveling of the end of a hole with a conical cutter called a machine countersink. Often a hole is slightly countersunk to guide pins which are to be driven into the workpiece; but more commonly, countersinking is used to form recesses for flathead screws (Figure 4-38) and is similar to counterboring.

Types of Countersinks

Machine countersinks for machining recessed screw heads commonly have an included angle of 82°. Another common countersink has an included angle of 60° machining lathe centers. Some countersinks have a pilot on the tip to guide the countersink into the recess. Since these pilots are not interchangeable, these types of countersinks can be used for only one size of hole and are not practical for field or maintenance shops.

Countersink Alignment

Proper alignment of the countersink and the hole to be recessed are important. Failure to align the tool and spindle with the axis of the hole, or failure to center the hole, will result in an eccentric or out-of-round recess.

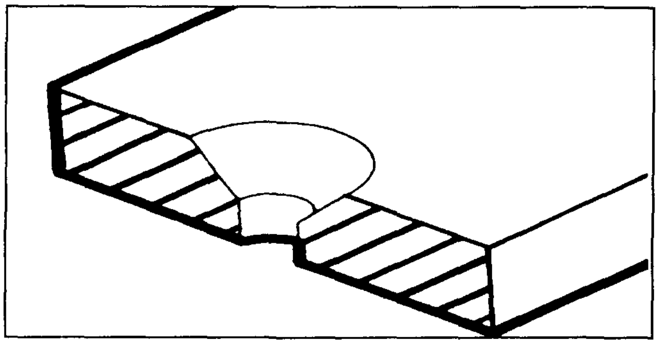


Figure 4-38. Countersunk hole.

Procedures for Countersinking

Good countersinking procedures require that the countersink be run at a speed approximately one-half of the speed for the same size drill. Feed should be light, but not too light to cause chatter. A proper cutting fluid should be used to produce a smooth finish. Rough countersinking is caused by too much speed, dull tools, failure to securely hold the work, or inaccurate feed. The depth stop mechanism should be used when countersinking to ensure the recess will allow the flathead screw to be flush with the surface (Figure 4-39).

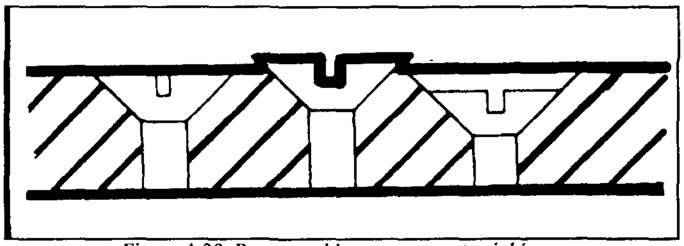


Figure 4-39. Proper and improper countersinking.

COUNTERBORING AND SPOT FACING

Counterboring is the process of using a counterbore to enlarge the upper end of a hole to a predetermined depth and machine a square shoulder at that depth (Figure 4-40). Spot facing is the smoothing off and squaring of a rough or curved surface around a hole to permit level seating of washers, nuts, or bolt heads (Figure 4-40). Counterbored holes are primarily used to recess socket head cap screws and similar bolt heads slightly below the surface. Both counterboring and spotfacing can be accomplished with standard counterbore cutters.

Counterbore cutters have a pilot to guide the counterbore accurately into the hole to be enlarged. If a counterbore is used without a pilot, then the counterbore flutes will not stay in one spot, but will wander away from the desired hole. The shank of counterbores can be straight or tapered. The pilots of counterbores can be interchangeable with one another so that many hole combinations can be accomplished.

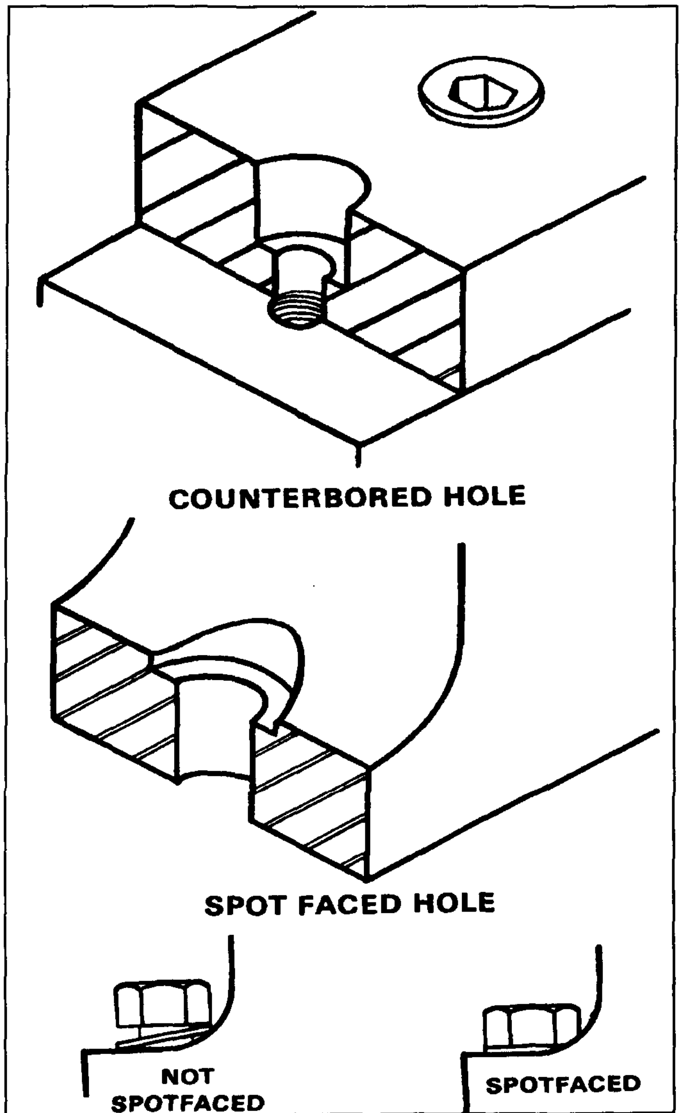


Figure 4-40. Counterboring and spot facing.

Counterboring

When counterboring, mount the tool into the drill chuck and set the depth stop ‘mechanism for the required depth of shoulder cut. Set the speed to approximately one-half that for the same size of twist drill. Compute for the actual cutter size

and not the shank size when figuring speed. Mount the workpiece firmly to the table or vise. Align the workpiece on the center axis of the counterbore by fitting the pilot into the drilled hole. The pilot should fit with a sliding motion inside the hole. If the pilot fits too tightly, then the pilot could be broken off when attempting to counterbore. If the pilot fits too loosely, the tool could wander inside the hole, causing chatter marks and making the hole out of round.

Feeds for counterboring are generally 0.002 to 0.005 inch per revolution, but the condition of the tool and the type of metal will affect the cutting operation. Slow the speed and feed if needed. The pilot must be lubricated with lubricating oil during counterboring to prevent the pilot seizing into the work. Use an appropriate cutting fluid if the material being cut requires it. Use hand feed to start and accomplish counterboring operations. Power feed counterboring is used mainly for production shops.

Spot Facing

Spot facing is basically the same as counterboring, using the same tool, speed, feed, and lubricant. The operation of spot facing is slightly different in that the spot facing is usually done above a surface or on a curved surface. Rough surfaces, castings, and curved surfaces are not at right angles the cutting tool causing great strain on the pilot and counterbore which can lead to broken tools. Care must be taken when starting the spot facing cut to avoid too much feed. If the tool grabs the workpiece because of too much feed, the cutter may break or the workpiece may be damaged. Ensure that the work is securely mounted and that all backlash is removed from drilling machine spindle.

TAPPING

Tapping is cutting a thread in a drilled hole. Tapping is accomplished on the drilling machine by selecting and drilling the tap drill size (see Table 4-5 in Appendix A), then using the drilling machine chuck to hold and align the tap while it is turned by hand. The drilling machine is not a tapping machine, so it should not be used to power tap. To avoid breaking taps, ensure the tap aligns with the center axis of the hole, keep tap flutes clean to avoid jamming, and clean chips out of the bottom of the hole before attempting to tap.

Tapping Large Holes

One method of hand tapping is to mount an adjustable tap and reamer wrench on the square shank of the tap and install a pointed tool with a center in the drilling machine spindle (Figure 4-41). The tap is placed in the drilled hole and the tool's center point is placed in the center hole. The tap is held steady, without forcing, by keeping light pressure on it with the hand feed lever of the drilling machine, while turning the wrench and causing the tap to cut into the hole.

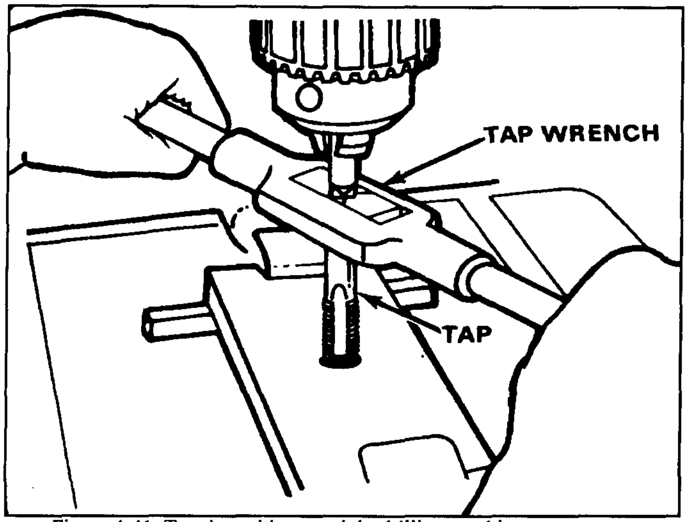


Figure 4-41. Tapping with an upright drilling machine.

Tapping Small Holes

Another method of hand tapping, without power, is to connect the tap directly into the geared drill chuck of the drilling machine and then turn the drill chuck by hand, while applying light pressure on the tap with the hand feed lever. This method works well on small hand-feed drilling machines when using taps smaller than 1/2-inch diameter.

REAMING

Reaming a drilled hole is another operation that can be performed on a drilling machine. It is difficult, if not impossible, to drill a hole to an exact standard diameter. When great accuracy is required, the holes are first drilled slightly undersized and then reamed to size (Figure 4-42). Reaming can be done on a drilling machine by using a hand reamer or using a machine reamer (Figure 4-43). When you must drill and ream a hole, it is best if the setup is not changed. For example, drill the hole (slightly undersized) and then ream the hole before moving to another hole. This method will ensure that the reamer is accurately aligned over the hole. If a previously drilled hole must be reamed, it must be accurately realigned under the machine spindle. Most hand and machine reamers have a slight chamfer at the tip to aid in alignment and starting (Figure 4-43).

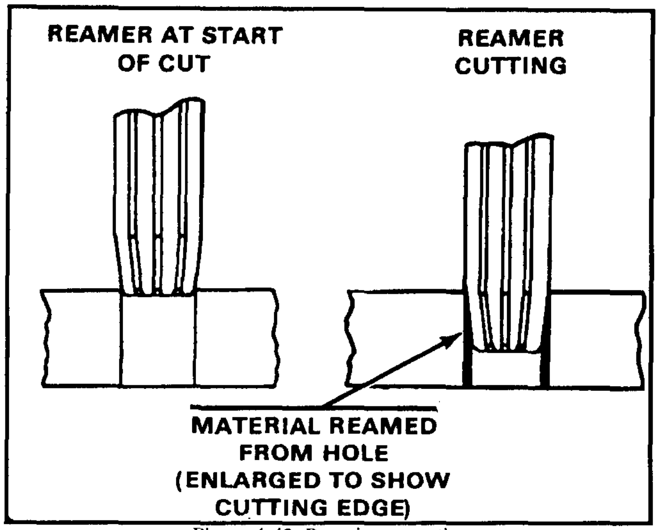


Figure 4-42. Reaming operations.

Hand Reamers

Solid hand reamers should be used when a greater accuracy in hole size is required. The cutting action of a hand reamer is performed on the taper (approximately 0.015 per inch) which extends 3/8- to 1/2- inch above the chamfer. This slight taper limits the stock allowance, or metal to be removed by the reamer, from 0.001- to 0.003-inch depending on the size of the reamer. The chamfer aids in aligning and starting the tool, and reamers usually have straight shanks and a square end to fit into an adjustable tap and reamer wrench. A hand reamer should never be chucked into a machine spindle for power reaming. A center may be installed in the drilling machine spindle to align and center the hand reamer. As the reamer is turned by hand into the hole, only a slight pressure is applied to the hand feed lever to keep the center in contact with the reamer and maintain accuracy in alignment.

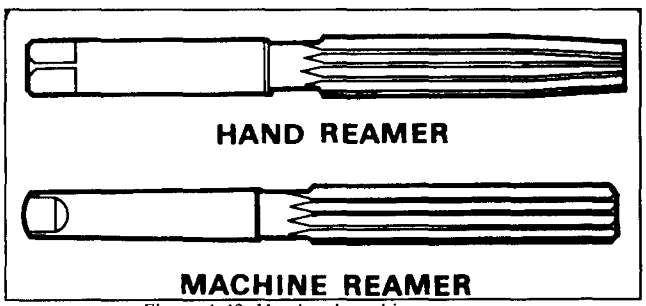


Figure 4-43. Hand and machine reamers.

Machine Reamer

Machine reamers can generally be expected to produce good clean holes if used properly. The cutting action of a machine reamer is performed on the chamfer and it will remove small amounts of material. The allowance for machine reamers is generally 1/64 inch for reamers l/2-inch to 1 inch in diameter, a lesser amount for smaller holes, and greater than 1/64-inch for holes over 1 inch. Machine reamers for use on drilling machines or lathes have taper shanks to fit the machine spindle or straight shanks for inserting into a drill chuck. A reamer must run straight and true to produce a smooth finish. The proper cutting fluid for the metal being cut should be used. Generally, the speed used for machine reaming would be approximately one-half that used for the same size drill.

Reaming Operations

Reamer cutting edges should be sharp and smooth. For accurate sizes, check each reamer with a micrometer prior to use. Never start a reamer on an uneven or rough surface, and never rotate a reamer backwards. Continue to rotate the reamer clockwise, even while withdrawing from the hole. Use just enough feed pressure to keep the reamer feeding into the work. Excessive feed may cause the reamer to dig in and break or grab the workpiece and wrench it from the vise.

BORING

Occasionally a straight and smooth hole is needed which is too large or odd sized for drills or reamers. A boring tool can be inserted into the drilling machine and bore any size hole into which the tool holder will fit. A boring bar with a tool bit installed is used for boring on the larger drilling machines. To bore accurately, the setup must be rigid, machine must be sturdy, and power feed must be used. Boring is not recommended for hand-feed drilling machines. Hand feed is not smooth enough for boring and can be dangerous. The tool bit could catch the workpiece and throw it back at the operator. First, secure the work and drill a hole for the boring bar. Then, insert the boring bar without changing the setup. Use a dial indicator to set the size of bored hole desired by adjusting the tool bit in the boring tool holder; then, set the machine speed and feed. The speed is set at the speed recommended for drilling a hole of the same size. Feed should be light, such as 0.005 to 0.010 inch per revolution. Start the machine and take a light cut. Check the size of the hole and make necessary adjustments. Continue boring with a more rough cut, followed by a smoother finishing cut. When finished, check the hole with an internal measuring device before changing the setup in case any additional cuts are required.

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, modem 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, bufting 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 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.

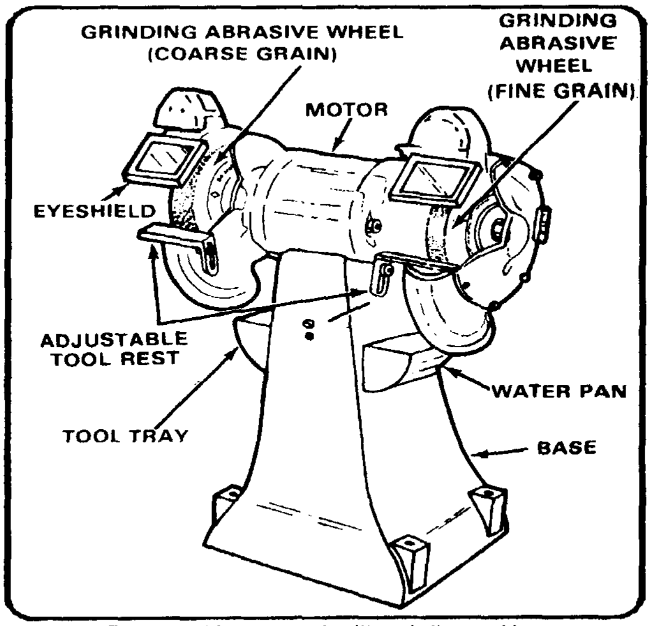


Figure 5-1. Floor-mounted utility grinding machine.

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).

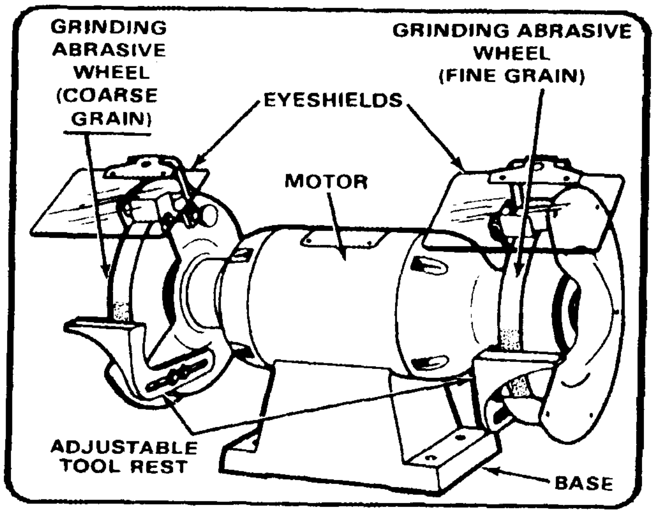


Figure 5-2. Bench-type utility grinding machine.

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.

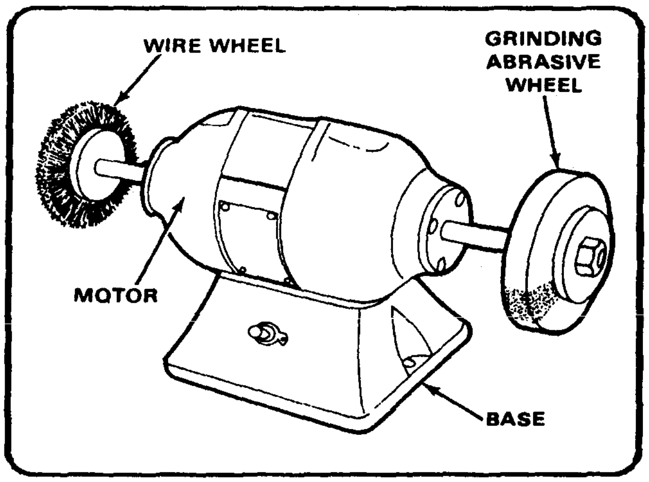


Figure 5-3. Bench type utility grinding and buffing machine

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 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.

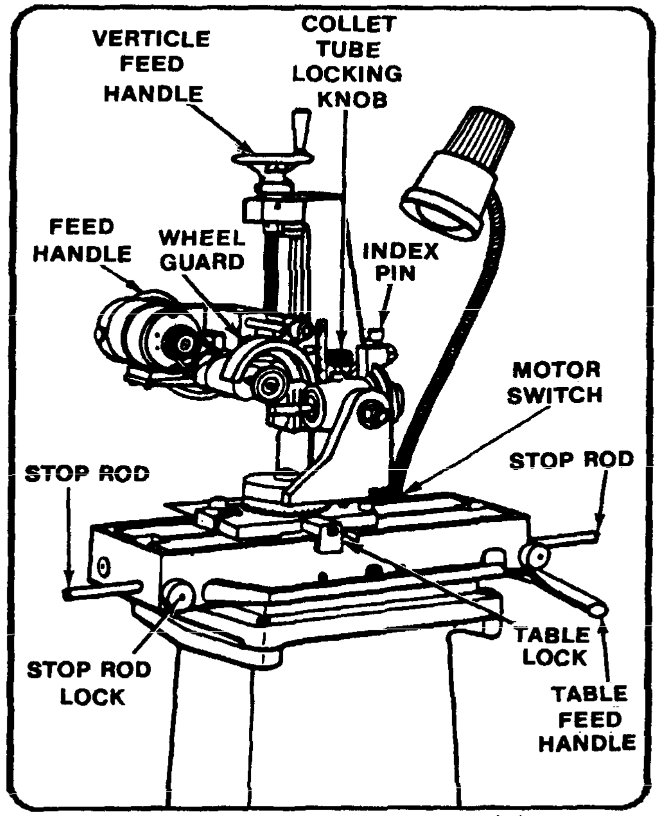


Figure 5-4. Bench-type tool and cutter grinder.

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.

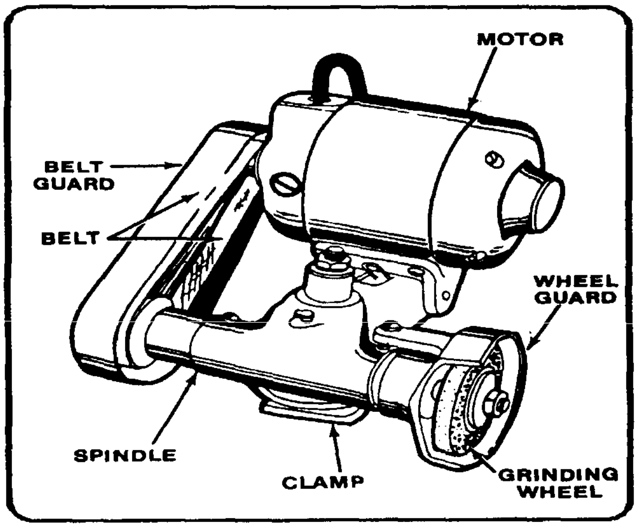


Figure 5-5. Tool post grinding machine.

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.

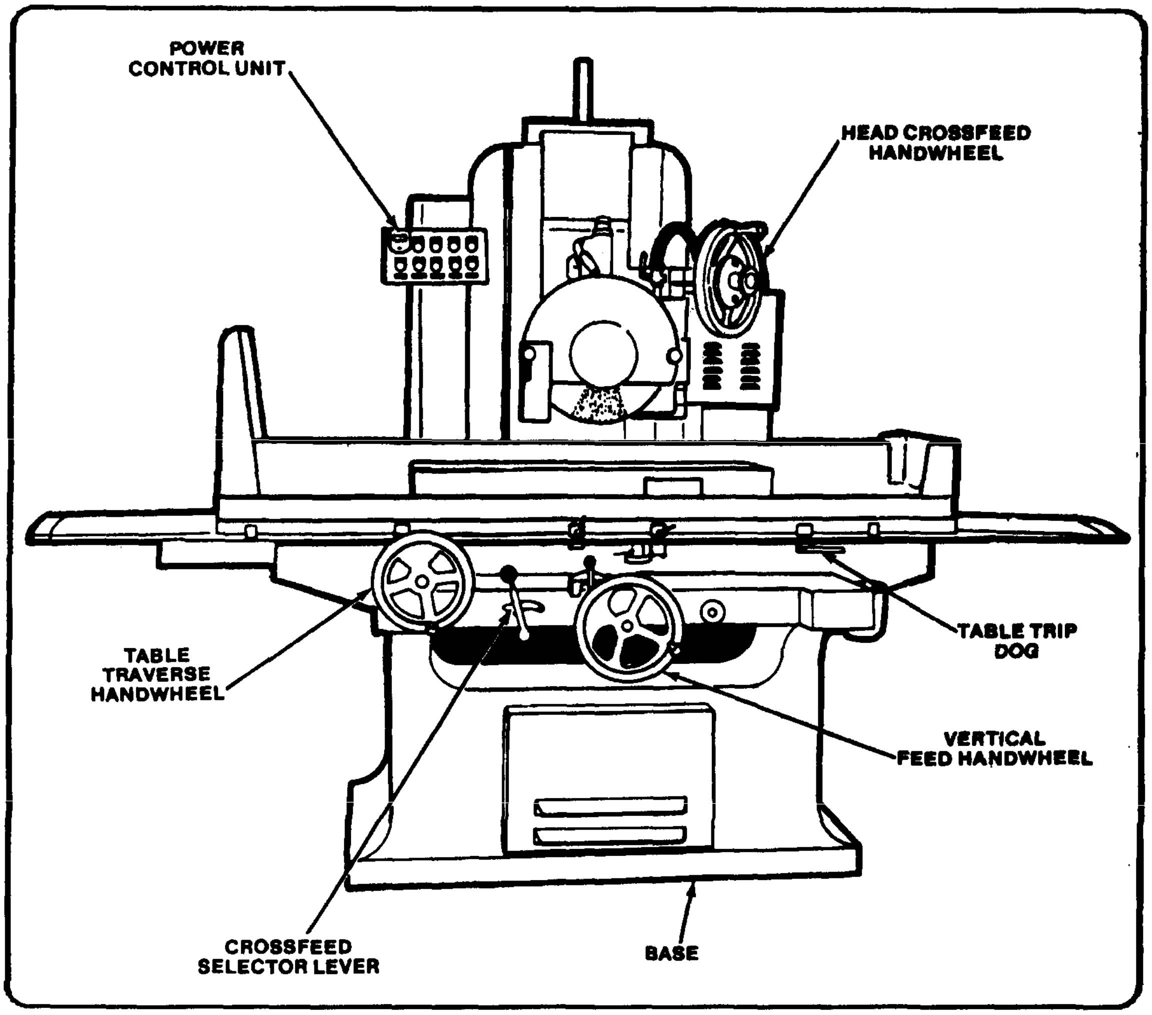


Figure 5-6. Reciprocating surface grinding machine.

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 maybe 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 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.

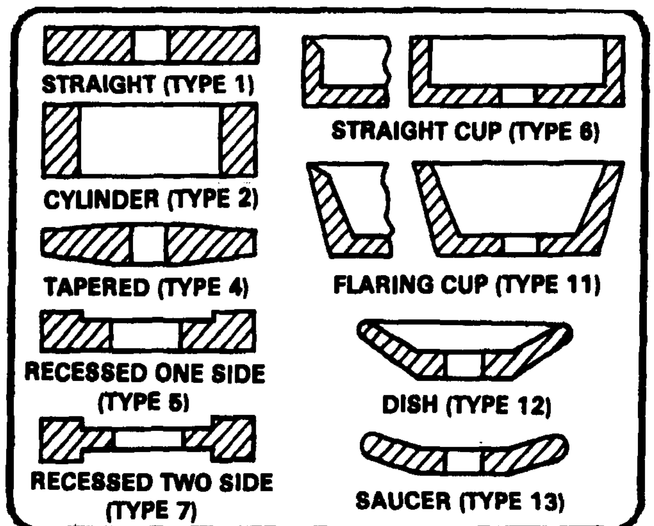


Figure 5-7. Standard types of grinding wheels.

ABRASIVE MATERIALS

The abrasive grains are the cutting took 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

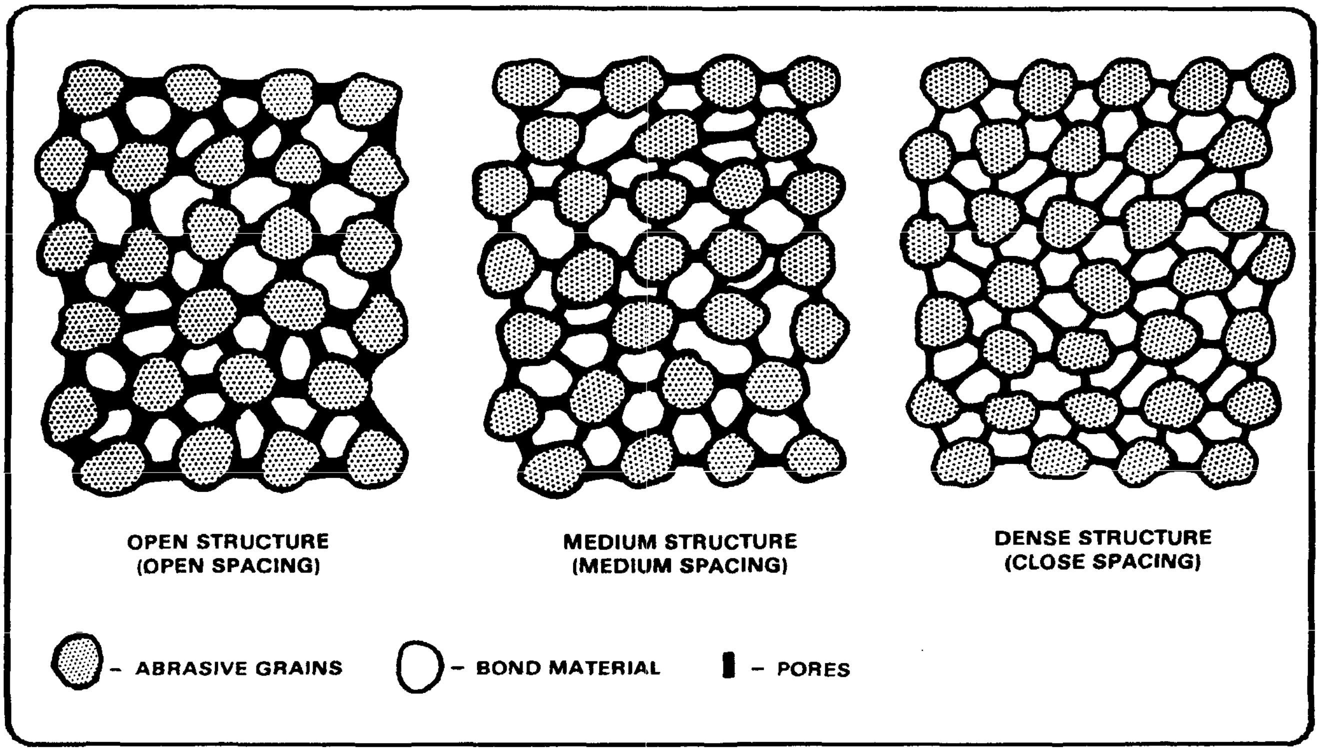


Figure 5-8. Grinding wheel abrasive.

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.

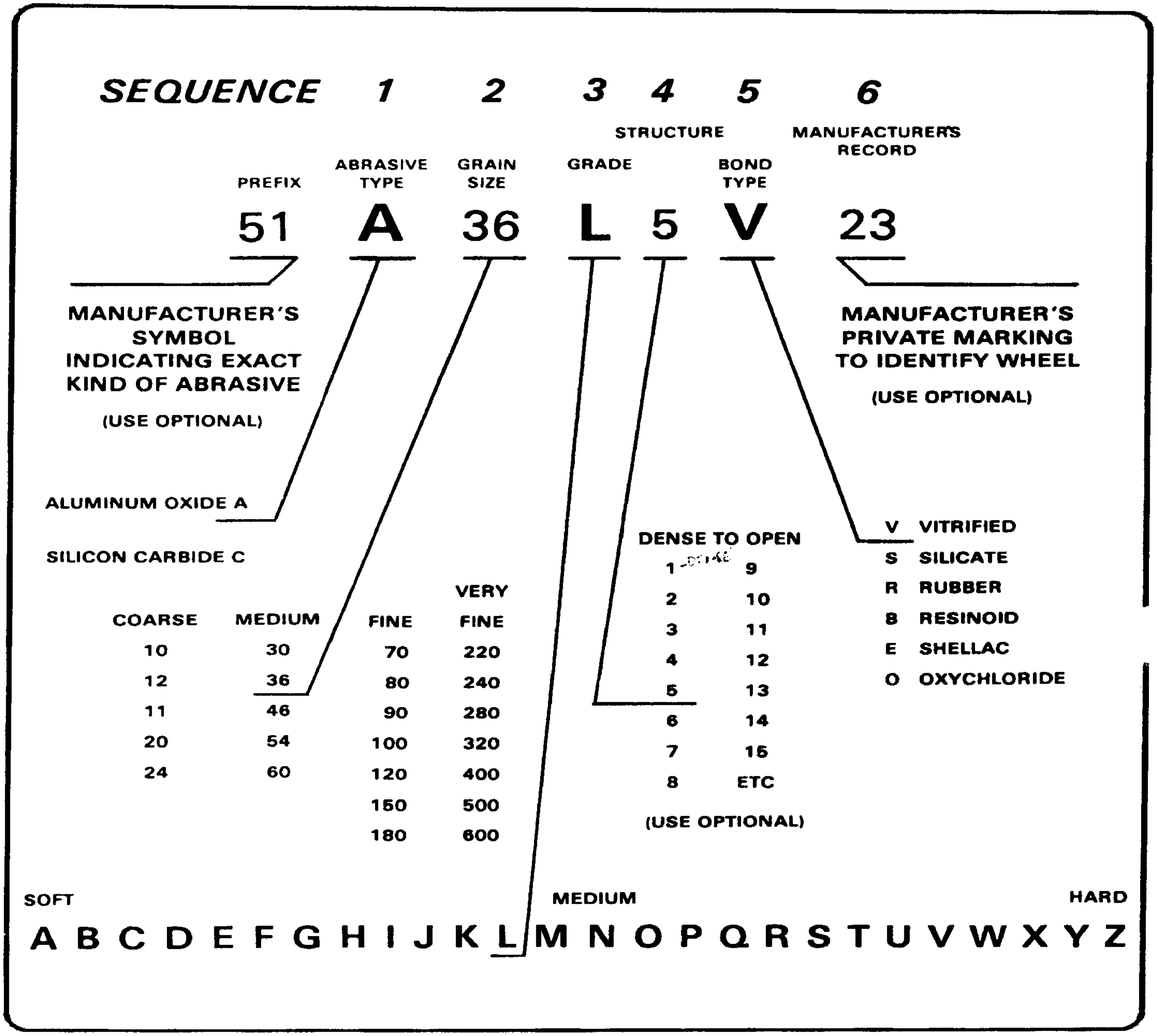


Figure 5-9. Standard system of markings.

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

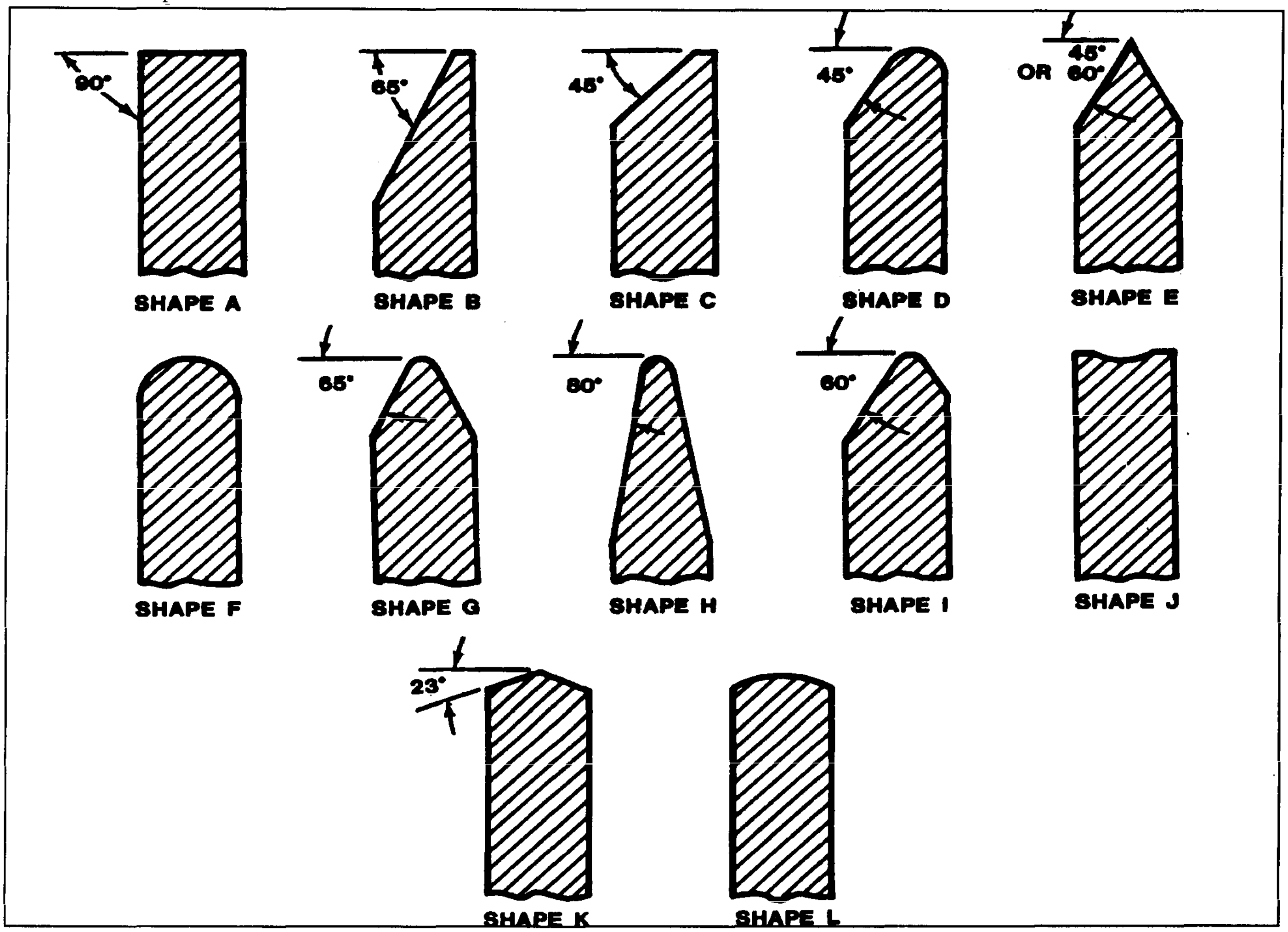


Figure 5-10. Standard shapes of grinding wheel faces.

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, thecoarser 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).

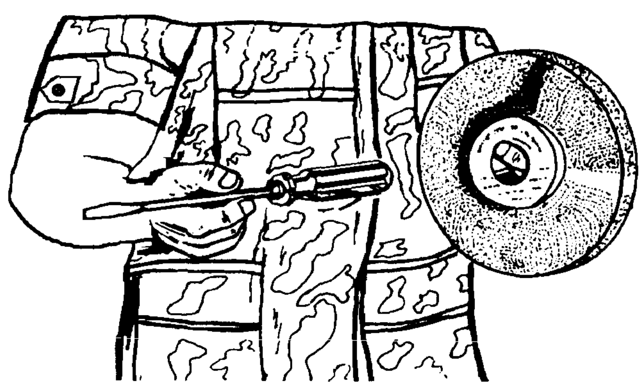


Figure 5-11. Checking for cracks.

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.

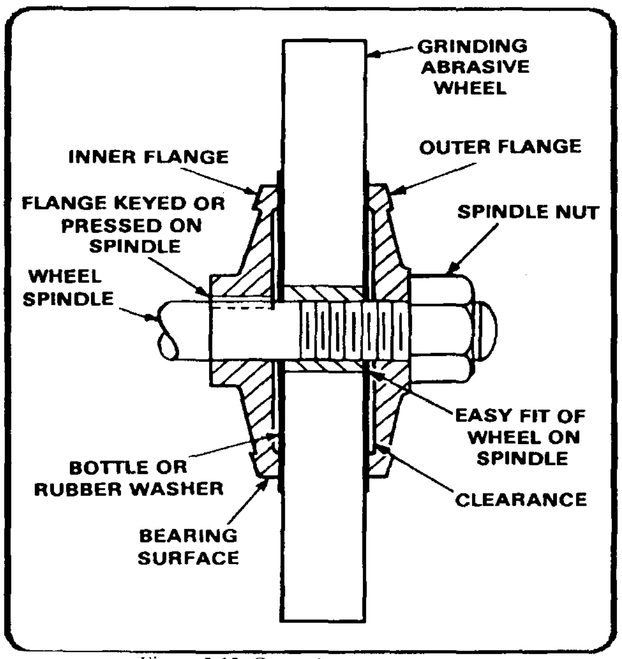


Figure 5-12. Correctly mounted wheel.

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. [n 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.

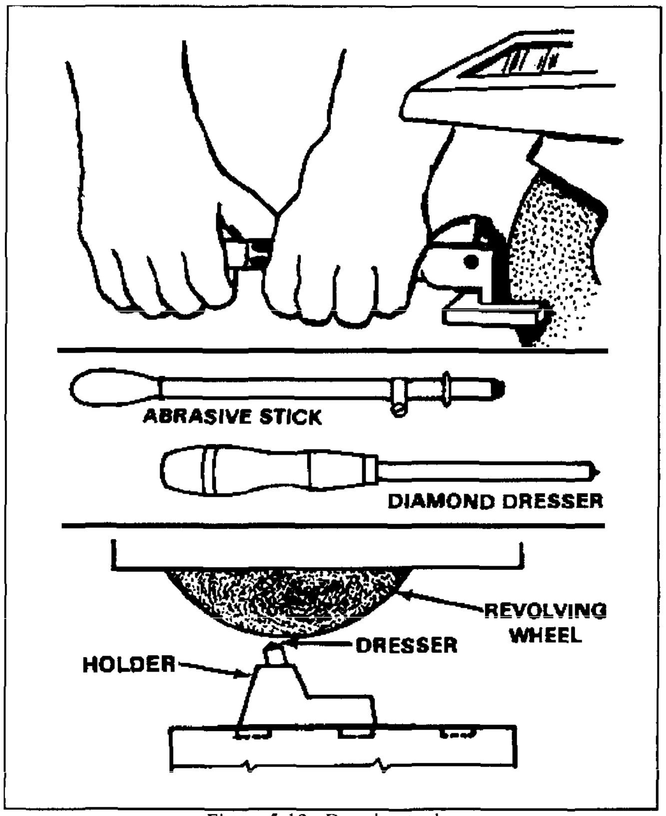


Figure 5-13. Dressing tools.

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° to 15° in the direction of rotation and 30° to the plane of the wheel as shown in Figure 5-14 to prevent chatter and gouging. Rotate the diamond slightly in it's 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.

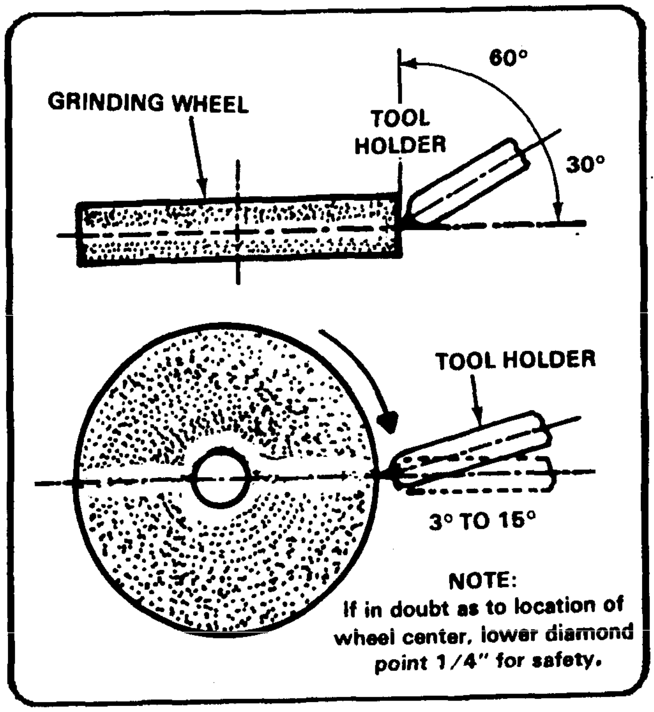


Figure 5-14. Position of diamond dresser.

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.

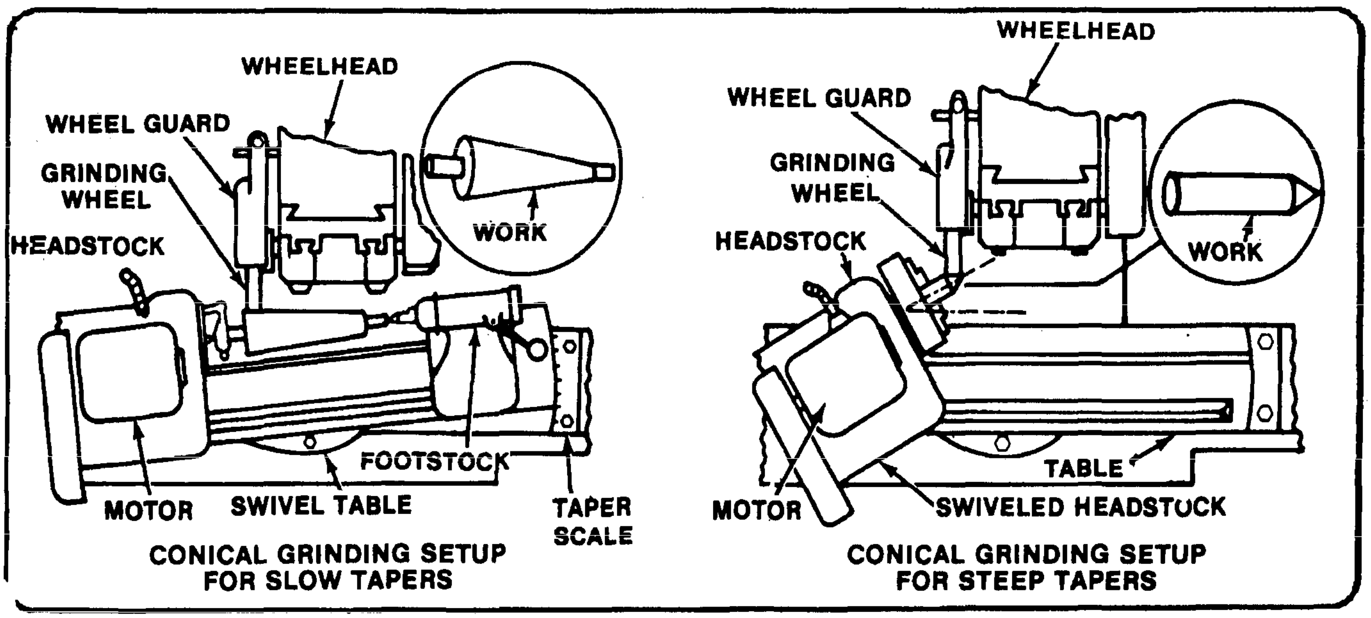


Figure 5-15. Conical grinding setups.

Cylindrical Grinding

If cylindrical grinding is to be performed, such as grinding of workplaces 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 concial 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.

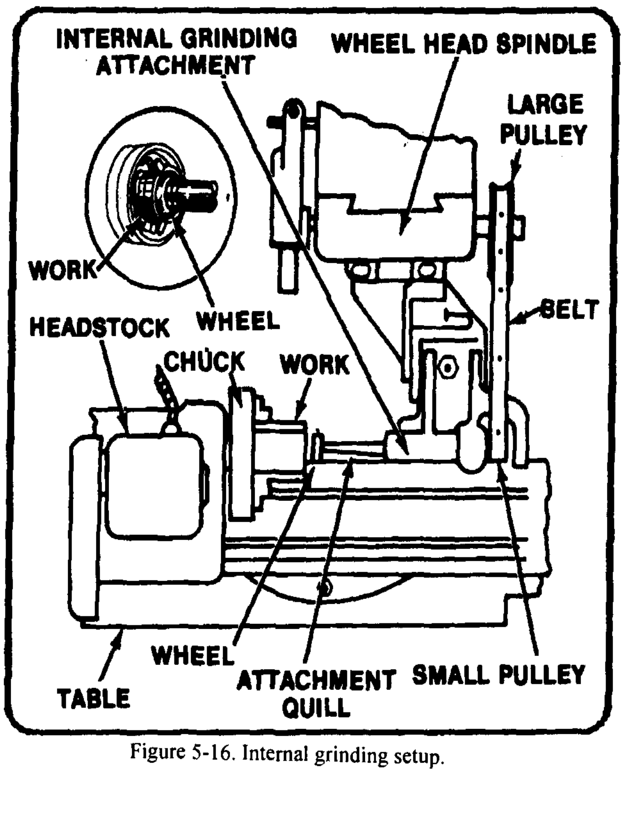


Figure 5-16. Internal grinding setup.

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 workplaces 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 cetain 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:

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

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:

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

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 l/4-HP electric motor mounted to a swivel-type support bracket which can be adjusted vertically and radically 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.

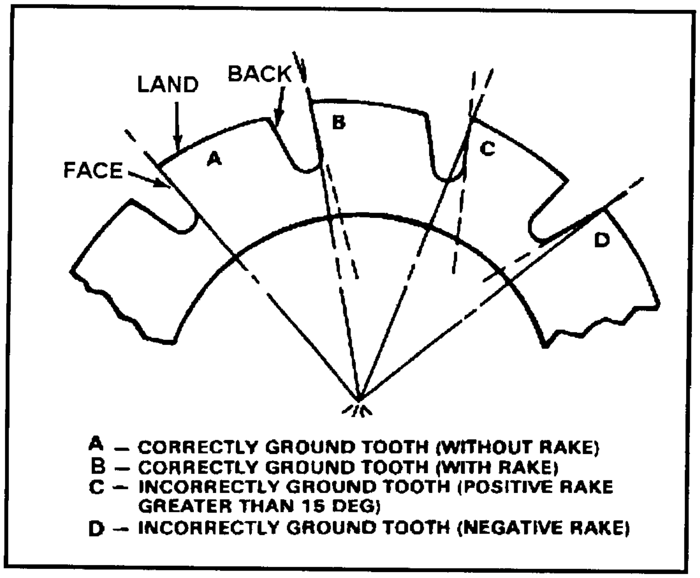


Figure 5-17. Correct and incorrect grinding of formed milling cutter teeth.

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.

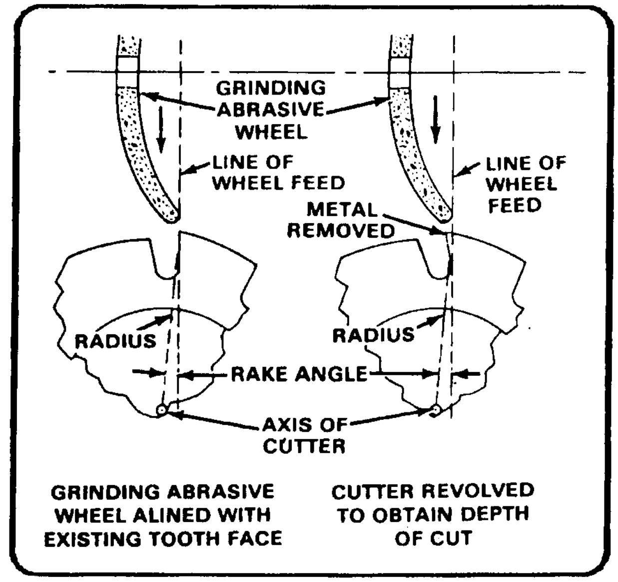


Figure 5-18. Aligning formed milling cutter and grinding wheel.

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.

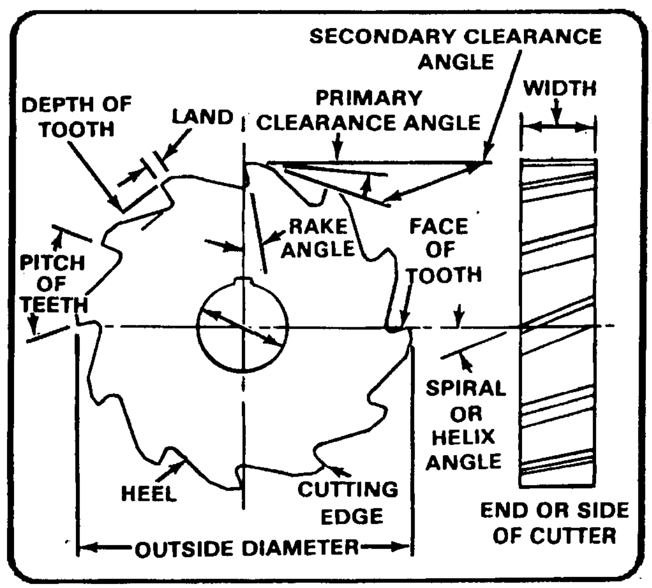


Figure 5-19. Milling, cutter nomenclature.

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 x 5 x6 = 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.

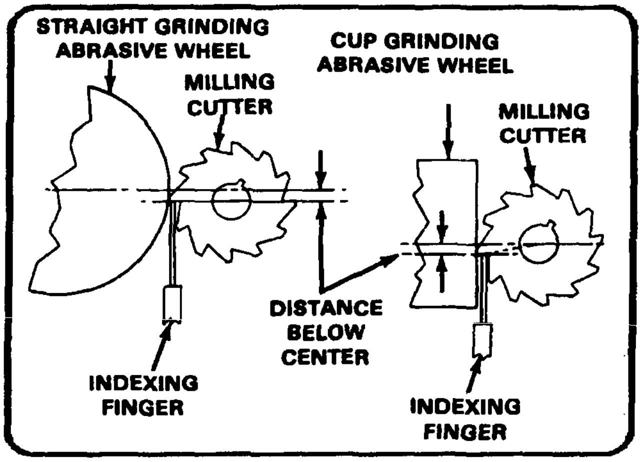


Figure 5-20. Grinding primary clearance angle.

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 workplaces 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 X FF X WRPM) + 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 l-inch-wide wheel is used to rough grind a hardened steel cylinder with a work RPM of 300.

Table travel =
(1 x 1/4 x 300) ÷ 12 = (75) ÷ 12 = 6.25 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.

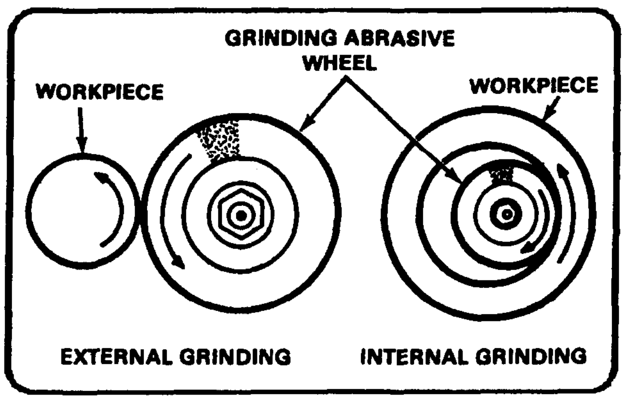


Figure 5-21. Direction of rotation for cylindrical grinding.

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.

Chapter 6

SAWING MACHINES

GENERAL

PURPOSE

The sawing machine is a machine tool designed to cut material to a desired length or contour. It functions by drawing a blade containing cutting teeth through the workpiece. The sawing machine is faster and easier than hand sawing and is used principally to produce an accurate square or mitered cut on the workpiece.

TYPES

The power hacksaw and the bandsaw are two common types of sawing machines used to cut metal in the machine shop. The power hacksaw uses a reciprocating (back and forth) cutting action similar to the one used in a hand hacksaw. The power hacksaw is used for square or angle cutting of stock. The band saw uses a continuous band blade. A drive wheel and an idler wheel support and drive the blade.

POWER HACKSAW MACHINES

DESCRIPTION

All power hacksaw machines are basically similar in design. Figure 6-1 shows a typical power hacksaw and identifies its main parts, which are discussed below.

Base

The base of the saw usually contains a coolant reservoir and a pump for conveying the coolant to the work. The reservoir contains baffles which cause the chips to settle to the bottom of the tank. A table which supports the vise and the metal being sawed is located on top of the base and is usually referred to as part of the base.

Vise

The vise is adjustable so that various sizes and shapes of metal may be held. On some machines the vise may be swiveled so that stock may be sawed at an angle. The size of a power hacksaw is determined by the largest piece of metal that can be held in the vise and sawed.

Frame

The frame of the saw supports and carries the hacksaw blade. The machine is designed so that the saw blade contacts the work only on the cutting stroke. This. action prevents unnecessary wear on the saw blade. The cutting stroke is on the draw or back stroke.

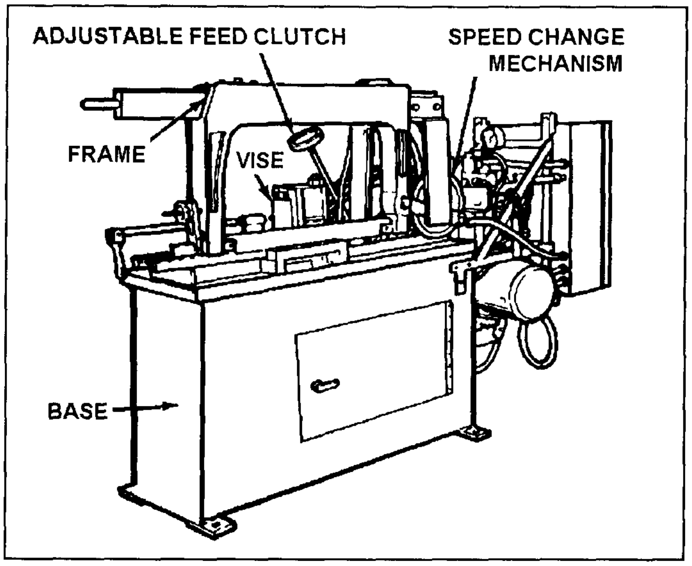


Figure 6-1. Power hacksaw.

Some machines feed by gravity, the saw frame having weights that can be shifted to give greater or less pressure on the blade. Other machines are power fed with the feed being adjustable. On these machines, the feed is usually stopped or reduced automatically when a hard spot is encountered in the material, thus allowing the blade to cut through the hard spot without breaking.

SPEED-CHANGE MECHANISM

The shift lever allows the number of strokes per minute to be changed so that a variety of metals may be sawed at the proper speeds. Some saws have a diagram showing the number of strokes per minute when the shift lever is in different positions; others are merely marked "F," M," and "S" (fast, medium, and slow).

ADJUSTABLE FEED CLUTCH

The adjustable feed clutch is a ratchet-and-pawl mechanism that is coupled to the feed screw. The feed clutch may be set to a desired amount of feed in thousandths of an inch. Because of the ratchet-and-pawl action, the feed takes place at the beginning of the cutting stroke. The clutch acts as a safety device and permits slippage if too much feed pressure is put on the saw blade. It may also slip because of a dull blade or if too large a cut is attempted. This slippage helps prevent excessive blade breakage.

BANDSAW MACHINES

Metal-cutting bandsaw machines fall into two basic categories: vertical machines (Figure 6-2) and horizontal machines (Figure 6-3). Band saws use a continuous saw blade. Chip removal is rapid, because each tooth is a precision cutting tool and accuracy can be held to close tolerances eliminating or minimizing many secondary machining operations.

VERTICAL BANDSAWING MACHINE

The metal-cutting vertical band sawing machine, also called a contour machine, is made in a variety of sizes and models by several manufacturers. The size of a contour machine is determined by the throat depth, which is the distance from the saw band to the column. Figure 6-2 shows a typical contour machine and identifies its main parts, which are discussed below.

- The head is the large unit at the top of the contour machine that contains the saw band idler wheel, the drive motor switch, the tension adjustment handwheel and mechanism, a flexible air line (directs a jet of air at the work to keep layout lines free from chips), and the adjustable post which supports the upper saw guide. The job selector dial is also located on the head.

- The column contains the speed indicator dial, which is driven by a cable from the transmission and indicates the speed in feet per minute (FPM). The butt welder is also mounted on the column.

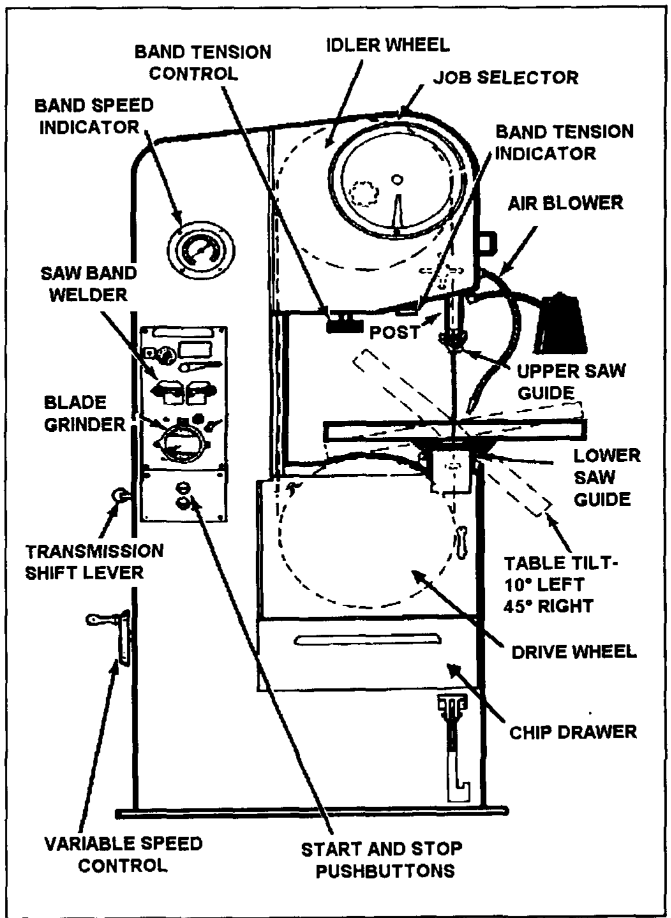


Figure 6-2. Vertical band sawing machine.

- The base contains the saw band drive wheel, the motor, and the transmission. The transmission has two speed ranges. The low range gives speeds from 50 FPM to 375 FPM. The high range gives speeds from 260 FPM to 1,500 FPM. A shift lever on the back of the base can be placed in the high, low, or neutral position. Low is recommended for all speeds under 275 FPM. The base also supports the table and contains the lower saw band guide, which is mounted immediately under the table slot. The power feed mechanism is located within the base, and the feed adjustment handle and foot pedal are located on the front of the base.

VARIABLE SPEED UNIT

The variable speed unit is located within the base of the machine. This unit consists of two V-type pulleys which are mounted on a common bearing tube. A belt on one pulley is driven by the transmission, while the belt on the other pulley drives the saw band drive wheel. The two outside cones of the pulleys are fixed, but the middle cone is shifted when the speed change wheel is turned. A shift in the middle cone causes the diameter of one pulley to increase and the diameter of the other pulley to decrease. This slowly changes the ratio between the two pulleys and permits a gradual increase or decrease in the speed of the machine.

HORIZONTAL BANDSAW MACHINE

The horizontal band sawing machine does the same job as the power hacksaw but does it more efficiently. The blade of the bandsaw is actually a continuous band which revolves around a drive wheel and idler wheel in the band support frame. Two band guides use rollers to twist the band so that the teeth are in the proper cutting position. The guides are adjustable and should be adjusted so that they are just slightly further apart than the width of the material to be cut. This will give maximum support to the saw band and help assure a straight cut.

The vise on the horizontal bandsaw is much like the one on the power hacksaw. However, the horizontal bandsaw has a much greater capacity for large stock than does the power hacksaw. The stationary jaw can be set at several angles. The movable jaw adjusts automatically to whatever position the stationary jaw is in when the vise handwheel is tightened.

The horizontal bandsaw is operated hydraulically by controls on a control box, which is located on the front side of the machine. A motor and pump assembly supplies hydraulic fluid from a reservoir in the base to a cylinder, which raises and lowers the support arm and also controls the feed pressure and band tension. A speed and feed chart is sometimes provided on the machine, but when it is not, consult the operator's manual for the proper settings for sawing.

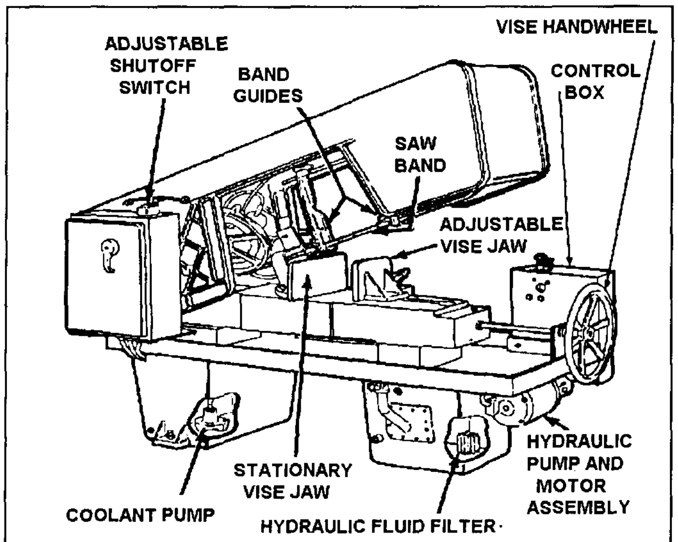


Figure 6-3. Horizontal Bandsaw.

A coolant pump is located in one of the legs of the base, which serves as a coolant reservoir. The coolant cools the saw band and also washes away chips from the cut before they can clog the band.

SAFETY PRECAUTIONS

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

- Keep hands away from the saw blade of the hacksawing machine or bandsawing machine when in operation.
- Ensure the power supply is disconnected prior to removal or installation of saw blades.
- Use a miter guide attachment, work-holding jaw device, or a wooden block for pushing metal workpieces into the blade of the bandsaw wherever possible. Keep fingers well clear of the blade at all times.
- When removing and installing band saw blades, handle the blades carefully. A large springy blade can be dangerous if the operator does not exercise caution.

TOOLS AND EQUIPMENT

POWER HACKSAW BLADES

Power hacksaw blades differ from hand hacksaw blades in that they are generally heavier, made in longer sizes, and have fewer teeth per inch. Hacksaw blades are discarded when they become dull; sharpening is not practical.

Materials commonly used in manufacturing power hacksaw blades are high-speed tungsten steel and high-speed molybdenum steel. On some blades only the teeth are hardened, leaving the body of the blade flexible. Other blades are hardened throughout.

The set is the amount of bend given the teeth. The set makes it possible for a saw to cut a kerf or slot wider than the thickness of the band back (gage), thus providing side clearance.

This is the pattern in which the teeth are set. There are three set patterns: raker, wave, and straight, as shown in Figure 6-4.

The pitch of hacksaw blade teeth (Figure 6-5) is expressed as the number of teeth per linear inch of blade. For example, a blade having 10 teeth per inch is said to be 10 pitch.

Power hacksaw blades are coarser in pitch (fewer teeth per inch) than hand hacksaw blades. Common pitches for power hacksaw blades range from 4 to 14 teeth per inch.

The following are guidelines for the selection of power hacksaw blades.

- Select power hacksaw blades for material to be cut.
- Soft materials require a coarser blade to provide adequate spaces between the teeth for removal of chips. Hard material requires a finer blade to distribute the cutting pressure to a greater number of teeth, thereby reducing wear to the blade.
- At least three teeth must be in contact with the workpiece at all times or the blade will snag on the workpiece and break teeth from the blade. Therefore, a blade must be selected with sufficient pitch so that three or more teeth will be in contact with the workpiece, no matter what type of material is being cut.

Figure 6-5 is provided to assist in the proper selection oxf power hacksaw blades. Note that sheet metal and tubing are listed separately from solid stock. It is assumed that solid stock will be sufficiently thick that three or more teeth will be in contact with the stock at all times.

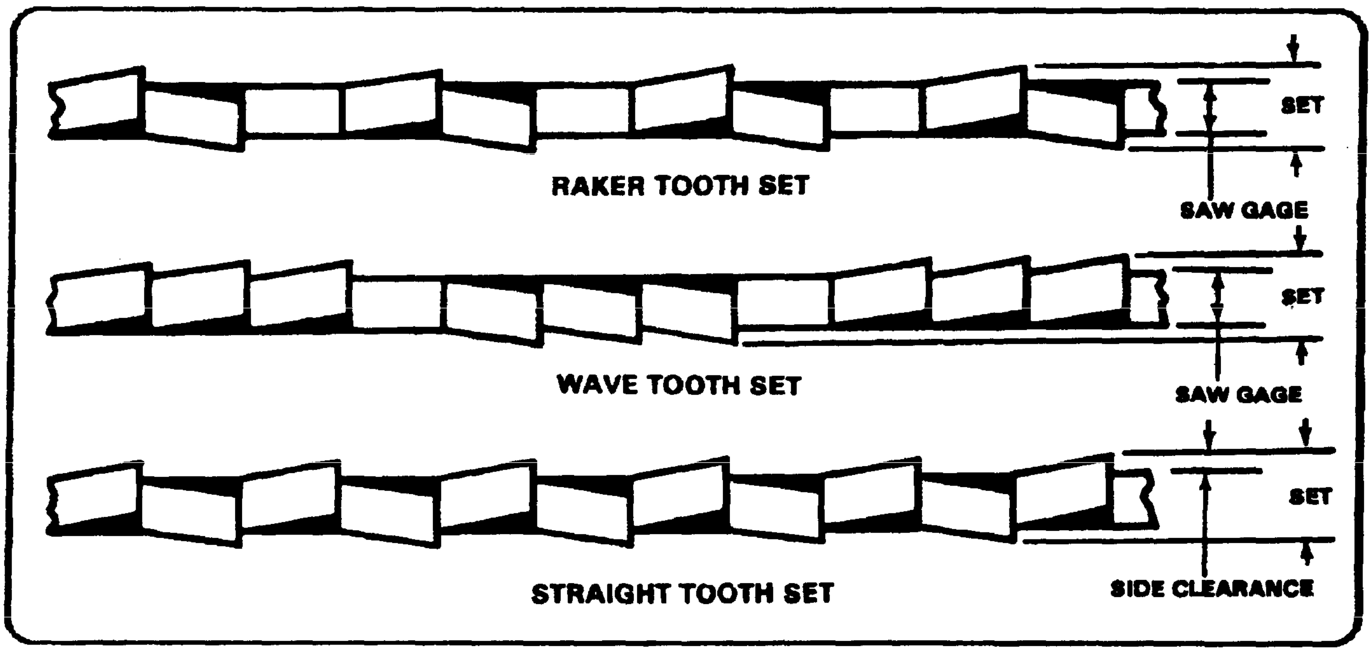


Figure 6-4. Set pattern.

MATERIAL	HACKSAW BLADE TEETH PER INCH (PITCH)
SHEET METAL	14
SOLID STOCK: 1	
ALUMINUM	4
BRASS	10
BRONZE	4
CAST IRON	4
COPPER	4
STEEL, ALLOY	6
STEEL, HIGH-SPEED	6
STEEL, MACHINE	4
STEEL, STAINLESS	6
STEEL, TOOL (ANNEALED)	6
STEEL, TOOL (UNANNEALED)	4
TUBING, THIN	14
TUBING, HEAVY	10

1. Three or more teeth must contact the workpiece at all times to prevent blade damage. If the recommended pitch for a material fails to meet this requirement, a blade with more teeth to the inch should be used.

Figure 6-5. Selection of power hacksaw blades.

BANDSAW BLADES

General

Bandsaw blades are manufactured in two forms. They are supplied in rolls of 50 to 500 feet for use on machines that have butt welders for forming their own blade bands. Bandsaw blades are also supplied in continuous welded bands for machines having no provisions for welding.

Materials

Bandsaw blades are made from special alloy steels. The blades are made flexible by annealing the body of the blade and hardening only the teeth.

Set

Metal cutting bandsaw blades have their teeth bent (Figure 6-4). This bend produces a kerf slightly wider than the thickness of the blade, which prevents the blade from being pinched by the stock. There are three set patterns: raker, wave, and straight, as shown in Figure 6-4.

Pitch

The pitch of bandsaw blades is expressed as the number of teeth per linear inch of the blade. Metal cutting blades range from 6 to 32 teeth per inch, the coarser tooth blades being used for sawing large stock and soft metals.

Selection of Bandsaw Blades

Select bandsaw blades according to the type of material to be cut, the thickness of the material to be cut, and the sawing operation to be performed. Always use the widest and thickest saw band possible. However, consider the curvature of the cut, since wide saw blades cannot cut sharp curves. Figure 6-6 shows saw band selection for various radii.

For general sawing, use the raker set pattern. The wave set pattern is used where thin work sections are encountered during the cut, such as tubing, angles, and channels.

Three teeth of the bandsaw blade must be in contact with the workpiece at all times to prevent chatter and shearing off teeth. Therefore, use fine tooth blades to cut sheet metal and

tubing. If the sheet metal is too thin to meet this requirement with the finest tooth blade available, place the metal between plywood fiberboard, or thicker metal. Figure 6-7 is a guide for selecting the proper pitch band saw blade for different metals and metal thickness.

The finish depends largely upon the saw pitch. The faster the saw speed and the finer the sawpitch, the finer the finish. Lubricating helps to improve the finish. A fine saw pitch, high velocity, and light feed produce the finest finish.

Bandsaw Blade Wear

Bandsaw blades naturally become dull from prolonged use, but some conditions promote greater than normal wear on the blades. Blades dull quickly if used at too high a speed for the material being cut. Also, if the material to be cut is too hard for the pitch of the blade, abnormal wear will result. The most common cause of premature blade dulling occurs from using too fine a pitch blade and from feeding too heavily.

The following symptoms indicate a dull bandsaw blade. When these symptoms are noticed, the blade should be replaced.

- It becomes difficult to follow a line, the blade being forced to one side or the other.
- The chips are granular (except for cast iron, which produces granular chips with both sharp and dull blades).
- The bandsaw blade cuts slowly or not at all when the workpiece is fed by hand.
- With the machine stopped or the bandsaw blade removed, run a finger slowly over the teeth in the cutting direction. If sharp edges are not felt the blade is dull.

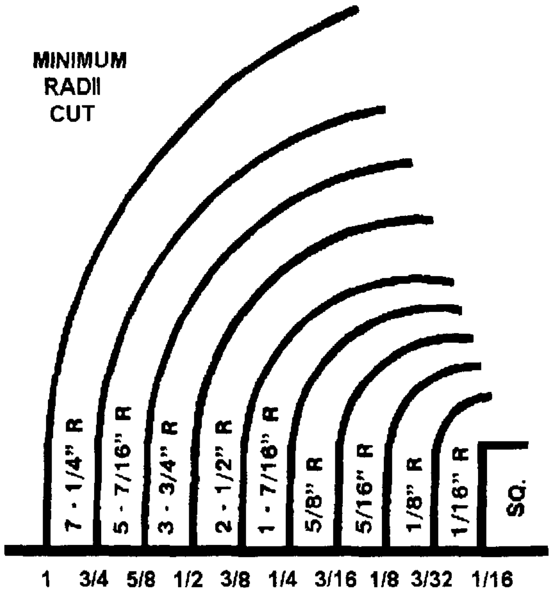


Figure 6-6. Saw band selection for various radii.

MATERIAL	BANDSAW BLADE (TPI)	MATERIAL	BANDSAW BLADE (TPI)
SHEET METAL UNDER 1/8 INCH THICK	24-32	SOLID STOCK CONTINUED	
SHEET METAL OVER 1/8 INCH THICK	18	STEEL, ALLOY	12-14
SOLID STOCK: 1		STEEL,HIGH-SPEED	12-14
ALUMINUM	6-10	STEEL, MACHINE	10-14
BRASS	10-12	STEEL, STAINLESS	12-14
BRONZE	12-14	STEEL, TOOL	12-14
CAST IRON	10-12	TUBING UNDER 1/8-INCH WALL THICKNESS	24-32
COPPER	10-12	TUBING OVER 1/8-INCH WALL THICKNESS	18

1. Three or more teeth must contact the workpiece at all times to prevent shearing of the blade teeth. If the recommended pitch for solid stock fails to meet this requirement, a blade with finer pitch must be selected.

Figure 6-7. Selection of band saw blades.

FILE BANDS

The bandsawing machine is adapted for filing by use of the band file attachment. A band file is fitted over the drive and idler wheels and in place of the bandsaw blade. The band is made up of several parts or segments which are riveted at one end (the leading end) to a spring steel band. The trailing end of each segment is free to lift during the time when the band bends over the drive and idler wheels of the band saw. When the band straightens out, the segments lock together. Figure 6-8 shows the construction of and terminology for file band parts.

Note that the gate segment (a segment at one end of the band that is specially designed to allow the two band ends to be locked together) has a shoulder rivet and a dowel rivet protruding from beneath it. The shoulder rivet locks into the other file band end, and the dowel rivet aligns the two end segments and prevents the shoulder rivet from sliding out of the locked position during tiling. The gate segment of a file band is identified by yellow paint.

Cut of File Teeth

File bands are either coarse or bastard cut and normally range in pitch from 10 to 20 teeth per inch. The coarse 10-pitch bands are used for filing softer metals such as aluminum, brass, copper, and cast iron. A bastard-cut 14-pitch band is a good choice for general steel tiling, while 16 to 20 pitch bastards are recommended for filing tool steel.

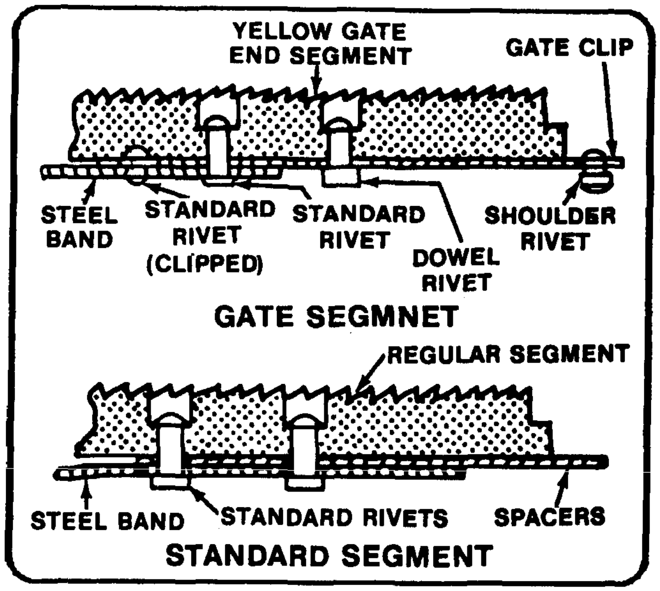


Figure 6-8. Construction and parts of a file band.

Selection of Band Files

Choose band files on the basis of workpiece thickness and type of material to be filed. In general, the thicker the workpiece, the coarser the file should be. This is due to a large; chip accumulation from the larger area of the workpiece, thus requiring additional space for the chips between the teeth. On thin sheet metal, a fine pitch file is required to prevent chatter. Use fine pitch files for filing tough carbon and alloy steels; use coarser pitch files for filing softer metals. Figure 6-9 is provided to aid in selecting the proper file for filing specific materials.

BAND FILE		
MATERIAL	CUT OF TEETH	TEETH PER INCH
ALUMINUM	SHORT ANGLE- OR BASTARD-CUT	10-12
BRASS	SHORT ANGLE- OR BASTARD-CUT	10-12
BRONZE	SHORT ANGLE- OR BASTARD-CUT	10-12
CAST IRON	SHORT ANGLE- OR BASTARD-CUT	10-12
COPPER	SHORT ANGLE- OR BASTARD-CUT	10-12
FIBER	SHORT ANGLE- OR BASTARD-CUT	10-12
MAGNESIUM	SHORT ANGLE- OR BASTARD-CUT	10-12
STEEL, ALLOY	BASTARD-CUT	14-24
STEEL, MACHINE	BASTARD-CUT	14-16
STEEL, TOOL	BASTARD-CUT	14-24

Figure 6-9. Selection of band files.

Care and Cleaning of Band Files

Clean the file often, using a stiff brush or a file card. Move the brush in the direction of each cut of the file to dislodge all particles hidden between the teeth.

The file band should not be coiled into more than three loops. The best means of storing file bands is in a cabinet looped over a 16-inch radius support with the ends hanging free.

Band File Attachment

A band file attachment (Figure 6-10) is provided with most bandsaw machines to permit the use of band files. A typical band file attachment consists of a band file guide and upper and lower guide supports that attach to the frame and part of the band saw. A special filing filler plate is provided to adapt the table slot to the extra width and depth required for the band file and file band guide.

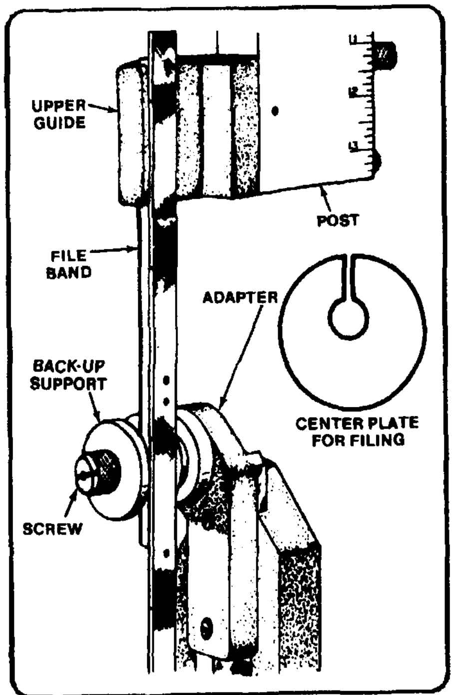


Figure 6-10. Band file attachment installed on bandsawing machine.

POLISHING BANDS

Polishing can be performed on the bandsaw using a polishing attachment and polishing band. The polishing band is usually 1 inch wide and has a heavy fabric backing.

Types of Polishing Bands

Polishing bands for bandsawing machines are usually supplied in various grain sizes of aluminum-oxide or silicone carbide abrasive: No 50 grain (coarse) for heavy stock removal and soft material, No 80 (medium) for general surface finishing, and No 120 or No 150 grain (fine) for high polishing and light stock removal.

Selection of Polishing Bands

Polishing bands should be selected according to the particular job to be performed, For removing tool marks and deburring edges, use the No 50 grain polishing band. Finer grain polishing bands should not be used on soft metals like aluminum or cast iron because the band will quickly fill with metal particles, reducing the cutting action

Polishing Attachment

The polishing attachment (Figure 6-11), similar to the band file attachment, provides support for the polishing band. The polishing band plate acts as a solid backing for the polishing band to prevent stretching and distorting the band when the workpiece is held against it. Use a polishing band filler plate to fill the table slot so the workpiece can be supported close to the polishing band.

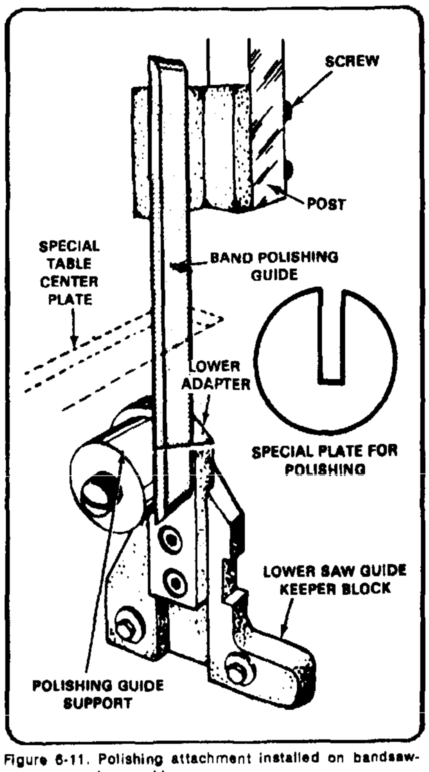


Figure 6-11. Polishing attachment installed on bandsawing machine.

DISC-CUTTING ATTACHMENT

Use the disc-cutting attachment (Figure 6-12) to saw internal or external circles and discs. The diameter of the circle that can be cut is limited to the length of the cylindrical bar on the attachment or to the throat depth of the machine. The disc-cutting attachment consists of three main parts a clamp and cylindrical bar, which is fastened to the saw guidepost; an adjustable arm, which slides on the cylindrical bar; and a pivot or centering pin. The disc must be laid out and center-drilled to a depth of 1/8 inch to 3/16 inch to provide a pivot point for the centering pin. The centerline of the centering pin must be in line with the front edge of the sawteeth and at the desired distance from the saw band.

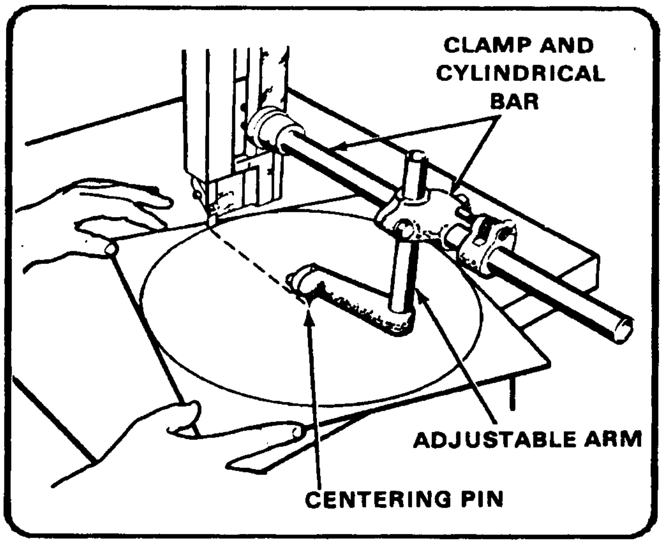


Figure 6-12. Disc-cutting attachment.

ANGULAR BLADE GUIDE ATTACHMENT

This attachment (Figure 6-13) twists the blade so that long workpieces that would not normally clear the machine column can be cut. The blade is twisted to a 30 degree angle on most machines.

MITER GUIDE ATTACHMENT

A typical miter guide attachment is illustrated in Figure 6-14. The workpiece is supported against the miter head which attaches to the slide arm. The attachment can be set at an angle with a protractor, using the table slot as a reference line. A gage rod can be extended from the attachment and used as a stop when identical lengths are sawed. When not in use, swing the attachment on the slide rod so that it hangs below the table.

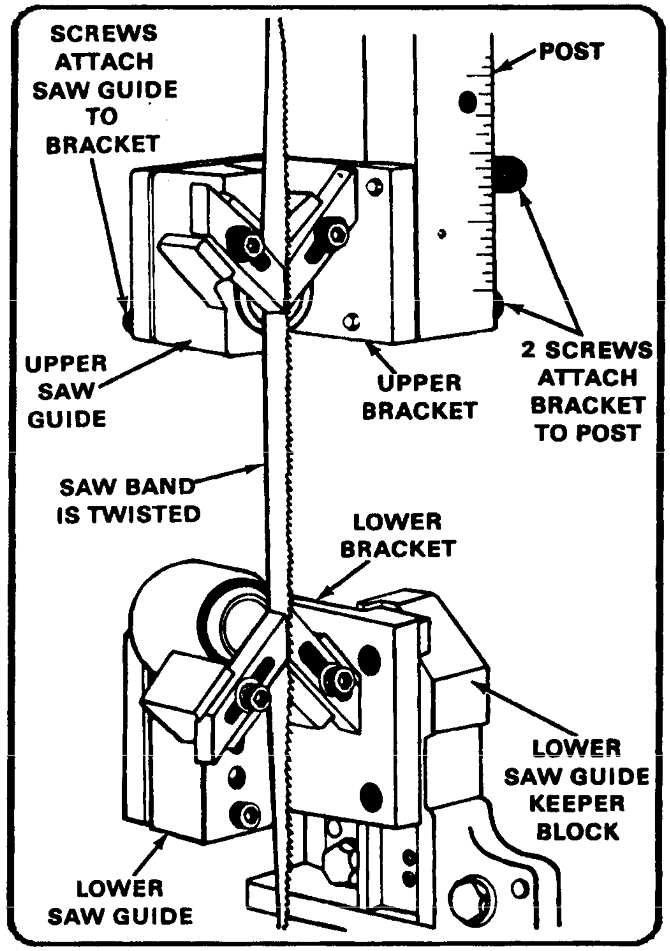


Figure 6-13. Angular saw guides.

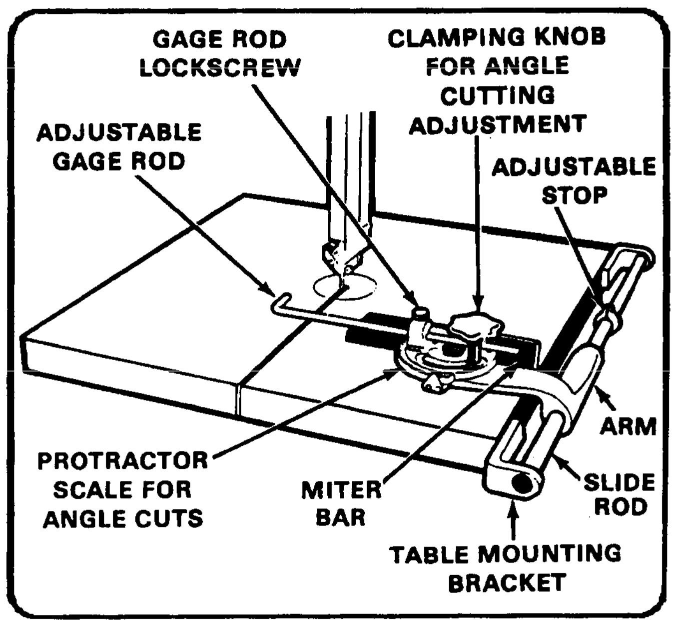


Figure 6-14. Miter guide attachment.

LAYING OUT AND MOUNTING WORK

POWER HACKSAWING

Layout

Power hacksaw machines are primarily intended for straight line cutting of stock to specific lengths. Laying out the workpiece consists of measuring the length to be cut and indicating the position for the cut by scribing a line on the stock.

Mounting

Before mounting the stock to be cut, the vise should be checked for squareness with the hacksaw blade. Place a machinist's square against the blade and the stationary vise jaw. Adjust the jaw, if necessary, at 90° to the blade. If the workpiece is to be cut at an angle other than 90°, loosen the vise and swivel it to the desired angle, measuring the angle carefully with a protractor.

Stroke

Move the blade frame and hacksaw blade by hand through one draw stroke and one return stroke. Observe whether the stroke is centered on the work and if the blade holders will clear the workpiece at the end of the stroke. Readjust the position of the vise if the stroke is not centered on the workpiece. Shorten the stroke if the blade holders hit the workpiece at the end of each stroke.

Stop gage

Use a stop gage to speed up mounting stock when several pieces of the same length are to be cut. Mount the first piece in the vise and align with the hacksaw blade to cut at the scribed line, When the workpiece is correctly positioned, move the stop gage up to the end of the workpiece and lock it in place. Cut subsequent pieces by moving the stock up to the stop gage and clamping the workpiece in the vise at this position.

Vise

The vise must be securely tightened on the workpiece to prevent loosening during cutting. Blade breakage might result from shifting workpieces not clamped tightly in the vise.

HORIZONTAL BAND SAWING MACHINES

The stock should be measured and the position of the cut machinist's square or a protractor against the bandsaw blade and the stationary vise jaw. Position the stock in the vise so that the saw blade aligns with the scribed line on the stock. If. more than one piece is to be cut to the same size, move the stock stop arm against the end of the stock and lock it in place. Additional pieces can then and moved up against the stop to produce pieces equal in length to the first piece

VERTICAL BANDSAWING MACHINES

When laying out workpieces for vertical bandsawing operations, consider the size of the stock in relation to the clearance of the bandsaw machine column. For straight-line sawing the clearance is easy to judge, but for contour sawing of large size stock, the directions of cut must be carefully figured to prevent the stock from hitting the column. If a small section is to be cut from a large sheet of metal, the section should be roughly cut oversize from the sheet and then carefully cut to the prescribed outline.

CIRCULUAR SAWING

When a circle or disk is to be sawed using the disk cutting attachment, lay out the circle on the stock as follows:

- Using a compass or pair of dividers, scribe a circle in the desired location and of the desired diameter on the stock.
- Center-punch and drill a center hole in the disk to accept the center pin of the disk cutting attachment. Make the hole only as deep and as large as required for the center pin; too large a hole will cause the center pin to fit loosely, which will result in an inaccurate cut.

CONTOUR SAWING

When an outline to be cut consists of more than two intersecting lines, the following procedure should be followed.

- Scribe the exact shape required on the stock. Take advantage of straight, clean edges on the uncut stock in laying out the piece to save unnecessary cuts.

- Determine the bandsaw blade size necessary to cut the smallest radius laid out on the workpiece
- Select a twist drill equal to or greater in diameter than the width of the bandsaw blade. Drill a hole in each comer of the pattern, making sure the holes fall within the section of material that will be removed. The comer sections are notched out after the piece is cut.
- If an internal section is to be removed from the stock and the edge must remain unbroken, layout and drill a starting hole (Figure 6-15) using a drill larger in diameter than the, width of the band saw blade. The bandsaw blade will be inserted through this hole before being welded into a band and installed on a bandsawing machine.

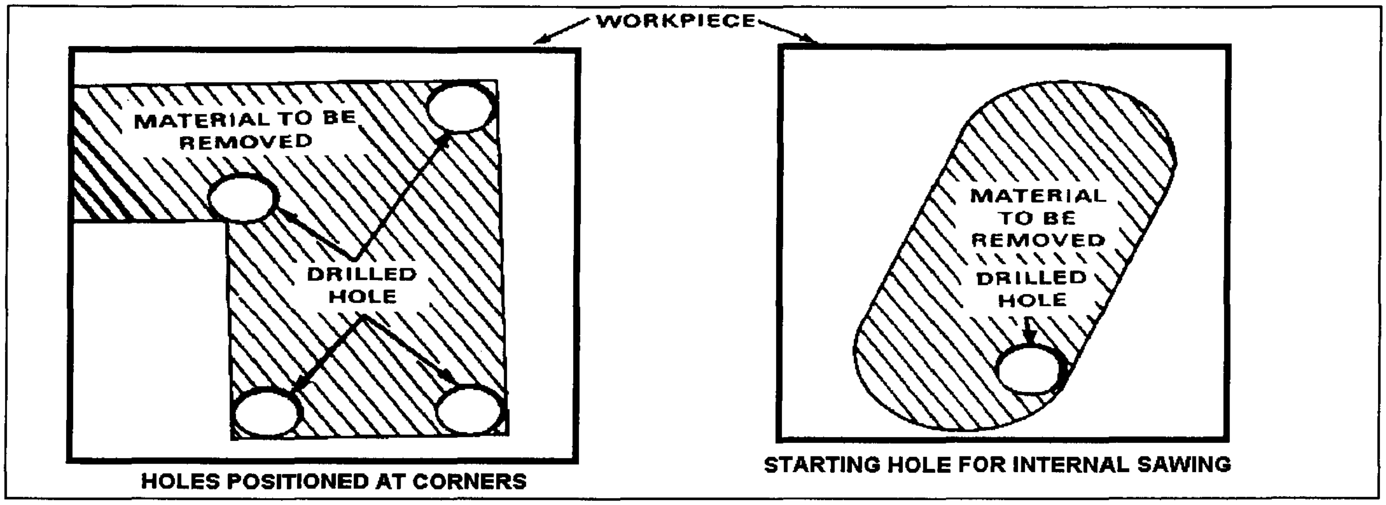


Figure 6-15. Hole layout for contour sawing.

GENERAL SAWING

Efficient sawing with sawing machines requires sharp saw blades in good condition. To prevent dulling and breakage of saw blades, proper speeds and feeds must be maintained. The speed of the saw blade for any specific operation depends upon the nature of the material being cut.

POWER HACKSAWING

Power hacksawing machines cut by drawing the hacksaw blade toward the motor end of the machine. At the completion of this movement called the draw stroke, the hacksaw blade is lifted slightly to clear the material being cut and moved an equal distance in the opposite direction.

Mounting Workpieces

Workpieces for metalcutting machines are not mounted to the machine, but are supported by the table of the machine and guided by one of the sawing machine attachments or by hand.

Power Hacksaw Speeds.

Since the cutting speed of hacksawing machines is measured in strokes per minuet, the length of the stroke is an important consideration. A longer stroke at a given speed will cut faster than a shorter stroke at the same speed. Thus. to obtain a proper cutting speed the length of the stroke must be specified.

The length of the stroke of most power hacksaws is between 4 and 10 inches depending upon the size of the machine. On machines with an adjustable stroke, the wider the stock being cut, the shorter the stroke to prevent the blade holders from hitting the stock.

With most power hacksaws, the stroke length is adjustable within 2 or 3 inches. and on some machines more than one speed can be selected. On single-speed hacksawing machines, the speed must be regulated by changing the stroke.

If the stroke is doubled the machine will cut twice as fast, and if the stroke is decreased by one-half, the machine will cut half as fast. This proportion can be applied to any fraction to increase or decrease the cutting speed of the machine.

The speeds given in the chart, Figure 6-16, bellow are for example only. The correct speeds for cutting various metals will depend on the type of machine you are using. In general the faster speeds are used for cutting soft materials and the slower speeds are used for cutting harder materials. If a recommended speed cannot be approximated either by changing the stroke or changing the speed, the feed can be decreased to prevent undue wear to the hacksaw blade.

Power hacksaw machines having a mechanical feed can usually be regulated to feed the saw downward from 0.001 to 0.025 inch per stroke, depending upon the type and size of the material to be cut. On these machines, a device to stop the feed when hard spots are encountered is usually incorporated into the design.

The feed of machines having gravity feed is regulated by the weight of the saw frame and any additional weights or springs that might be connected or attached to the frame to increase or decrease the downward force of the hacksaw blade. Maximum and minimum blade pressures obtainable are determined by the manufacturer of the hacksawing machine, and are specified as relatively light or heavy.

The following general rules apply for selecting proper feeds for hacksawing machines:

- The feed should be very light when starting a cut and can be increased after the cut is well started.
- Hard materials require a lighter feed than soft materials; reduce the feed when welds or hard spots in materials are encountered.
- Wide material requires a heavier feed than narrow material because the pressure is distributed over a larger surface.
- Sharp hacksaw blades will cut well with lighter feeds. Heavier feeds are necessary for cutting with dull blades.

MATERIAL	SPEED IN STROKES PER MINUTE	
	4 TO 6 INCH	8 TO 10 INCH
ALUMINUM	135	65
BRASS	135	65
BRONZE	90	45
CAST IRON	90	45
COPPER	135	65
STEEL, ALLOY	90	45
STEEL, HIGH-SPEED	60	30
STEEL, MACHINE	135	65
STEEL, STAINLESS	60	30
STEEL, TOOL (ANNEALED)	90	45
STEEL, TOOL (UNANNEALED)	60	30

Figure 6-16. Power hacksawing machine speeds.

BANDSAWING

The cutting speed of the bandsaw machine is the speed of the bands blade as it passes the table measured in feet per minute. The feed of the horizontal band saw machines downward pressure applied to the material being cut by the bands blade. The feed of vertical bandsawing machines is the pressure applied to the bands blade by the material being cut.

Bandsawing Speeds

Proper bandsaw speeds are important in conserving bands blades. Too great a speed for the material being cut will cause abnormally rapid blade wear, while too slow a speed will result in inefficient production. The chart of recommended speeds (Figure 6-17) are guidelines only. It shows the speeds for a given type of machine. The cutting speed always depends on the type of machine you are using and the manufactures' recommendations.

All bandsawing machines have several cutting speeds. Since the diameter of the drive wheel of the bandsaw machine establishes a fixed ratio between the motor or transmission speed in RPM to the blade speed in FPM, it is not necessary to convert RPM into FPM as with most other machine tools. The speeds are identified in FPM on the sawing machine speed selector controls. Some machines have a speed indicator so a careful check of sawing speeds may be made when the machine is operating with or without a load.

In general the following principles apply to speeds of bandsaw blades:

- The harder the material, the slower the speed; conversely, the softer the material, the faster the speed.
- The faster the speed, the finer the finish produced on the cut surface. This principle applies to light feeds in conjunction with fast feeds.

Horizontal Bandsawing Machine Feeds

Feed of horizontal bandsaw machines is controlled by adjusting the pressure applied by the saw blade against the material being cut, as with hacksawing machines.

The horizontal saw has a spring counterbalance and a sliding weight to adjust the pressure of the blade. When the sliding weight is moved toward the pivot point of the saw frame the band saw blade pressure is reduced. When the weight is moved away from the pivot point, the pressure is increased.

The following general principles apply when regulating the feed of horizontal band saw machines.

- The feed should be very light when starting a cut. After the cut is started, increase the feed.
- Wider material requires a heavier feed than narrow material.
- Wide blades will stand greater pressure than narrow blades and can therefore be used with heavier feeds.
- A lighter feed is required for hard materials; a heavier feed can be used for soft materials.
- Reduce the feed when hard spots in the material are encountered such as chilled spots in cast iron and welds in joined sections.

MATERIAL	BANDSAWING SPEED (fpm)	MATERIAL	BANDSAWING SPEED (fpm)
ALUMINUM	200 TO 2,000	RUBBER, HARD	150 TO 250
BAKELITE	200 TO 900	STEEL, ALLOY	50 TO 100
BRASS, SOFT	175 TO 300	STEEL, HIGH CARBON	50 TO 100
BRASS, HARD	75 TO 150	STEEL, HIGH-SPEED	50 TO 90
BRASS, SHEETS	200 TO 900	STEEL, MACHINE	75 TO 175
BRONZE	75 TO 150	STEEL, SHEEET	150 TO 200
CAST IRON	50 TO 100	STEEL, STAINLESS	50 TO 75
COPPER	115 TO 175	STEEL, TOOL	50 TO 150
MONEL METAL	50 TO 100		

Figure 6-17. Band sawing speeds.

Vertical Machine Feeds

With vertical machines, the feed is the pressure applied to the saw blade by the material being cut. The workpiece may be hand fed or power fed depending upon the operation to be performed. Cutting curves or special contours requires that the workpiece be guided and fed into the saw blade by hand.

The power feed on bandsaw machines is operated by adjustable weights in the machine pedestal. The weights are connected by cables to one of the work-holding attachments of the sawing machine to pull the workpiece against the bandsaw blade. To operate the power feed, the weights are raised by depressing a pedal and the cables are then fixed to the work-holding attachment. When the pedal is released the weights pull the piece into the blade.

The following general rules apply to feeding workpieces on bandsawing machines:

- The feed should be light when starting a cut. The pressure can be increased after the cut is established.
- Hard materials require lighter feeds than softer materials.
- Wider band saw blades will stand greater pressure than narrow blades and can therefore be used with heavier feeds.
- When hard spots in the material being cut are encountered, reduce the feed until the spots are cut through.
- Use a light feed when cutting curves; a heavier feed for straight-line cutting.

COOLANTS

Most sawing machines used in military operations are dry cutting machines; that is, they are not intended for use with liquid coolants. However, some power hacksaws and horizontal bandsaws are equipped with a coolant attachment. Soluble oil products, when mixed with water to form emulsions, are used for these machines. This type of coolant has proven very satisfactory for sawing where cooling is an important factor. Most manufacturers of water oil emulsion coolants add a rust inhibitor to the solution to prevent rusting caused by the water in the coolant.

STRAIGHT-LINE SAWING

Straight-line sawing is the most common machine sawing operation. It may be performed using the power hacksaw, horizontal, or vertical band saw.

Power Hacksawing

The power hacksaw machine is designed primarily for straight-line sawing. A typical sawing operation is outlined below:

- Select a hacksaw blade of the proper length for the machine and proper pitch for the material to be cut. Install the hacksaw blade with the teeth pointing downward and toward the motor end of the hacksawing machine.
- Check the alignment of the vise and hacksaw blade and mount the workpiece in the vise. Make sure the vise holds the workpiece securely.
- Check the stroke of the hacksawing machine and adjust if necessary. After adjusting the stroke, move the hacksaw blade and sawing machine frame through one cycle (draw stroke and return stroke) by hand to check the blade clearance at each end of the workpiece. Readjust the position of the vise if necessary.
- Position the hacksaw blade about 1/4 inch above the workpiece and set the feed control to its lightest feed setting.
- Set the desired speed of the hacksawing machine.
- Start the machine and let the blade feed lightly into the workpiece for about 1/4 inch. Readjust the feed to whatever the material will stand for normal cutting.
- Permit the hacksaw blade to cut completely through the workpiece. The blade frame will trip a switch on the sawing machine bed to stop the sawing machine.

Horizontal Bandsawing

Like hacksawing machines, the horizontal bandsaw machine is used primarily for straight-line sawing. The typical sequence of operation for this machine is outlined on next page.

- Select and install a bandsaw blade of the proper pitch for the type and size of material to be cut.
- Set the vise to the desired angle and check the angle by measuring it from the line of the band saw blade.
- Mount the workpiece in the vise. Make sure the work piece is secured and will not loosen during cutting.
- Check the alignment of the blade guides for vertical positioning and adjust if necessary.
- Position the saw frame so that the bandsaw blade is 1/4 inch above the workpiece. The power feed weight should be placed at its lightest feed setting.
- Set the desired speed on the horizontal band sawing machine.
- Start the machine and let the bandsaw blade cut into the workpiece about 1/4 inch. After the cut has been established, readjust the feed weight to exert the desired amount of pressure on the workpiece.
- The machine will stop itself when it cuts completely through the workpiece.

Vertical Band Saw Operation

Straight-line sawing is performed on the vertical band saw machine by using one or a combination of several mechanisms or attachments: the miter guide attachment, with or without power feed, with or without the work-holding jaw device-. and the work-holding jaw device with power feed and angular blade guide attachment.

- The miter guide attachment on some machines can be connected to the power feed mechanism and on others must be fed by hand. The workpiece is clamped or hand-held against the miter guide attachment and the workpiece and attachment are moved on a track parallel to the blade, thereby assuring a straight-line cut.
- The work-holding jaw device on some machines can be connected to the power feed to produce straight-line cuts (Figure 6-18).
- The angular blade guide attachment is used for straight-line sawing when the workpiece cannot be cut in the usual manner because it is too large or too long to clear the column of the bar, sawing machine frame.

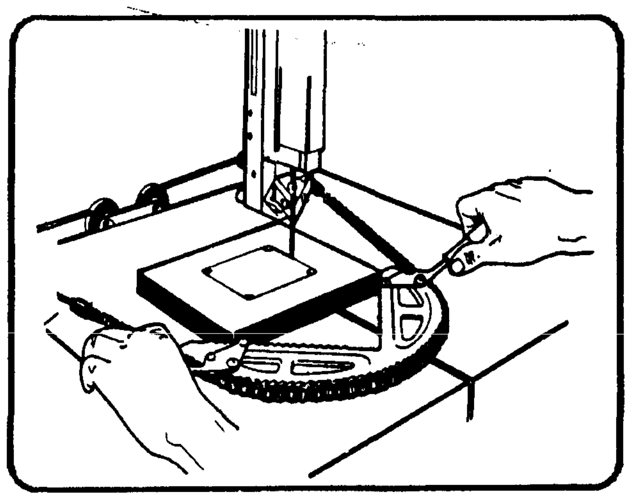


Figure 6-18. Work holding jaw device used for straight-line sawing with power feed.

A typical example of straight-line sawing is outlined below :

- Select a band saw blade of the desired pitch for the nature of material to be cut. The blade should be as wide as possible for straight-line sawing.
- Set the desired speed on the bandsawing machine.
- Position the workpiece at the desired angle in one of the machine attachments and connect the cable to the power feed mechanism if power feed is to be used.
- Start the bandsawing machine and feed the workpiece lightly into the blade to start the cut. Once the cut is started, the feed can be increased. If feeding is by hand, the pressure applied to the workpiece by the operator can be varied to find the best cutting conditions.

RADIUS SAWING

Radius sawing is performed on the bandsaw by either guiding the workpiece by hand or by using the disk-cutting attachment.

Blade Selection

Care must be taken to select a bandsaw blade of the proper width for the radius or circle to be cut. If the blade is too wide for the radius, the heel of the blade will press against the outer edge of the kerf (Figure 6-19). When the heel contacts this edge, any further twisting of the workpiece in an attempt to cut a sharper radius will twist the bandsaw blade and may result in the blade breaking.

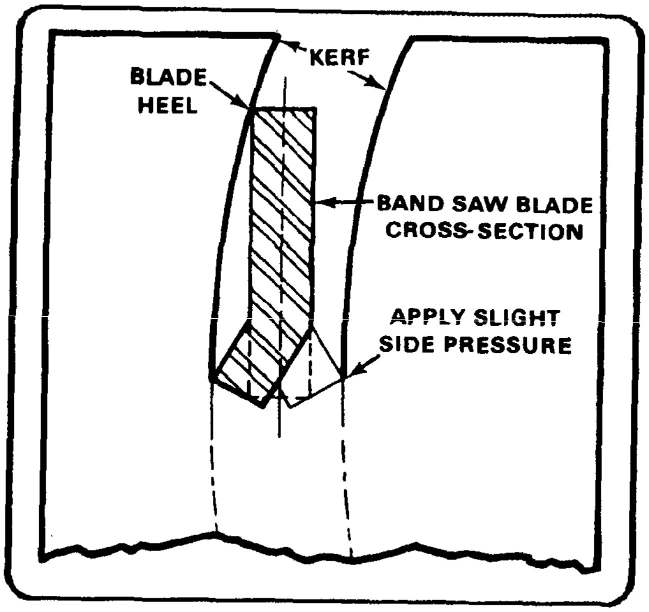


Figure 6-19. Radius limitation for bandsaw blade.

Cutting Pressure

When cutting a radius, apply a slight side pressure at the inner cutting edge of the bandsaw blade (Figure 6-19). This pressure will give the blade a tendency to provide additional clearance.

CONTOUR SAWING

Contour sawing is the process of cutting shapes in which the direction of the cut must be changed at intervals. Holes larger in diameter than the width of the saw blade must be drilled at each corner where a change of direction of the bandsaw blade will occur. Figure 6-20 illustrates the methods of changing direction of a cut at a hole.

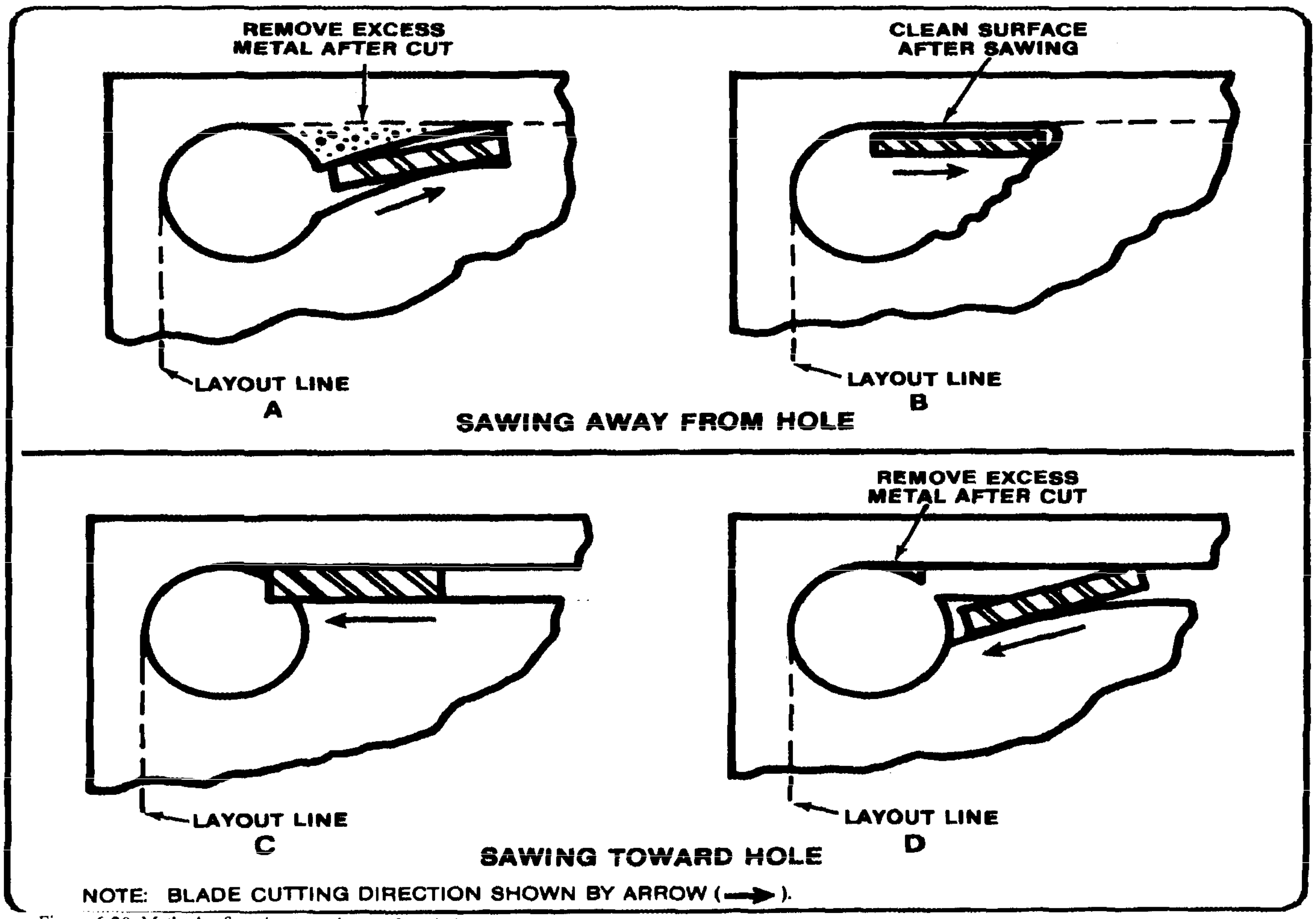


Figure 6-20. Methods of sawing to and away from holes.

Sawing Away From the Hole

To saw away from the hole on a line tangent to the hole, the saw blade must cut away from the center of the hole, or the blade will bow and cause a belly in the cut. The cut should be started as in A, Figure 6-20, in which a curve is cut outward from the hole to meet the layout line, leaving apiece of excess metal which can be removed later by filing. An alternate method is shown at B, Figure 6-20, in which a section of metal is notched out with a saw blade by several short cuts to give the blade clearance for starting the cut along the layout line.

Sawing Toward the Hole

The diagrams at C and D, Figure 6-20, show the proper method of sawing up to a hole in two cuts. The excess metal can be removed later by tiling. After the shape is cut and the slug or waste material is removed, the comers should be finished by filing or notching. The bandsaw blade should not be used for these operations because the blade will bow and cut unevenly.

SPECIAL OPERATIONS ON SAWING MACHINES

INTERNAL SAWING

Internal sawing is performed in the same manner as contour sawing except that the bandsaw blade cannot start cutting from the edge of the workpiece but must start cutting from a drilled hole in the workpiece (Figure 6-20). With the pattern laid out on the workpiece and the starting hole drilled, insert an unwelded bandsaw blade of the proper length through the starting hole. Bring the two ends of the blade together at the butt welder of the bandsawing machine and weld the blade into a continuous band as described in the pertinent operation manual for the machine. Install the bandsaw blade on the sawing machine and make the necessary adjustments to the machine. With the cut starting from the hole as shown in A or B, Figure 6-20. When the sawing is completed, cut the bandsaw blade so that it can be removed from the workpiece.

BAND FILING

Filing is performed on the vertical band saw machine using a band tile and the band file attachment. As with sawing, the quality of filing and the economical wear of the band file depend upon proper selection of files and filing speeds for different materials and conditions.

Band Filing Speed

Band files should be run at relatively slow speeds as compared to speeds used for band sawing. Figure 6-21 lists recommended speeds for band filing. Note that, in general, the slower speeds are used for filing harder metals and faster speeds are used for filing softer metals.

Band Filing Feeds

Work pressure on the band file should not be excessive. A medium amount of pressure applied against the band file moving at the proper speed will produce curled chips which will not clog the file. Heavy pressure will cause clogging and can cause the file to break or the machine to stall. A light pressures should be used for finish filing, with a slow, sideways motion that will not leave vertical file marks on the workpiece.

MATERIAL	BAND FILING SPEED (fpm)	MATERIAL	BAND FILING SPEED (fpm)
ALUMINUM	75 TO 175	FIBER	115 TO 175
BRASS	115 TO 260	MAGNESIUM	75 TO 175
BRONZE	75 TO 115	STEEL, ALLOY	50 TO 115
CAST IRON	50 TO 115	STEEL, MACHINE	75 TO 175
COPPER	115 TO 260	STEEL, TOOL	50 TO 75

Figure 6-21. Band filing speeds.

POLISHING

Polishing bands and a polishing attachment are provided with the vertical band saw machine so that light polishing can be performed. The polishing bands are intended primarily for removing saw marks on the cut edges of workpieces.

Polishing Speeds

Move polishing bands at speeds between 75 and 260 FPM, the faster speeds being used for softer materials and the slower speeds being used for harder materials.

Polishing Feeds

Feeds should be light for polishing. Use a slow, sideways motion so that the polishing band will leave no marks on the workpiece. If the band does not remove the tool marks quickly, change to a coarser polishing band.

Chapter 7

LATHES

The lathe is a machine tool used principally for shaping articles of metal (and sometimes wood or other materials) by causing the workpiece to be held and rotated by the lathe while a tool bit is advanced into the work causing the cutting action. The basic lathe that was designed to cut cylindrical metal stock has been developed further to produce screw threads. tapered work. drilled holes. knurled surfaces, and crankshafts. The typical lathe provides a variety of rotating speeds and a means to manually and automatically move the cutting tool into the workpiece. Machinists and maintenance shop personnel must be thoroughly familiar with the lathe and its operations to accomplish the repair and fabrication of needed parts.

TYPES OF LATHES

Lathes can be divided into three types for easy identification: engine lathes, turret lathes, and special purpose lathes. Small lathes can be bench mounted, are lightweight, and can be transported in wheeled vehicles easily. The larger lathes are floor mounted and may require special transportation if they must be moved. Field and maintenance shops generally use a lathe that can be adapted to many operations and that is not too large to be moved from one work site to another. The engine lathe (Figure 7-1) is ideally suited for this purpose. A trained operator can accomplish more machining jobs with the engine lathe than with any other machine tool. Turret lathes and special purpose lathes are usually used in production or job shops for mass production or specialized parts. while basic engine lathes are usually used for any type of lathe work. Further reference to lathes in this chapter will be about the various engine lathes.

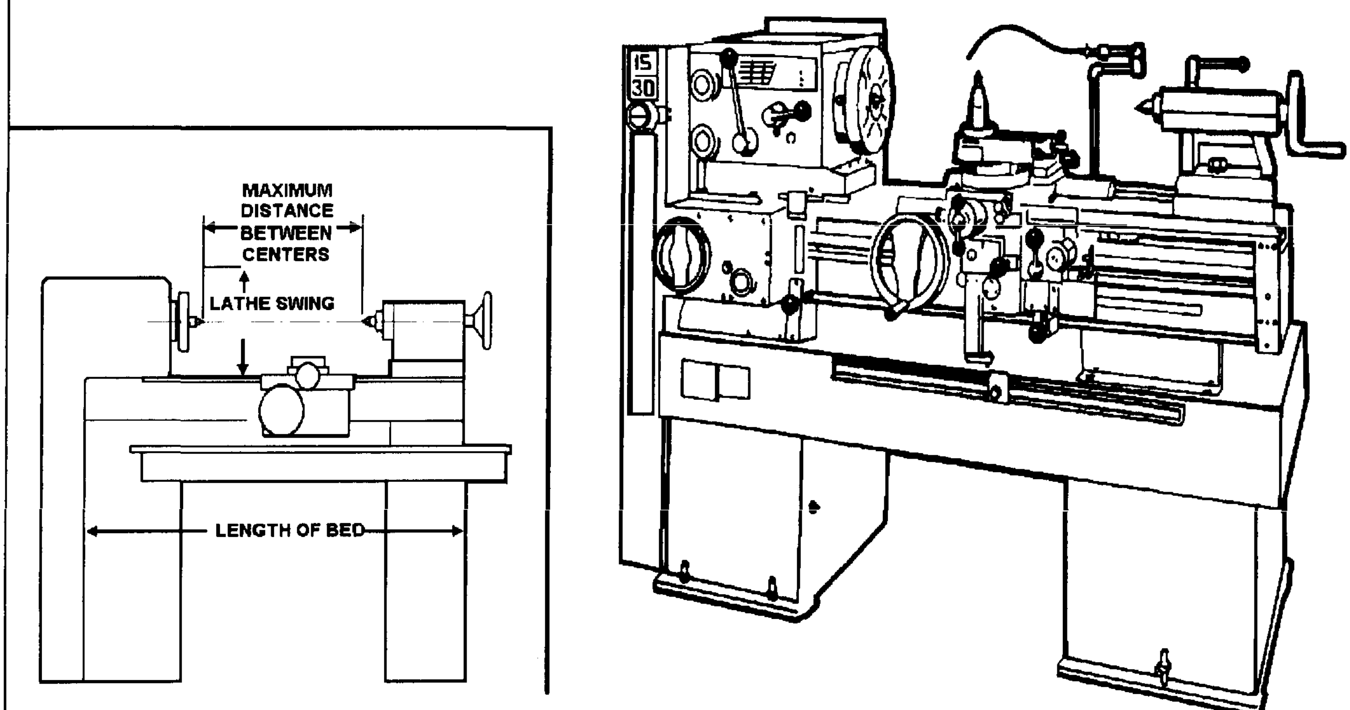


Figure7-1. Engine lathe.

ENGINE LATHES

Sizes

The size of an engine lathe is determined by the largest piece of stock that can be machined. Before machining a workpiece, the following measurements must be considered: the diameter of the work that will swing over the bed and the length between lathe centers (Figure 7-1).

Categories

Slight differences in the various engine lathes make it easy to group them into three categories: lightweight bench engine lathes, precision tool room lathes, and gap lathes, which are also known as extension- type lathes. These lathe categories are shown in Figure 7-2 Different manufacturers may use different lathe categories.

Lightweight

Lightweight bench engine lathes are generally small lathes with a swing of 10 inches or less, mounted to a bench or table top. These lathes can accomplish most machining jobs, but may be limited due to the size of the material that can be turned.

Precision

Precision tool room lathes are also known as standard manufacturing lathes and are used for all lathe operations, such as turning, boring, drilling, reaming, producing screw threads, taper turning, knurling, and radius forming, and can be adapted for special milling operations with the appropriate fixture. This type of lathe can handle workplaces up to 25 inches in diameter and up to 200 inches long. However, the general size is about a 15-inch swing with 36 to 48 inches between centers. Many tool room lathes are used for special tool and die production due to the high accuracy of the machine.

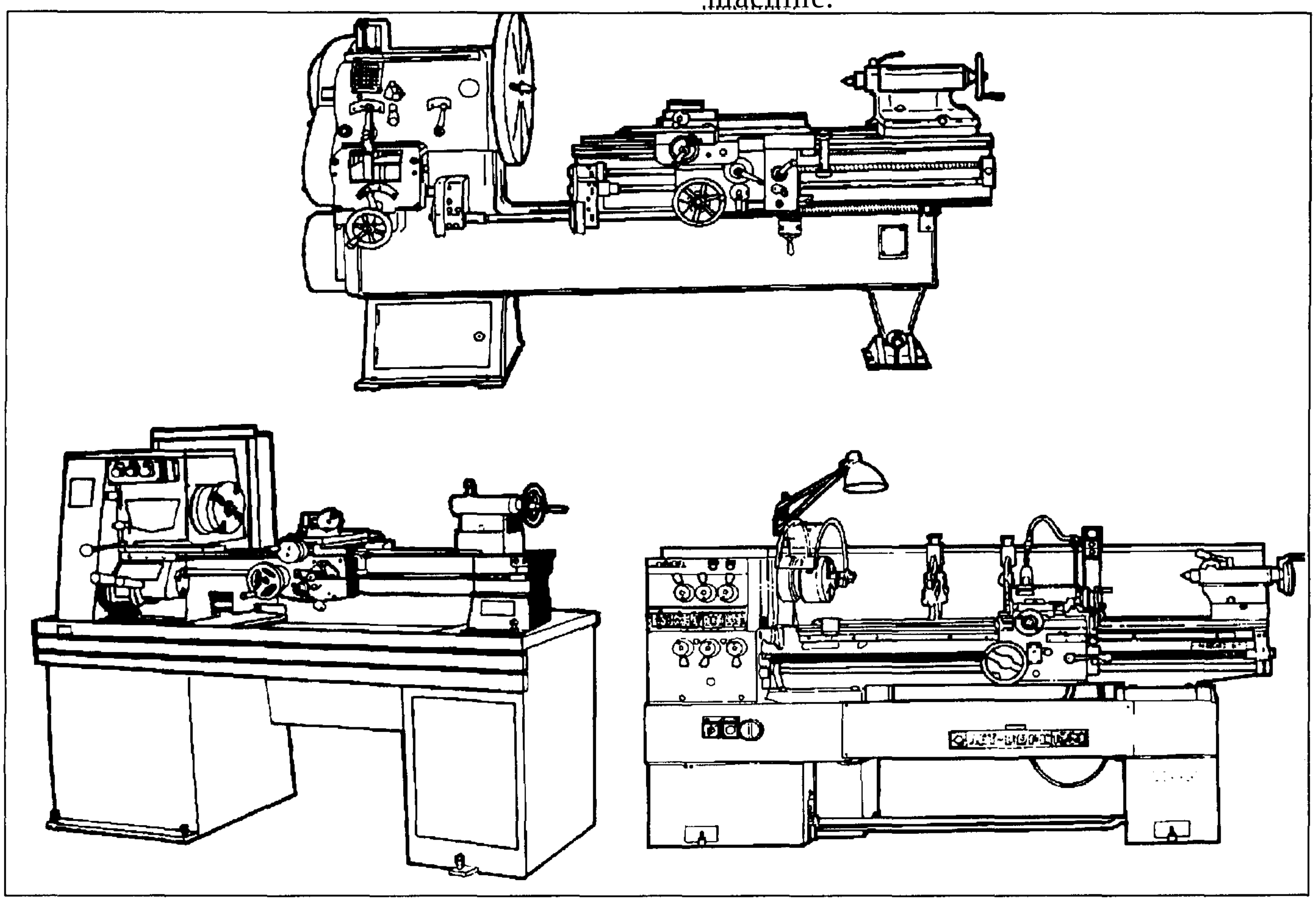


Figure 7-2. Lathe categories.

GAP OR EXTENSION-TYPE LATHES

Gap or extension-type lathes are similar to toolroom lathes except that gap lathes can be adjusted to machine larger diameter and longer workplaces The operator can increase the swing by moving the bed a distance from the headstock, which is usually one or two feet. By sliding the bed away from the headstock, the gap lathe can be used to turn very long workplaces between centers.

LATHE COMPONENTS

Engine lathes all have the same general functional parts, even though the specific location or shape of a certain part may differ from one manufacturer The bed is the foundation of the working parts of the lathe to another (Figure 7-3).

The main feature of its construction are the ways which are formed on its upper surface and run the full length of the bed. Ways provide the means for holding the tailstock and carriage, which slide along the ways, in alignment with the permanently attached headstock

The headstock is located on the operator's left end of the lathe bed. It contains the main spindle and oil reservoir and the gearing mechanism for obtaining various spindle speeds and for transmitting power to the feeding and threading mechanism. The headstock mechanism is driven by an electric motor connected either to a belt or pulley system or to a geared system. The main spindle is mounted on bearings in the headstock and is hardened and specially ground to fit different lathe holding devices. The spindle has a hole through its entire length to accommodate long workplaces. The hole in the nose of the spindle usually has a standard Morse taper which varies with the size of the lathe. Centers, collets, drill chucks, tapered shank drills and reamers may be inserted into the spindle. Chucks, drive plates, and faceplates may be screwed onto the spindle or clamped onto the spindle nose.

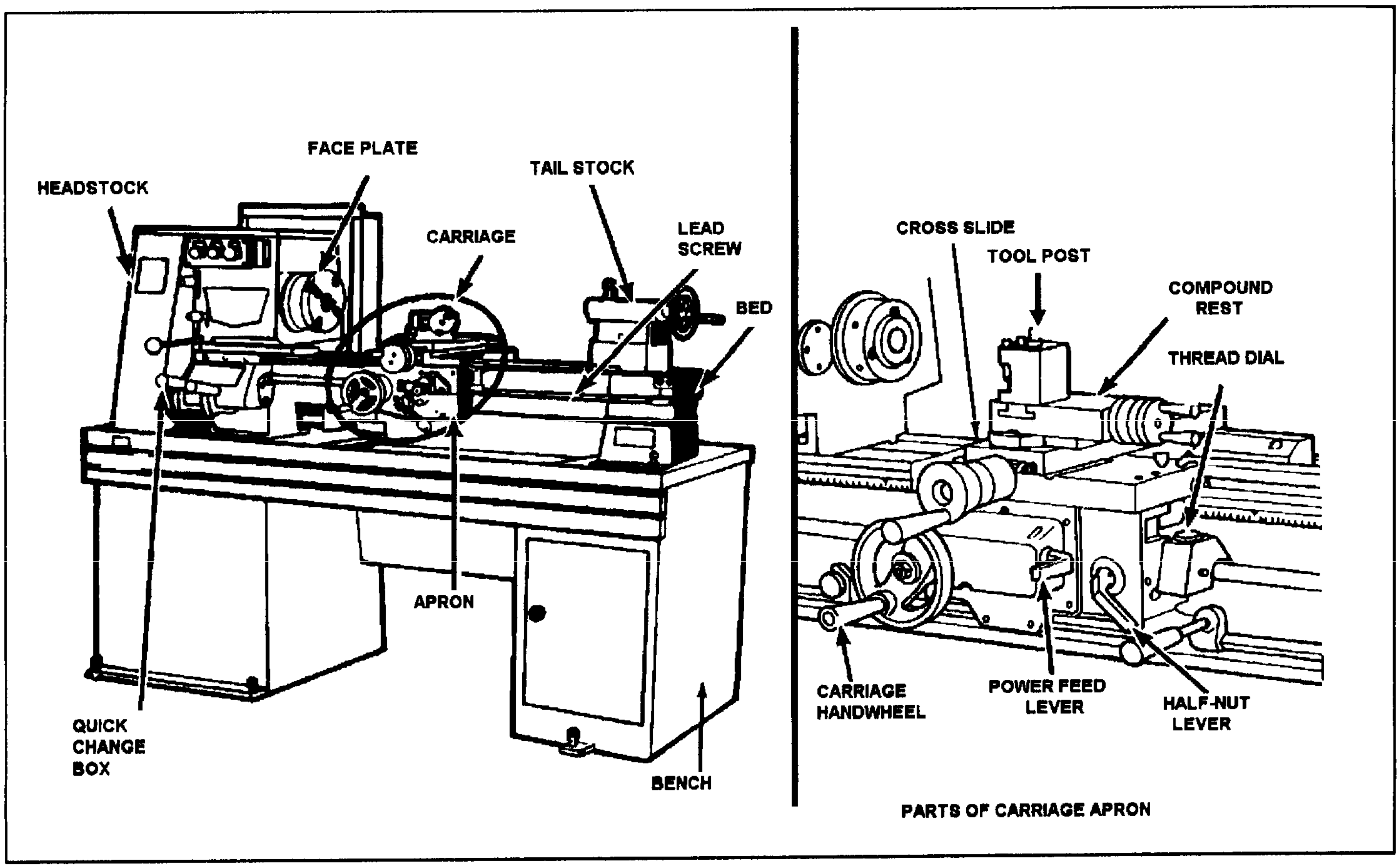


Figure 7-3. Lathe components.

The tailstock is located on the opposite end of the lathe from the headstock. It supports one end of the work when machining between centers, supports long pieces held in the chuck, and holds various forms of cutting tools, such as drills, reamers, and taps. The tailstock is mounted on the ways and is designed to be clamped at any point along the ways. It has a sliding spindle that is operated by a hand wheel and clamped in position by means of a spindle clamp. The tailstock may be adjusted laterally (toward or away from the operator) by adjusting screws. It should be unclamped from the ways before any lateral adjustments are made, as this will allow the tailstock to be moved freely and prevent damage to the lateral adjustment screws.

The carriage includes the apron, saddle, compound rest, cross slide, tool post, and the cutting tool. It sits across the lathe ways and in front of the lathe bed. The function of the carriage is to carry and move the cutting tool. It can be moved by hand or by power and can be clamped into position with a locking nut. The saddle carries the cross slide and the compound rest. The cross slide is mounted on the dovetail ways on the top of the saddle and is moved back and forth at 90° to the axis of the lathe by the cross slide lead screw. The lead screw can be hand or power activated. A feed reversing lever, located on the carriage or headstock, can be used to cause the carriage and the cross slide to reverse the direction of travel. The compound rest is mounted on the cross slide and can be swiveled and clamped at any angle in a horizontal plane. The compound rest is used extensively in cutting steep tapers and angles for lathe centers. The cutting tool and tool holder are secured in the tool post which is mounted directly to the compound rest. The apron contains the gears and feed clutches which transmit motion from the feed rod or lead screw to the carriage and cross slide.

CARE AND MAINTENANCE OF LATHES

Lathes are highly accurate machine tools designed to operate around the clock if properly operated and maintained. Lathes must be lubricated and checked for adjustment before operation. Improper lubrication or loose nuts and bolts can cause excessive wear and dangerous operating conditions.

The lathe ways are precision ground surfaces and must not be used as tables for other tools and should be kept clean of grit and dirt. The lead screw and gears should be checked frequently for any metal chips that could be lodged in the gearing mechanisms. Check each lathe prior to operation for any missing parts or broken shear pins. Refer to the operator's instructions before attempting to lift any lathe. Newly installed lathes or lathes that are transported in mobile vehicles should be properly leveled before any operation to prevent vibration and wobble. Any lathes that are transported out of a normal shop environment should be protected from dust, excessive heat, and very cold conditions. Change the lubricant frequently if working in dusty conditions. In hot working areas, use care to avoid overheating the motor or damaging any seals. Operate the lathe at slower speeds than normal when working in cold environments.

SAFETY

All lathe operators must be constantly aware of the safety hazards that are associated with using the lathe and must know all safety precautions to avoid accidents and injuries. Carelessness and ignorance are two great menaces to personal safety. Other hazards can be mechanically related to working with the lathe, such as proper machine maintenance and setup. Some important safety precautions to follow when using lathes are:

- Correct dress is important, remove rings and watches, roll sleeves above elbows.
- Always stop the lathe before making adjustments.
- Do not change spindle speeds until the lathe comes to a complete stop.
- Handle sharp cutters, centers, and drills with care.
- Remove chuck keys and wrenches before operating
- Always wear protective eye protection.
- Handle heavy chucks with care and protect the lathe ways with a block of wood when installing a chuck.
- Know where the emergency stop is before operating the lathe.
- Use pliers or a brush to remove chips and swarf, never your hands.
- Never lean on the lathe.
- Never lay tools directly on the lathe ways. If a separate table is not available, use a wide board with a cleat on each side to lay on the ways.
- Keep tools overhang as short as possible.

- Never attempt to measure work while it is turning.
- Never file lathe work unless the file has a handle.
- File left-handed if possible.
- Protect the lathe ways when grinding or filing.
- Use two hands when sanding the workpiece. Do not wrap sand paper or emery cloth around the workpiece.

TOOLS AND EQUIPMENT

GENERAL PURPOSE CUTTING TOOLS

The lathe cutting tool or tool bit must be made of the correct material and ground to the correct angles to machine a workpiece efficiently. The most common tool bit is the general all-purpose bit made of high-speed steel. These tool bits are generally inexpensive, easy to grind on a bench or pedestal grinder, take lots of abuse and wear, and are strong enough for all-around repair and fabrication. High-speed steel tool bits can handle the high heat that is generated during cutting and are not changed after cooling. These tool bits are used for turning, facing, boring and other lathe operations. Tool bits made from special materials such as carbides, ceramics, diamonds, cast alloys are able to machine workplaces at very high speeds but are brittle and expensive for normal lathe work. High-speed steel tool bits are available in many shapes and sizes to accommodate any lathe operation.

SINGLE POINT TOOL BITS

Single point tool bits can be one end of a high-speed steel tool bit or one edge of a carbide or ceramic cutting tool or insert. Basically, a single point cutter bit is a tool that has only one cutting action proceeding at a time. A machinist or machine operator should know the various terms applied to the single point tool bit to properly identify and grind different tool bits (Figure 7-4).

- The shank is the main body of the tool bit.
- The nose is the part of the tool bit which is shaped to a point and forms the corner between the side cutting edge and the end cutting edge. The nose radius is the rounded end of the tool bit.

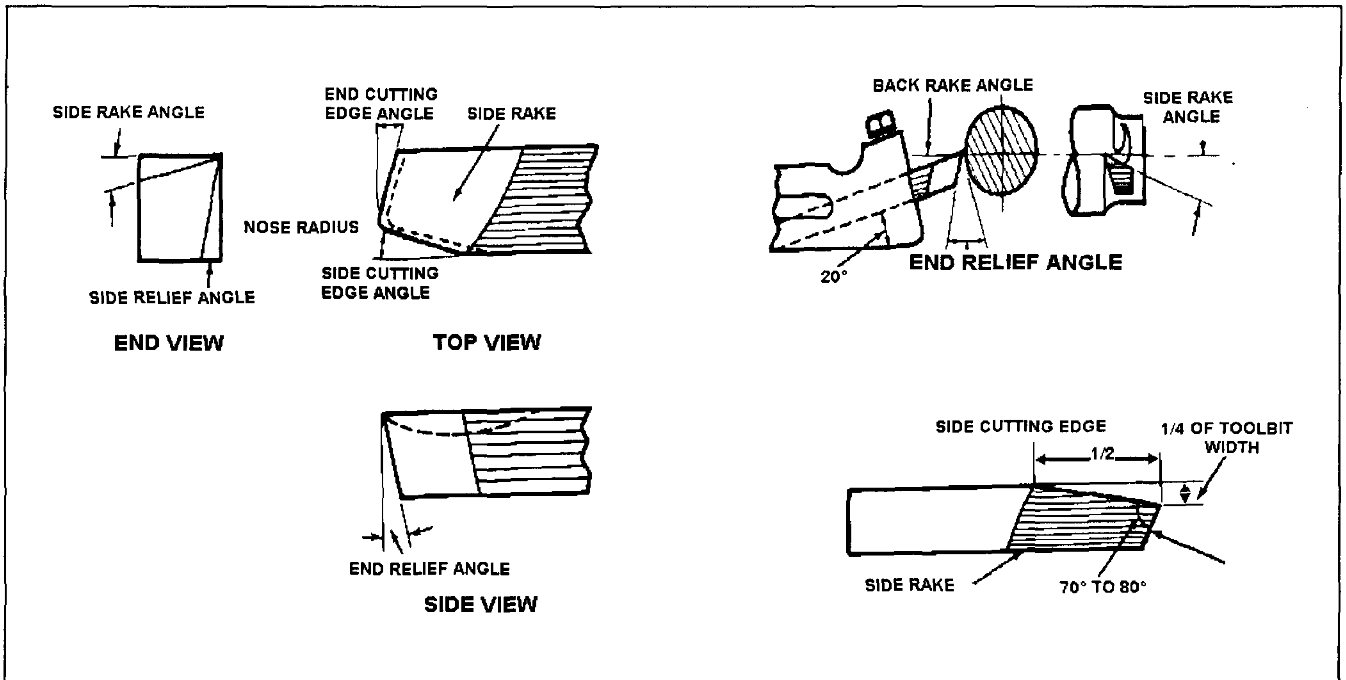


Figure 7-4. Tool bit angles.

- The face is the top surface of the tool bit upon which the chips slide as they separate from the work piece.
- The side or flank of the tool bit is the surface just below and adjacent to the cutting edge.
- The cutting edge is the part of the tool bit that actually cuts into the workpiece, located behind the nose and adjacent to the side and face.
- The base is the bottom surface of the tool bit, which usually is ground flat during tool bit manufacturing.
- The end of the tool bit is the near-vertical surface which, with the side of the bit, forms the profile of the bit. The end is the trailing surface of the tool bit when cutting.
- The heel is the portion of the tool bit base immediately below and supporting the face.

Angles of Tool Bits

The successful operation of the lathe and the quality of work that may be achieved depend largely on the angles that form the cutting edge of the tool bit (Figure 7-4). Most tools are hand ground to the desired shape on a bench or pedestal grinder. The cutting tool geometry for the rake and relief angles must be properly ground, but the overall shape of the tool bit is determined by the preference of the machinist or machine operator. Lathe tool bit shapes can be pointed, rounded, squared off, or irregular in shape and still cut quite well as long as the tool bit angles are properly ground for the type of material being machined. The angles are the side and back rake angles, the side and end cutting edge angles, and the side and end relief angles. Other angles to be considered are the radius on the end of the tool bit and the angle of the tool holder. After knowing how the angles affect the cutting action, some recommended cutting tool shapes can be considered.

Rake angle pertains to the top surface of the tool bit. There are two types of rake angles, the side and back rake angles (Figure 7-4). The rake angle can be positive, negative, or have no rake angle at all. The tool holder can have an angle, known as the tool holder angle, which averages about 15°, depending on the model of tool holder selected. The tool holder angle combines with the back rake angle to provide clearance for the heel of the tool bit from the workpiece and to facilitate chip removal. The side rake angle is measured back from the cutting edge and can be a positive rake angle or have no rake at all.

Rake angles cannot be too great or the cutting edge will lose strength to support the cutting action. The side rake angle determines the type and size of chip produced during the cutting action and the direction that the chip travels when leaving the cutting tool. Chip breakers can be included in the side rake angle to ensure that the chips break up and do not become a safety hazard.

Side and relief angles, or clearance angles, are the angles formed behind and beneath the cutting edge that provide clearance or relief to the cutting action of the tool. There are two types of relief angles, side relief and end relief. Side relief is the angle ground into the tool bit, under the side of the cutting edge, to provide clearance in the direction of tool bit travel. End relief is the angle ground into the tool bit to provide front clearance to keep the tool bit heel from rubbing. The end relief angle is supplemented by the tool holder angle and makes up the effective relief angle for the end of the tool bit.

Side and cutting edge angles are the angles formed by the cutting edge with the end of the tool bit (the end cutting edge angle), or with the side of the tool bit (the side cutting edge angle). The end cutting edge angle permits the nose of the tool bit to make contact with the work and aids in feeding the tool bit into the work. The side cutting edge angle reduces the pressure on the tool bit as it begins to cut. The side rake angle and the side relief angle combine to form the wedge angle (or lip angle) of the tool bit that provides for the cutting action (Figure 7-4).

A radius ground onto the nose of the tool bit can help strengthen the tool bit and provide for a smooth cutting action.

Shapes of Tool Bits

The overall shape of the lathe tool bits can be rounded, squared, or another shape as long as the proper angles are included. Tool bits are identified by the function they perform, such as turning or facing. They can also be identified as roughing tools or finishing tools. Generally, a roughing tool has a radius ground onto the nose of the tool bit that is smaller than the radius for a finishing or general-purpose tool bit. Experienced machinists have found the following shapes to be useful for different lathe operations.

A right-hand turning tool bit is shaped to be fed from right to left. The cutting edge is on the left side of the tool bit and the face slopes down away from the cutting edge. The left side and end of the tool bit are ground with sufficient clearance to

permit the cutting edge to bear upon the workpiece without the heel rubbing on the work. The right-hand turning tool bit is ideal for taking light roughing cuts as well as general all-around machining.

A left-hand turning tool bit is the opposite of the right-hand turning tool bit, designed to cut when fed from left to right. This tool bit is used mainly for machining close in to a right shoulder.

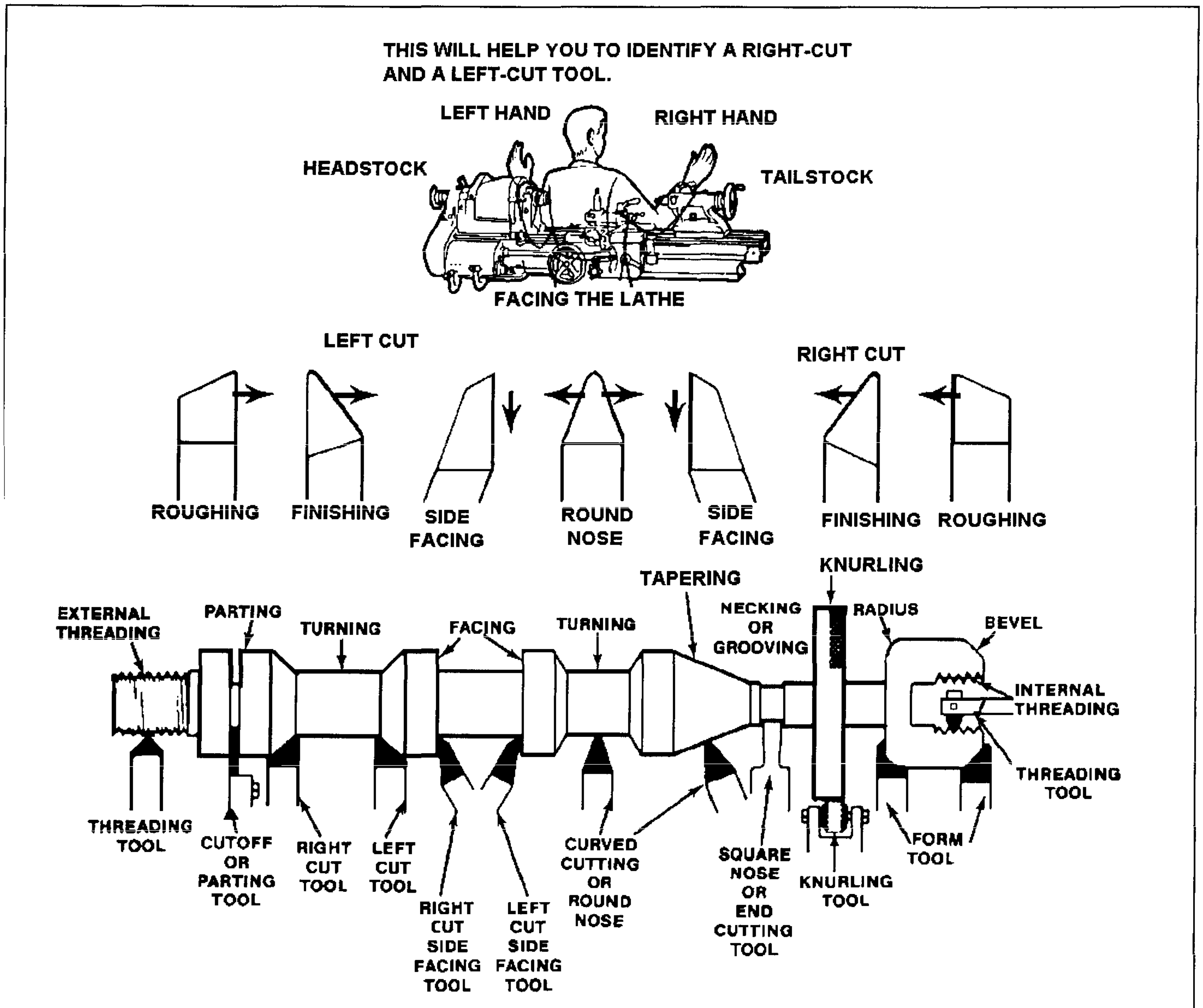


Figure 7-5. Tool bit shapes.

The round-nose turning tool bit is very versatile and can be used to turn in either direction for roughing and finishing cuts. No side rake angle is ground into the top face when used to cut in either direction, but a small back rake angle may be needed for chip removal. The nose radius is usually ground in the shape of a half-circle with a diameter of about 1/32 inch.

The right-hand facing tool bit is intended for facing on right-hand side shoulders and the right end of a workpiece. The cutting edge is on the left-hand side of the bit. and the nose is ground very sharp for machining into a square corner. The direction of feed for this tool bit should be away from the center axis of the work, not going into the center axis.

A left-hand facing tool bit is the opposite of the right-hand facing tool bit and is intend to machine and face the left sides of shoulders.

The parting tool bit, Figure 7-6, is also known as the cutoff tool bit. This tool bit has the principal cutting edge at the squared end of the bit that is advanced at a right angle into the workpiece. Both sides should have sufficient clearance to prevent binding and should be ground slightly narrower at the back than at the cutting edge. Besides being used for parting operations, this tool bit can be used to machine square corners and grooves.

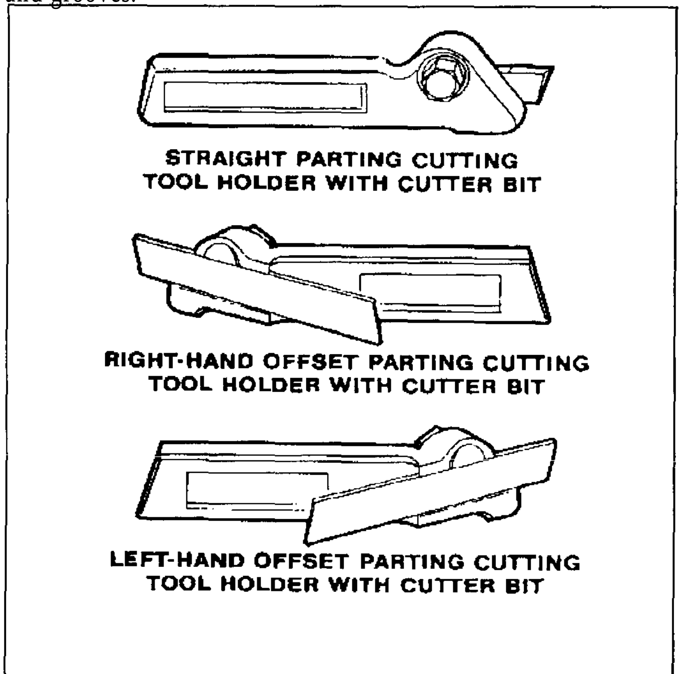


Figure 7-6. Parting tool bits.

Thread-cutting tool bits, Figure 7-7, are ground to cut the type and style of threads desired. Side and front clearances must be ground, plus the special point shape for the type of thread desired. Thread-cutting tool bits can be ground for standard 60° thread forms or for square, Acme, or special threads. Thread-cutting forms are discussed in greater detail later in this chapter.

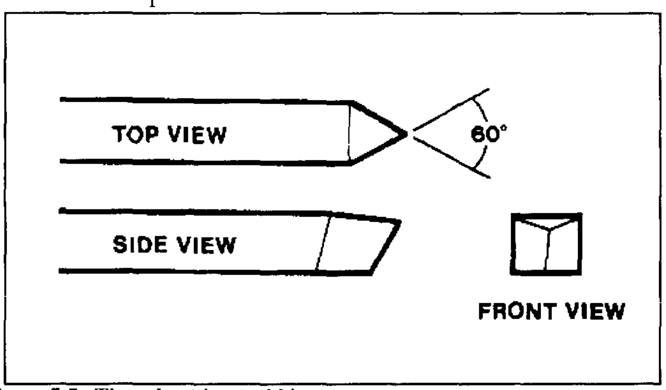


Figure 7-7. Thread cutting tool bit.

SPECIAL TYPES OF LATHE CUTTING TOOLS

Besides the common shaped tool bits, special lathe operations and heavy production work require special types of cutting tools. Some of the more common of these tools are listed below.

Tungsten carbide, tantalum carbide, titanium carbide. ceramic, oxide, and diamond-tipped tool bits (Figure 7-8). and cutting tool inserts are commonly used in high-speed production work when heavy cuts are necessary and where exceptionally hard and tough materials are encountered. Standard shapes for tipped tool bits are similar to high-speed steel-cutting tool shapes. Carbide and ceramic inserts can be square, triangular, round, or other shapes. The inserts are designed to be indexed or rotated as each cutting edge gets dull and then discarded. Cutting tool inserts are not intended for reuse after sharpening.

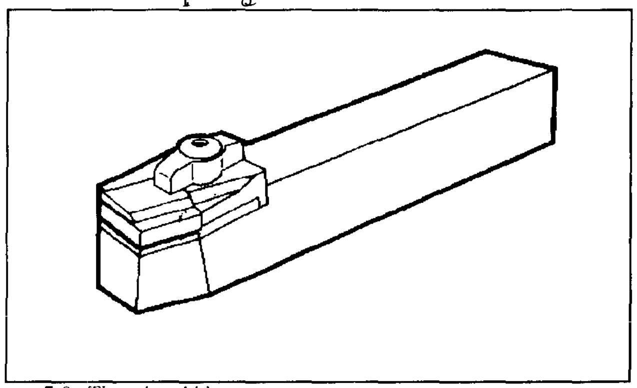


Figure 7-8. Tipped tool bit.

Specially formed thread cutter mounted in a thread "cutter holder (Figure 7-9). This tool is designed for production high-speed thread cutting operations. The special design of the cutter allows for sharp and strong cutting edges which need only to be resharpened occasionally by grinding the face. The cutter mounts into a special tool holder that mounts to the lathe tool post

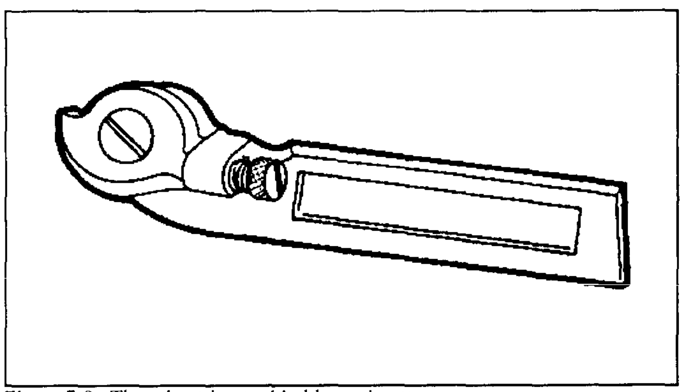


Figure 7-9. Thread cutting tool holder and cutter.

The common knurling tool, Figure 7-10, consists of two cylindrical cutters, called knurls, which rotate in a specially designed tool holder. The knurls contain teeth which are rolled against the surface of the workpiece to form depressed patterns on the workpiece. The common knurling tool accepts different pairs of knurls, each having a different pattern or pitch. The diamond pattern is most widely used and comes in three pitches: 14, 21, or 33. These pitches produce coarse, medium, and fine knurled patterns.

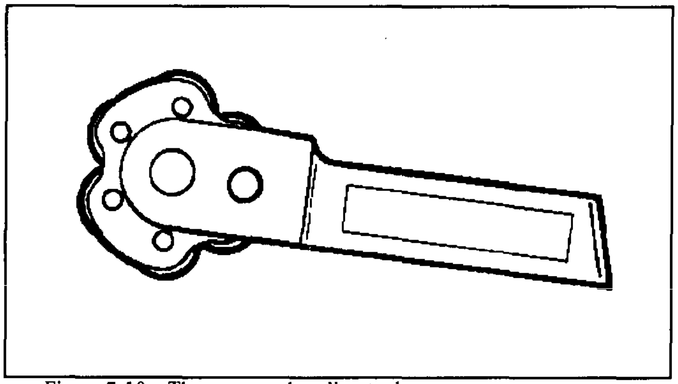


Figure 7-10. The common knurling tool.

Boring tool bits, Figure 7-11, are ground similar to left-hand turning tool bits and thread-cutting tool bits, but with more end clearance angle to prevent the heel of the tool bit from rubbing against the surface of the bored hole. The boring tool bit is usually clamped to a boring tool holder, but it can be a one-piece unit . The boring tool bit and tool holder clamp into the lathe tool post.

There is no set procedure to grinding lathe tool bit angles and shapes, but there are general guidelines that should be followed. Do not attempt to use the bench or pedestal grinder without becoming fully educated as to its safety, operation, and capabilities. In order to effectively grind a tool bit, the grinding wheel must have a true and clean face and be of the appropriate material for the cutting tool to be ground. Carbide tool bits must be ground on a silicon carbide grinding wheel to remove the very hard metal.

High-speed steel tool bits are the only tool bits that can effectively be ground on the bench or pedestal grinder when equipped with the aluminum oxide grinding wheel which is standard for most field and maintenance shops. Before grinding, shaping, or sharpening a high-speed steel tool bit, inspect the entire grinder for a safe setup and adjust the tool rests and guards as needed for tool bit grinding (Figure 7- 12).

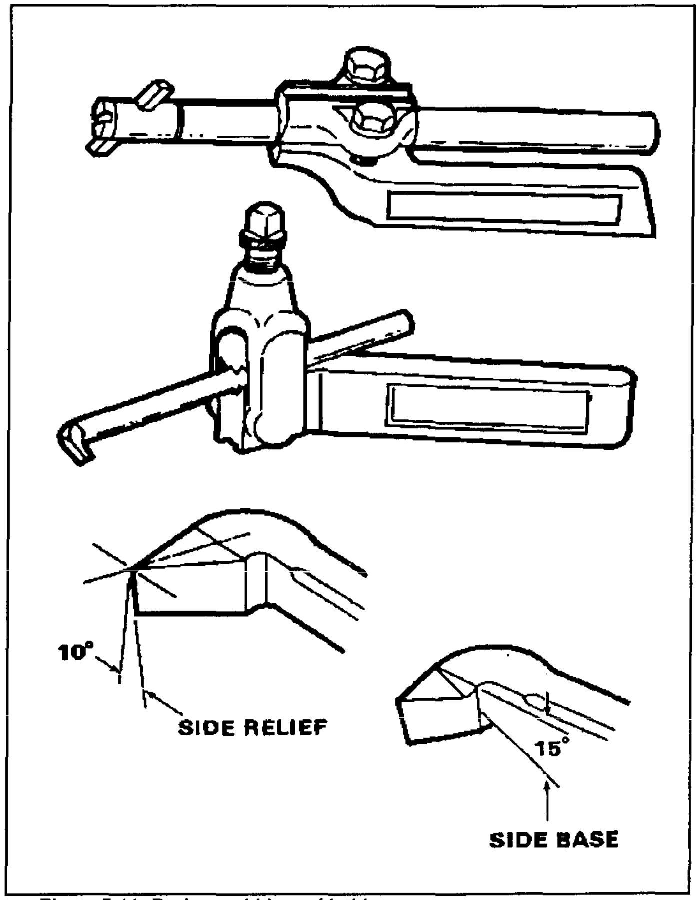


Figure 7-11. Boring tool bits and holders.

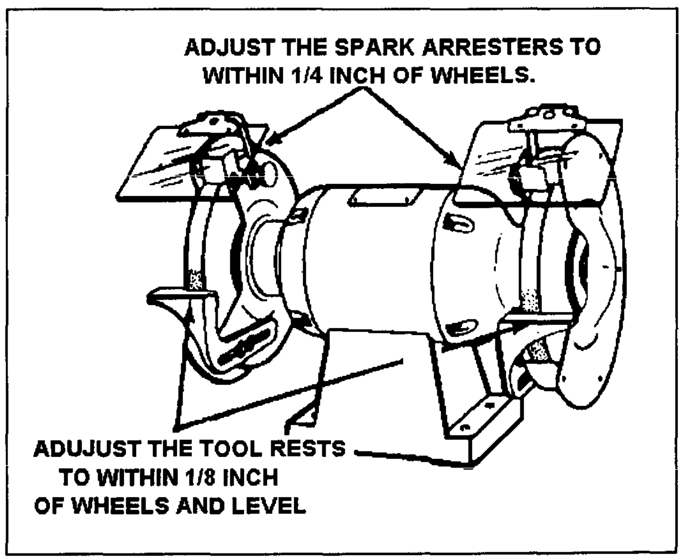


Figure 7-12. Grinder setup for lathe tool bit grinding.

Set the tool rest 1/8 inch or less from the wheel, and adjust the spark arrestor 1/4 inch or less. Each grinder is usually equipped with a coarse-grained wheel for rough grinding and a fine-grained wheel for fine and finish grinding. Dress the face of the grinding wheels as needed to keep a smooth, flat grinding surface for the tool bit. When grinding the side and back rake angles, ensure the grinding wheel has a sharp corner for shaping the angle. Dip the tool bit in water occasionally while grinding to keep the tool bit cool enough to handle and to avoid changing the property of the metal by overheating. Frequently inspect the tool bit angles with a protractor or special grinding gage. Grind the tool bit to the recommended angles in the reference for tool bit geometry (Table 7-l in Appendix A). After grinding to the finished shape, the tool bit should be honed lightly on an oilstone to remove any burrs or irregular high spots. The smoother the finish on the cutting tool, the smoother the finish on the work. Figure 7-13 shows the steps involved in grinding a round nose tool bit to be used for turning in either direction. As a safety note, never use the side of the grinding wheel to grind a tool bit, as this could weaken the bonding of the wheel and cause it to crack and explode.

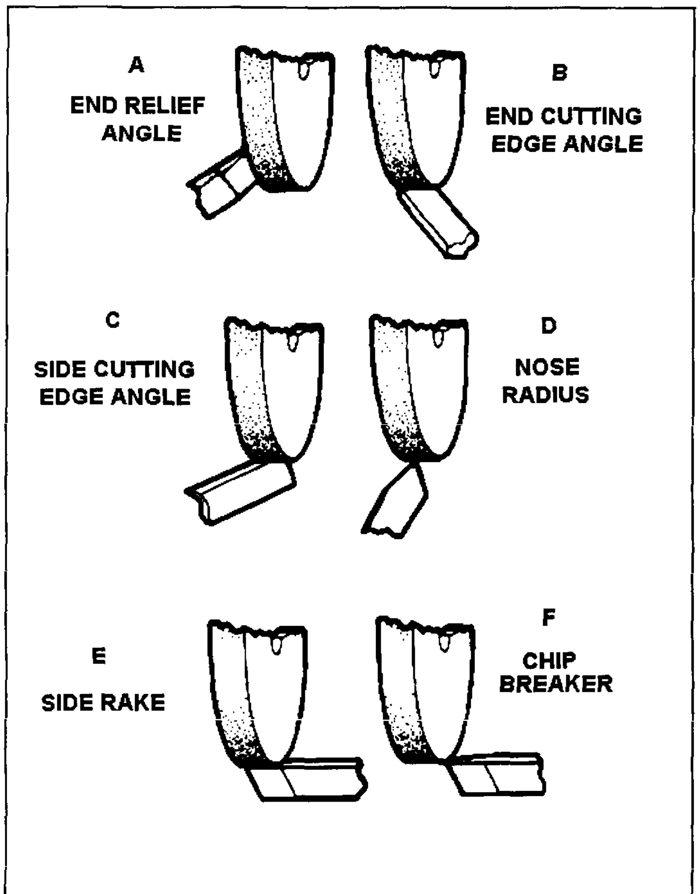


Figure 7-13. Grinding tool bits.

TOOL HOLDERS AND TOOL POSTS

Lathe tool holders are designed to securely and rigidly hold the tool bit at a fixed angle for properly machining a workpiece (Figure 7-14). Tool holders are designed to work in conjunction with various lathe tool posts, onto which the tool holders are mounted. Tool holders for high speed steel tool bits come in various types for different uses. These tool holders are designed to be used with the standard round tool post that usually-is supplied with each engine lathe (Figure 7-15). This tool post consists of the post, screw, washer, collar, and rocker, and fits into the T-slot of the compound rest.

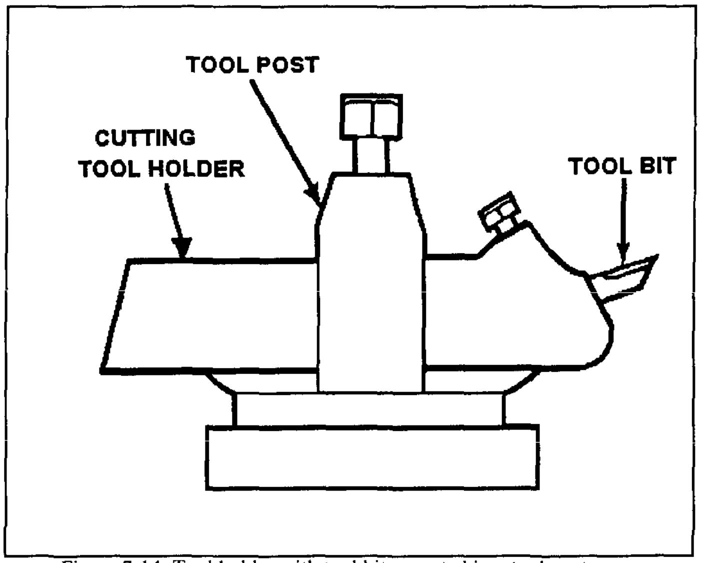


Figure 7-14. Tool holder with tool bit mounted in a tool post.

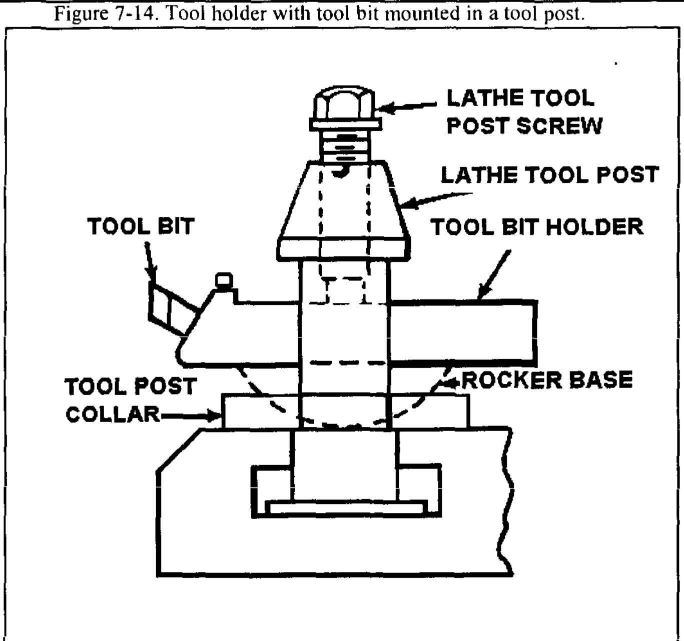


Figure 7-15. Standard round tool post.

Standard tool holders for high-speed steel cutting tools have a square slot made to fit a standard size tool bit shank. Tool bit shanks can be 1/4-inch, 5/16-inch, 3/8-inch, and greater, with all the various sizes being manufactured for all the different lathe manufacturer's tool holder models. Some standard tool holders for steel tool bits are the straight tool holder, right and left offset tool holder, and the zero rake tool holder designed for special carbide tool bits. Other tool holders to fit the standard round tool post include straight, left, and right parting tool holders, knurling tool holders, boring bar tool holders, and specially formed thread cutting tool holders.

The turret tool post (Figure 7-16) is a swiveling block that can hold many different tool bits or tool holders. Each cutting tool can quickly be swiveled into cutting position and clamped into place using a quick clamping handle. The turret tool post is used mainly for high-speed production operations.

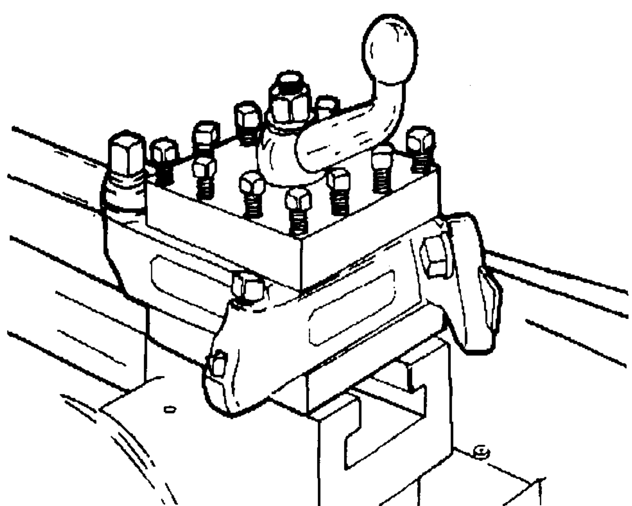


Figure 7-16. Turret tool post.

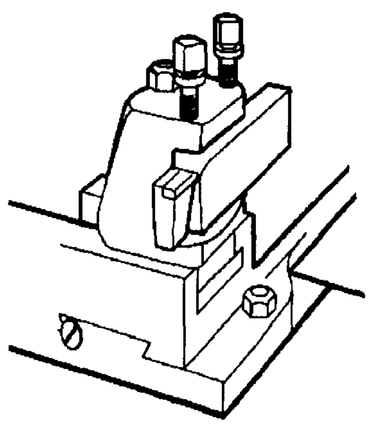


Figure 7-17. Heavy-duty or open sided tool post.

The heavy-duty or open-sided tool post (Figure 7-17) is used for holding a single carbide-tipped tool bit or tool holder. It is used mainly for very heavy cuts that require a rigid tool holder.

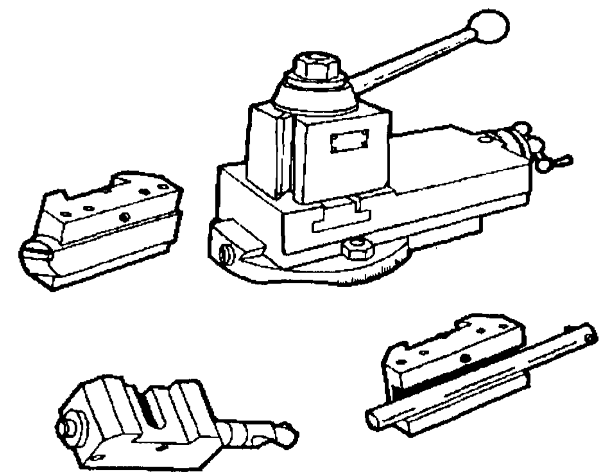


Figure 7-18. Quick change tool system.

The quick-change tool system (Figure 7-18) consists of a quick-change dovetail tool post with a complete set of matching dovetailed tool holders that can be quickly changed as different lathe operations become necessary. This system has a quick-release knob on the top of the tool post that allows tool changes in less than 5 seconds, which makes this system valuable for production machine shops.

WORK HOLDING DEVICES

Many different devices, such as chucks, collets, faceplates, drive plates, mandrels, and lathe centers, are used to hold and drive the work while it is being machined on a lathe. The size and type of work to be machined and the particular operation that needs to be done will determine which work holding device is best for any particular job. Another consideration is how much accuracy is needed for a job, since some work holding devices are more accurate than others. Operational details for some of the more common work holding devices follow.

The universal scroll chuck, Figure 7-19, usually has three jaws which move in unison as an adjusting pinion is rotated. The advantage of the universal scroll chuck is its ease of operation in centering work for concentric turning. This chuck is not as accurate as the independent chuck, but when in good condition it will center work within 0.002 to 0.003 inches of runout.

The jaws are moved simultaneously within the chuck by a scroll or spiral-threaded plate. The jaws are threaded to the scroll and move an equal distance inward or outward as the scroll is rotated by the adjusting pinion. Since the jaws are individually aligned on the scroll, the jaws cannot usually be reversed. Some manufactures supply two sets of jaws, one for internal work and one for external work. Other manufactures make the jaws in two pieces so the outside, or gripping surface may be reversed. which can be interchanged.

The universal scroll chuck can be used to hold and automatically center round or hexagonal workplaces. Having only three jaws, the chuck cannot be used effectively to hold square, octagonal, or irregular shapes.

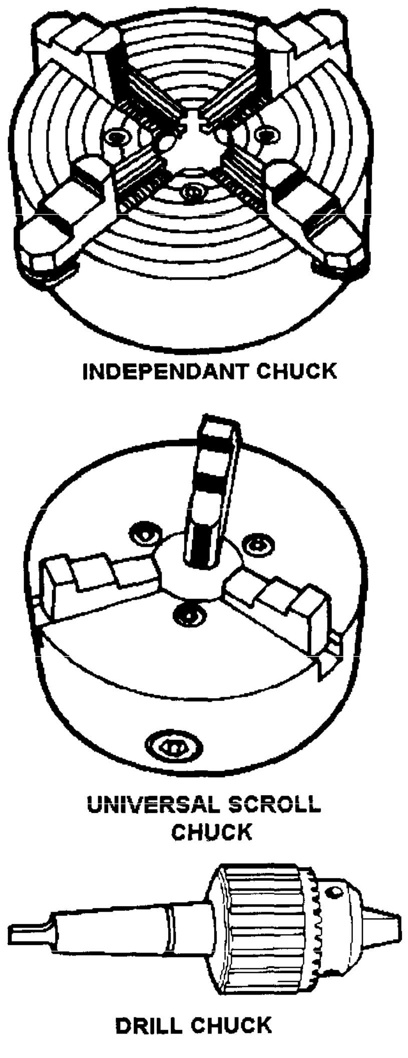


Figure 7-19. Lathe chucks.

The independent chuck, Figure 7-19, generally has four jaws which are adjusted individually on the chuck face by means of adjusting screws. The chuck face is scribed with concentric circles which are used for rough alignment of the jaws when chucking round workplaces. The final adjustment is made by turning the workpiece slowly by hand and using a dial indicator to determine it's concentricity. The jaws are then readjusted as necessary to align the workpiece within the desired tolerances.

The jaws of the independent chuck may be used as illustrated or may be reversed so that the steps face in the opposite direction; thus workplaces can be gripped either externally or internally. The independent chuck can be used to hold square, round, octagonal, or irregularly shaped workplaces in either a concentric or eccentric position due to the independent operation of each jaw.

Because of its versatility and capacity for fine adjustment, the independent chuck is commonly used for mounting odd-shaped workplaces which must be held with extreme accuracy.

A combination chuck combines the features of the independent chuck and the universal scroll chuck and can have either three or four jaws. The jaws can be moved in unison on a scroll for automatic centering or can be moved individually if desired by separate adjusting screws.

The drill chuck, Figure 7-19, is a small universal chuck which can be used in either the headstock spindle or the tailstock for holding straight-shank drills, reamers, taps, or small diameter workplaces. The drill chuck has three or four hardened steel jaws which are moved together or apart by adjusting a tapered sleeve within which they are contained. The drill chuck is capable of centering tools and small-diameter workplaces to within 0.002 or 0.003 inch when firmly tightened.

The collet chuck is the most accurate means of holding small workplaces in the lathe. The collet chuck consists of a spring machine collet (Figure 7-20) and a collet attachment which secures and regulates the collet on the headstock spindle of the lathe.

The spring machine collet is a thin metal bushing with an accurately machined bore and a tapered exterior. The collet has three lengthwise slots to permit its sides being sprung slightly inward to grip the workpiece. To grip the workpiece accurately, the collet must be no more than 0.005 inch larger or smaller than the diameter of the piece to be chucked. For this reason, spring machine collets are available in increments of 1/64 inch. For general purposes, the spring machine collets are limited in capacity to 1 1/8 inch in diameter.

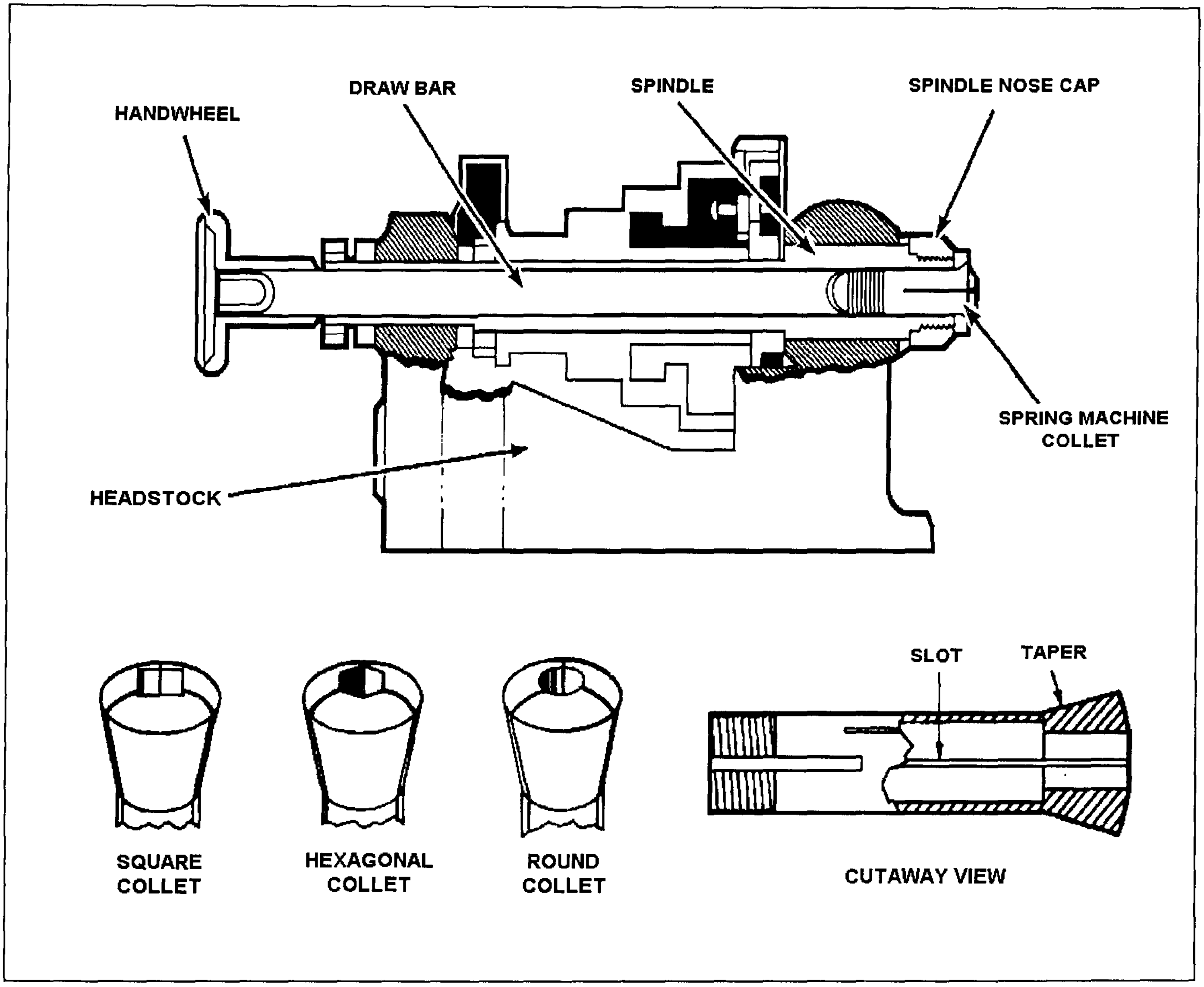


Figure 7-20. Spring machine collet chucks and installation method.

THE COLLET CHUCK IS THE MOST ACCURATE MEANS OF HOLDING SMALL WORKPIECES IN THE LATHE

For general purposes, the spring machine collets are limited in capacity to 1 1/8 inch in diameter.

The collet attachment consists of a collet sleeve, a drawbar, and a handwheel or hand lever to move the drawbar. The spring machine collet and collet attachment together form the collet chuck. Figure 7-20 illustrates a typical collet chuck installation. The collet sleeve is fitted to the right end of the headstock spindle. The drawbar passes through the headstock spindle and is threaded to the spring machine collet. When the drawbar is rotated by means of the hand wheel, it draws the collet into the tapered adapter, causing the collet to tighten on the workpiece. Spring machine collets are available in different shapes to chuck square and hexagonal workplaces of small dimensions as well as round workplaces.

The Jacob's spindle-nose collet chuck (Figure 7-21) is a special chuck is used for the Jacob's rubber flex collets. This chuck combines the functions of the standard collet chuck and drawbar into one single compact unit. The chuck housing has a handwheel on the outer diameter that turns to tighten or loosen the tapered spindle which holds the rubber flex collets. Rubber flex collets are comprised of devices made of hardened steel jaws in a solid rubber housing. These collets have a range of 1/8 inch per collet. The gripping power and accuracy remain constant throughout the entire collet capacity. Jacob's rubber flex collets are designed for heavy duty turning and possess two to four times the grip of the conventional split steel collet. The different sets of these collets are stored in steel boxes designed for holding the collets. Collets are normally stored in steel boxes designed for holding the collets.

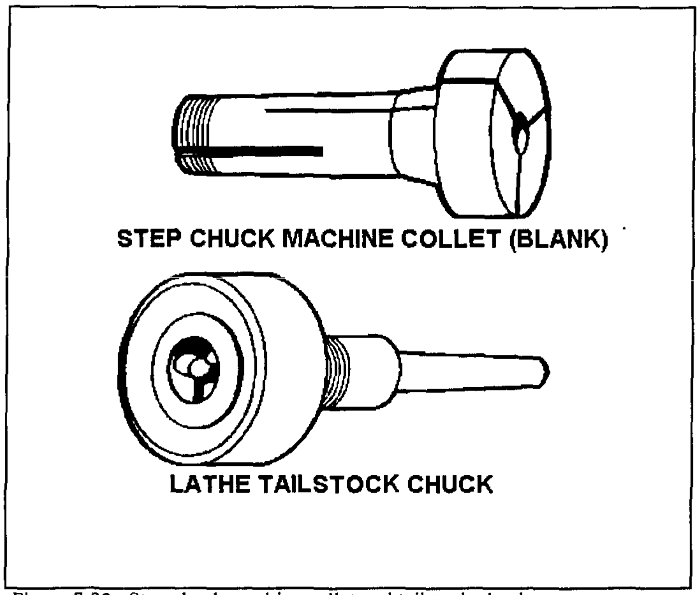


Figure 7-22. Step chuck machine collet and tailstock chuck.

The step chuck, Figure 7-22, is a variation of the collet chuck, and it is intended for holding small round workplaces or discs for special machining jobs. Step chucks are blank when new, and then are machined in the lathe for an exact fit for the discs to be turned. The step chuck machine collet, which is split into three sections like the spring machine collet, is threaded to the drawbar of the collet attachment.

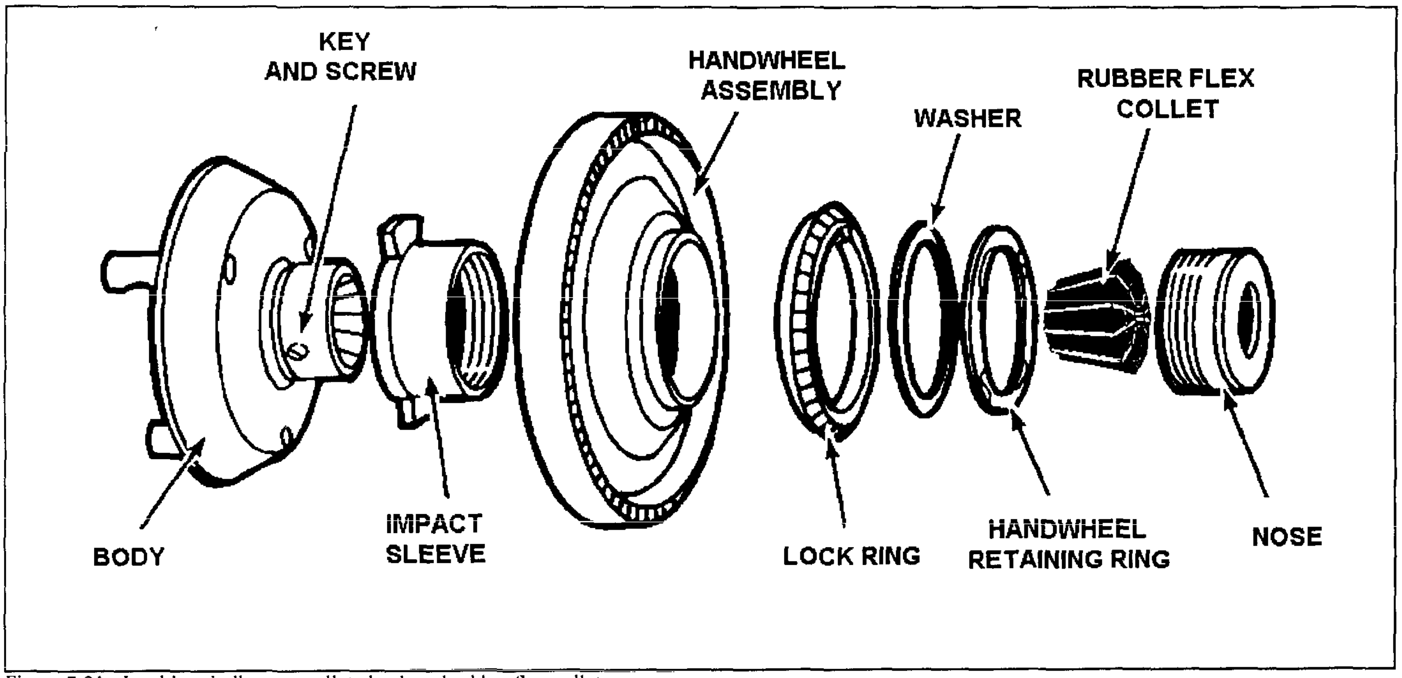


Figure 7-21. Jacob's spindle nose collet chuck and rubber flex collet.

The lathe tailstock chuck, Figure 7-22, is a device designed to support the ends of workplaces in the tailstock when a lathe center cannot be used conveniently. The chuck has a taper arbor that fits into the lathe tailstock spindle. The three bronze self-centering jaws of the chuck will accurately close upon workplaces between 1/4 and 1 inch in diameter. The bronze jaws provide a good bearing surface for the workpiece. The jaws are adjusted to the diameter of the workpiece and then locked in place.

A lathe faceplate, Figure 7-23, is a flat, round plate that threads to the headstock spindle of the lathe. The faceplate is used for irregularly shaped workplaces that cannot be successfully held by chucks or mounted between centers. The workpiece is either attached to the faceplate using angle plates or brackets or bolted directly to the plate. Radial T-slots in the faceplate surface facilitate mounting workplaces. The faceplate is valuable for mounting workplaces in which an eccentric hole or projection is to be machined. The number of applications of the faceplates depends upon the ingenuity of the machinist. A small faceplate known as a driving faceplate is used to drive the lathe dog for workpieces mounted between centers. The driving faceplate usually has fewer T-slots than the larger faceplates. When the workpiece is supported between centers, a lathe dog is fastened to the workpiece and engaged in a slot of the driving faceplate.

Lathe centers, Figure 7-24, are the most common devices for supporting workplaces in the lathe. Most lathe centers have a tapered point with a 60° included angle to fit workplace holes with the same angle. The workpiece is supported between two centers, one in the headstock spindle and one in the tailstock spindle. Centers for lathe work have standard tapered shanks that fit directly into the tailstock and into the headstock spindle using a center sleeve to convert the larger bore of the spindle to the smaller tapered size of the lathe center. The centers are referred to as live centers or dead centers. A live center revolves with the work and does not need to be lubricated and hardened. A dead center does not revolve with the work and must be hardened and heavily lubricated when holding work. Live and dead centers commonly come in matched sets, with the hardened dead center marked with a groove near the conical end point.

The ball bearing live center is a special center mounted in a ball bearing housing that lets the center turn with the work and eliminates the need for a heavily lubricated dead center. Ball bearing types of centers can have interchangeable points which make this center a versatile tool in all lathe operations. Modern centers of this type can be very accurate. Descriptions for some common lathe centers follow.

The male center or plain center is used in pairs for most general lathe turning operations. The point is ground to a 60° cone angle. When used in the headstock spindle where it revolves with the workpiece, it is commonly called a live center. When used in the tailstock spindle where it remains stationary when the workpiece is turned, it is called a dead center. Dead centers are always made of hardened steel and must be lubricated very often to prevent overheating.

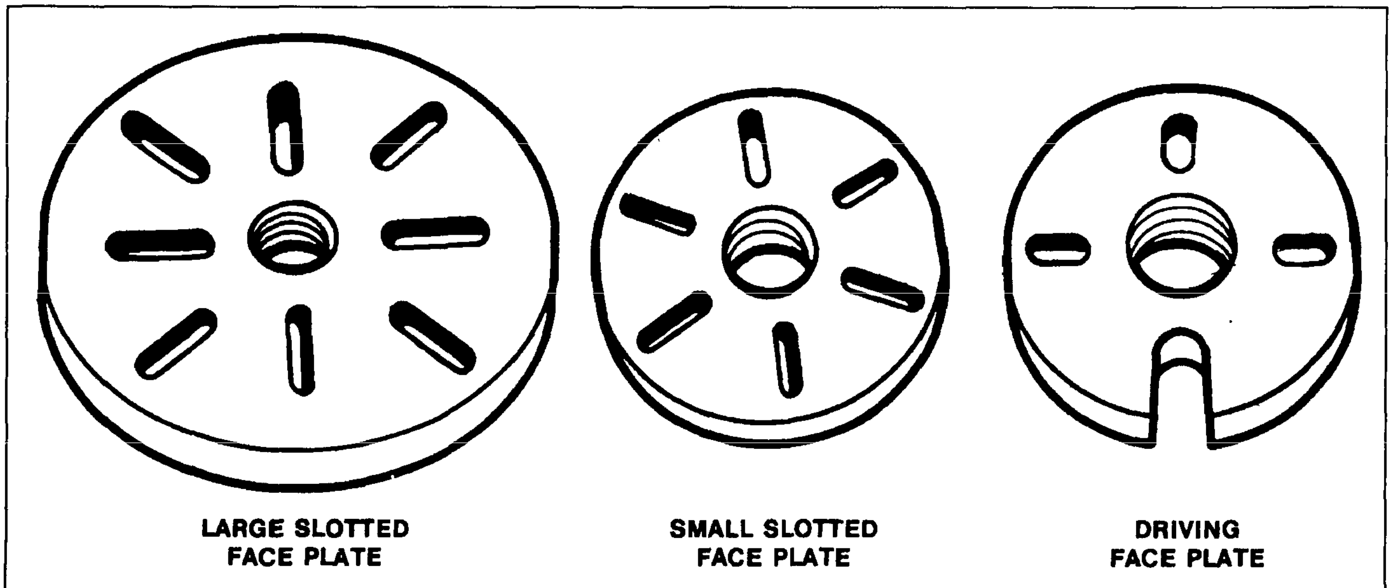


Figure 7-23. Faceplates.

The half male center is a male center that has a portion of the 60° cone cut away. The half male center is used as a dead center in the tailstock where facing is to be performed. The cutaway portion of the center faces the cutting tool and provides the necessary clearance for the tool when facing the surface immediately around the drilled center in the workpiece.

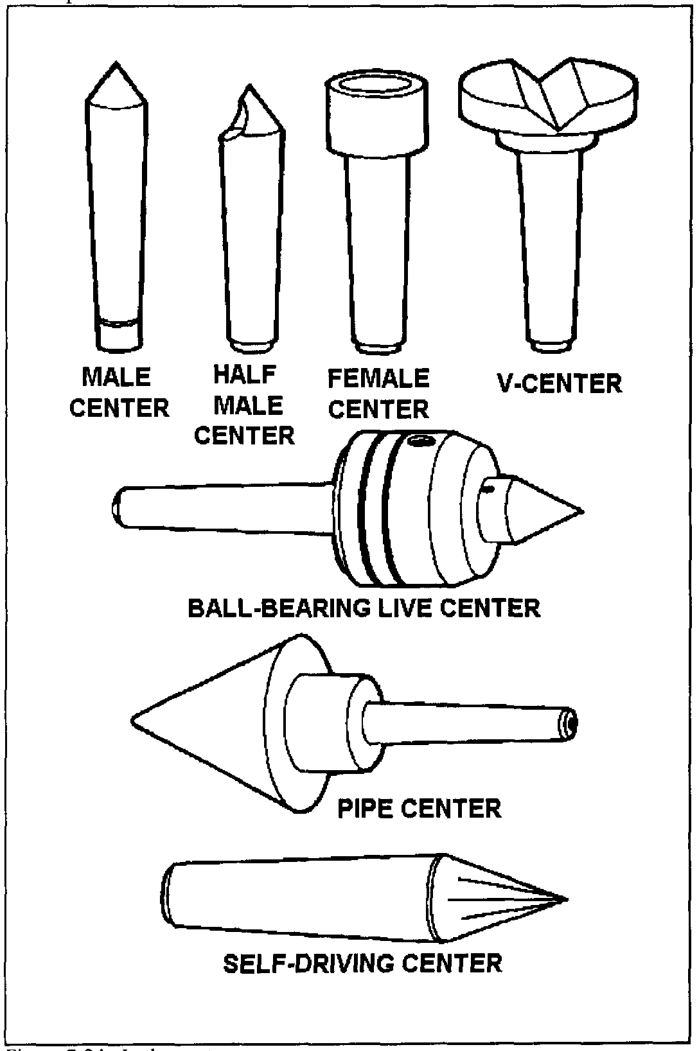


Figure 7-24. Lathe centers.

The V-center is used to support round workpieces at right angles to the lathe axis for special operations such as drilling or reaming. The pipe center is similar to the male center but its cone is ground to a greater angle and is larger in size. It is used for holding pipe and tubing in the lathe. The female center is conically bored at the tip and is used to support workplaces that are pointed on the end. A self-driving lathe center is a center with serrated ground sides that can grip the work while turning between centers without having to use lathe dogs.

A self driving center is a center that has grips installed on the outer edge of the center diameter that can be forced into the work to hold and drive the work when turning between centers without using lathe dogs.

Lathe dogs are cast metal devices used to provide a firm connection between the headstock spindle and the workpiece mounted between centers. This firm connection permits the workpiece to be driven at the same speed as the spindle under the strain of cutting. Three common lathe dogs are illustrated in Figure 7-25. Lathe dogs may have bent tails or straight tails. When bent-tail dogs are used, the tail fits into a slot of the driving faceplate. When straight-tail dogs are used, the tail bears against a stud projecting from the faceplate. The bent-tail lathe dog with headless setscrew is considered safer than the dog with the square head screw because the headless setscrew reduces the danger of the dog catching in the operator's clothing and causing an accident. The bent-tail clamp lathe dog is used primarily for rectangular workplaces.

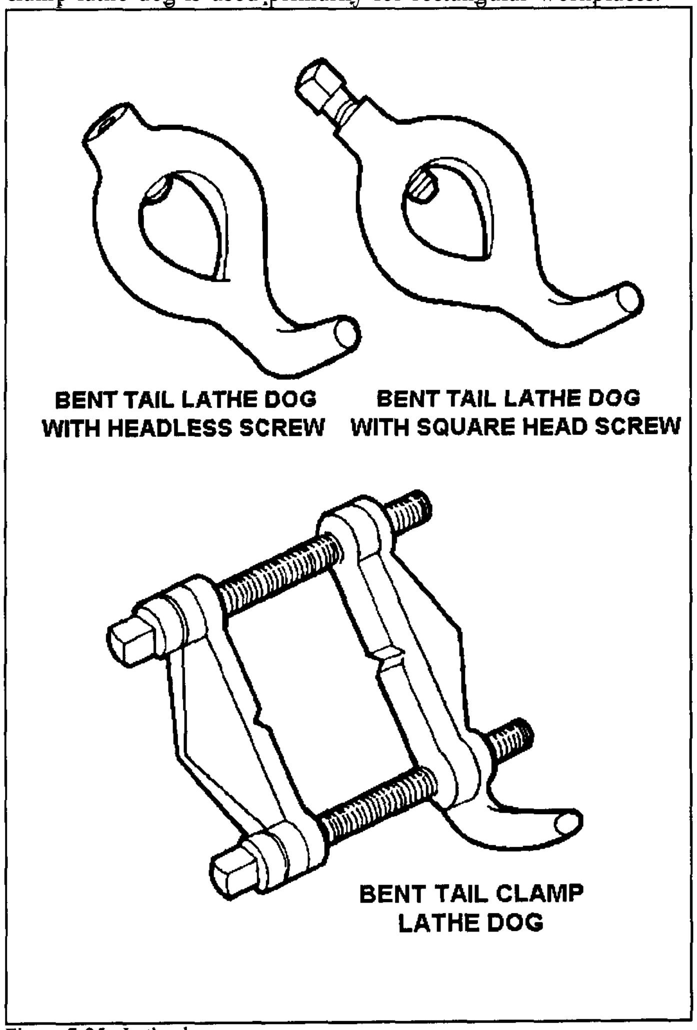


Figure 7-25. Lathe dogs.

MANDRELS

A workpiece which cannot be held between centers because its axis has been drilled or bored, and which is not suitable for holding in a chuck or against a faceplate, is usually machined on a mandrel. A mandrel is a tapered axle pressed into the bore of the workpiece to support it between centers.

A mandrel should not be confused with an arbor, which is a similar device but used for holding tools rather than workplaces. To prevent damage to the work, the mandrel should always be oiled before being forced into the hole. When turning work on a mandrel, feed toward the large end which should be nearest the headstock of the lathe.

A solid machine mandrel is generally made from hardened steel and ground to a slight taper of from 0.0005 to 0.0006 inch per inch. It has very accurately countersunk centers at each end for mounting between centers. The ends of the mandrel are smaller than the body and have machined flats for the lathe dog to grip. The size of the solid machine mandrel is always stamped on the large end of the taper. Since solid machine mandrels have a very slight taper, they are limited to workplaces with specific inside diameters.

An expansion mandrel will accept workplaces having a greater range of sizes. The expansion mandrel is, in effect, a chuck arranged so that the grips can be forced outward against the interior of the hole in the workpiece.

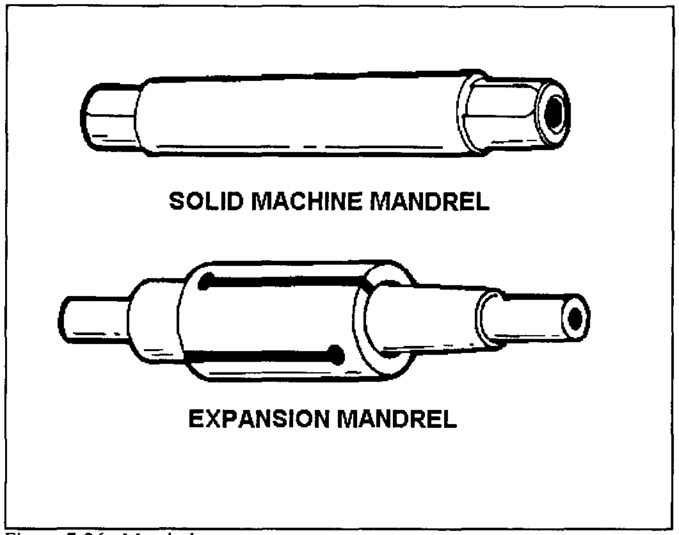


Figure 7-26. Mandrels.

LATHE ATTACHMENTS

The variety of work that can be performed on the lathe is greatly increased by the use of various lathe attachments. Some lathes come equipped with special attachments; some attachments must be ordered separately. Some common lathe attachments are the steady rest with cathead, the follower rest, the tool post grinding machine, the lathe micrometer stop, the lathe milling fixture, the lathe coolant attachment, the lathe indexing fixture, and the milling-grinding-drilling-slotting attachment (or Versa-Mil). The lathe indexing fixture and Versa-Mil unit are detailed in Chapter 9. Descriptions for the other lathe attachments follows.

RESTS

Workpieces often need extra support, especially long, thin workplaces that tend to spring away from the tool bit. Three common supports or rests are the steady rest, the cathead, and the follower rest (Figure 7-27).

Steady Rest.

The steady rest, also called a center rest, is used to support long workplaces for turning and boring operations. It is also used for internal threading operations where the workpiece projects a considerable distance from the chuck or faceplate. The steady rest is clamped to the lathe bed at the desired location and supports the workpiece within three adjustable jaws. The workpiece must be machined with a concentric bearing surface at the point where the steady rest is to be applied. The jaws must be carefully adjusted for proper alignment and locked in position. The area of contact must be lubricated frequently. The top section of the steady rest swings away from the bottom section to permit removal of the workpiece without disturbing the jaw setting.

Cathead

When the work is too small to machine a bearing surface for the adjustable jaws to hold, then a cathead should be used. The cathead has a bearing surface, a hole through which the work extends, and adjusting screws. The adjusting screws fasten the cathead to the work. They are also used to align the bearing surface so that it is concentric to the work axis. A dial indicator must be used to set up the cathead to be concentric and accurate.

Follower Rest

The follower rest has one or two jaws that bear against the workpiece. The rest is fastened to the lathe carriage so that it will follow the tool bit and bear upon the portion of the

workpiece that has just been turned. The cut must first be started and continued for a short longitudinal distance before the follower rest may be applied. The rest is generally used only for straight turning and for threading long, thin workplaces. Steady rests and follower rests can be equipped with ball-bearing surfaces on the adjustable jaws. These types of rests can be used without excessive lubricant or having to machine a polished bearing surface.

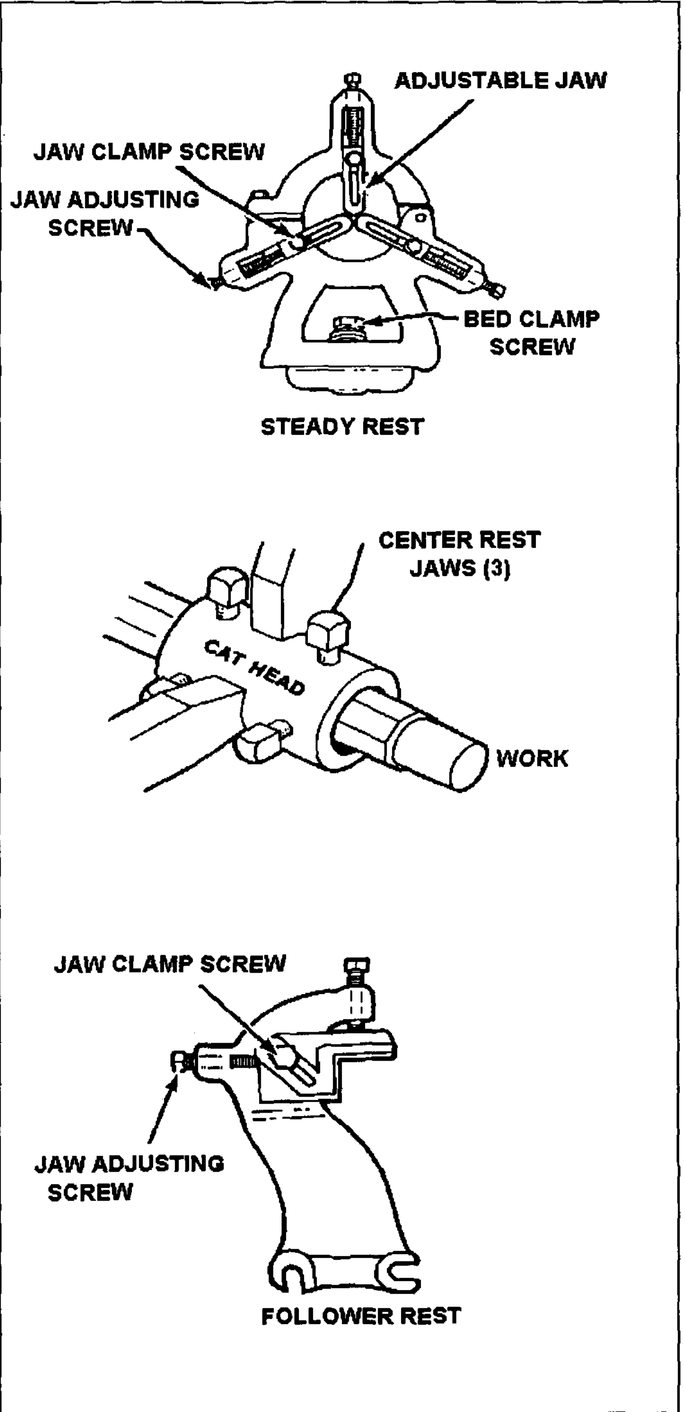


Figure 7-27. Lathe rests.

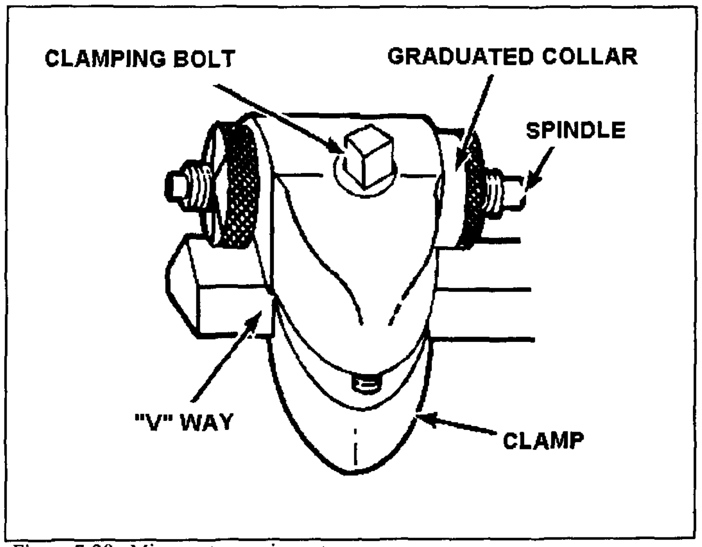


Figure 7-28. Micrometer carriage stop.

Micrometer Carriage Stop

The micrometer carriage stop, Figure 7-28, is used to accurately position the lathe carriage. The micrometer stop is designed so the carriage can be moved into position against the retractable spindle of the stop and locked into place. A micrometer gage on the stop enables carriage movement of as little as 0.001 inch. This tool is very useful when facing work to length, turning a shoulder, or cutting an accurate groove.

Tool Post Grinder

The tool post grinder (Figure 7-29) is a machine tool attachment specially designed for cylindrical grinding operations on the lathe. It consists primarily of a 1/4- or 1/3-horsepower electric motor and a wheel spindle connected by pulleys and a belt. The machine fastens to the compound rest of the lathe with a T-slot bolt which fits in the slot of the compound rest in the same manner as the lathe tool post. The tool post grinding machine mounts grinding abrasive wheels ranging from 1/4 inch to 3 or 4 inches in diameter for internal and external grinding operations. The pulleys on the wheel spindle and motor shaft are interchangeable to provide proper cutting speeds for the various wheel sizes. The larger grinding abrasive wheels used for external grinding are attached to the wheel spindle with an arbor. Small, mounted grinding abrasive wheels for internal grinding are fixed in a chuck which screws to the wheel spindle. The electric motor is connected to an electrical power source by a cable and plug. A switch is usually provided at the attachment to facilitate starting and stopping the motor.

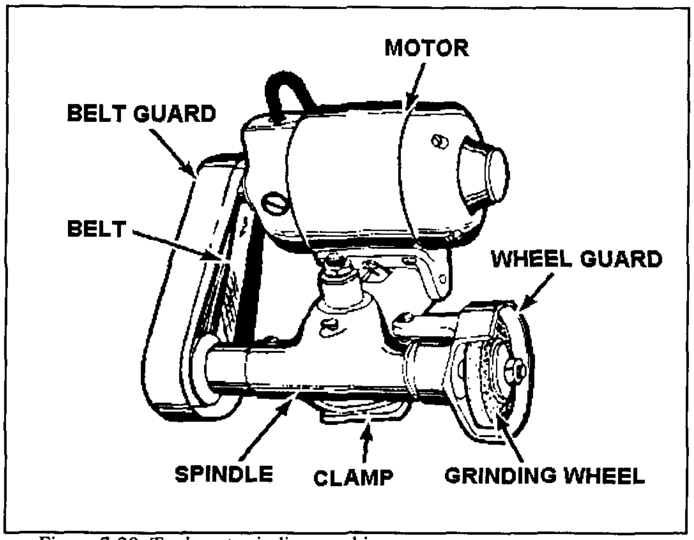


Figure 7-29. Tool post grinding machine.

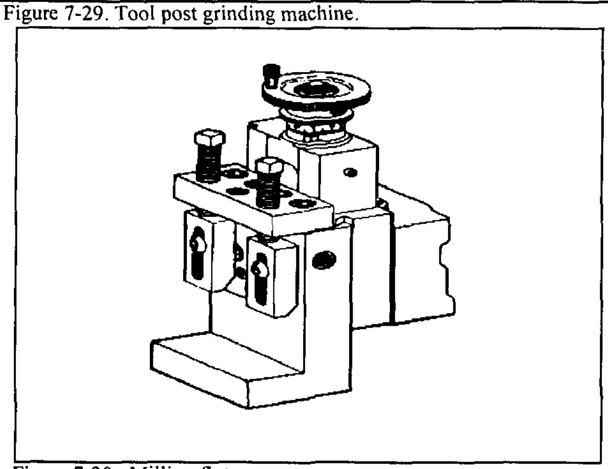


Figure 7-30. Milling fixture.

Lathe Milling Fixture

This is a fixture designed to provide the ability for limited milling operations. Many repair and fabrication jobs cannot be satisfactorily completed on the standard engine lathe, but with the lathe milling attachment, the small machine shop that is not equipped with a milling machine can mill keyslots, keyways, flats, angles, hex heads, squares, splines, and holes. For specific operating instructions and parts, refer to TM 9-3465-200-10.

TOOLS NECESSARY FOR LATHE WORK

In order to properly setup and operate most engine lathes, it is recommended to have the following tools on hand. A machinist tool box with all wrenches, screwdrivers, and common hand tools. A dial indicator may be necessary for some procedures on the lathe. References, charts, tables, and other predetermined data on machine operations may be useful to lathe operators. Keep all safety equipment, along with necessary cleaning marking, and lubricating equipment, in the immediate lathe area to use as needed.

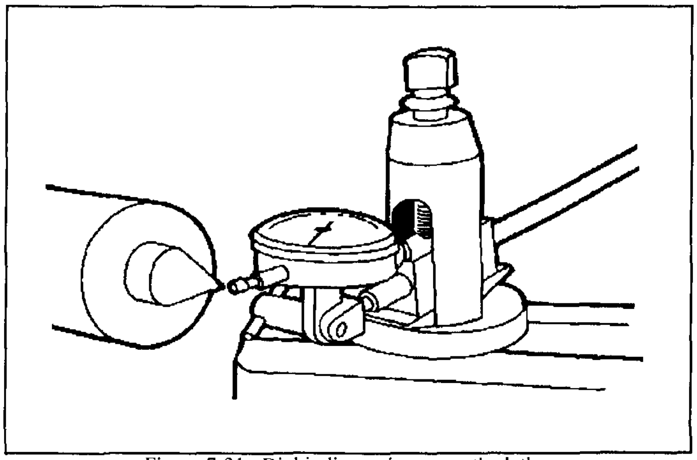


Figure 7-31. Dial indicator in use on the lathe.

CUTTING FLUIDS

The purposes of using cutting fluids on the lathe are to cool the tool bit and workpiece that are being machined, increase the life of the cutting tool, make a smoother surface finish, deter rust, and wash away chips. Cutting fluids can be sprayed, dripped, wiped, or flooded onto the point where the cutting action is taking place. Generally, cutting fluids should only be used if the speed or cutting action requires the use of cutting fluids. Descriptions of some common cutting fluids used on the lathe follow. Use Table 4-3 in Appendix A for additional information on cutting fluids.

Lard Oil

Pure lard oil is one of the oldest and best cutting oils. It is especially good for thread cutting, tapping, deep hole drilling, and reaming. Lard oil has a high degree of adhesion or oiliness, a relatively high specific heat, and its fluidity changes only slightly with temperature. It is an excellent rust preventive and produces a smooth finish on the workpiece. Because lard oil is expensive, it is seldom used in a pure state but is combined with other ingredients to form good cutting oil mixtures.

Mineral Oil

Mineral oils are petroleum-base oils that range in viscosity from kerosene to light paraffin oils. Mineral oil is very stable and does not develop disagreeable odors like lard oil; however, it lacks some of the good qualities of lard oil such as adhesion, oiliness, and high specific heat. Because it is relatively inexpensive, it is commonly mixed with lard oil or other chemicals to provide cutting oils with desirable characteristics. Two mineral oils, kerosene and turpentine, are often used alone for machining aluminum and magnesium. Paraffin oil is used alone or with lard oil for machining copper and brass.

Mineral-Lard Cutting Oil Mixture

Various mixtures of mineral oils and lard oil are used to make cutting oils which combine the good points of both ingredients but prove more economical and often as effective as pure lard oil.

Sulfurized Fatty-Mineral Oil

Most good cutting oils contain mineral oil and lard oil with various amounts of sulfur and chlorine which give the oils good antiweld properties and promote free machining. These oils play an important part in present-day machining because they provide good finishes on most materials and aid the cutting of tough material.

Soluble Cutting Oils

Water is an excellent cooling medium but has little lubricating value and hastens rust and corrosion. Therefore, mineral oils or lard oils which can be mixed with water are often used to form a cutting oil. A soluble oil and water mix has lubricating qualities dependent upon the strength of the solution. Generally, soluble oil and water is used for rough cutting where quick dissipation of heat is most important. Borax and trisodium phosphate (TSP) are sometimes added to the solution to improve its corrosion resistance.

Soda-Water Mixtures

Salts such as soda ash and TSP are sometimes added to water to help control rust. This mixture is the cheapest of all coolants and has practically no lubricating value. Lard oil and soap in small quantities are sometimes added to the mixture to improve its lubricating qualities. Generally, soda water is used only where cooling is the prime consideration and lubrication a secondary consideration. It is especially suitable in reaming and threading operations on cast iron where a better finish is desired.

White Lead and Lard Oil Mixture

White lead can be mixed with either lard oil or mineral oil to form a cutting oil which is especially suitable for difficult machining of very hard metals.

LAYING OUT AND MOUNTING WORK

There is relatively little layout work to be done for most lathe work because of the lathe's ability to guide the cutting tool accurately to the workpiece. If center holes must be located and drilled into the end of a workpiece for turning lay out and center-punch the workpiece using other methods. Some suggested methods are to use a bell-type center punch between centers and this cannot be accomplished on the lathe, (Figure 7-32), use hermaphrodite calipers to scribe intersecting arcs, use the centering head of the combination square, or use dividers (Figure 7-33).

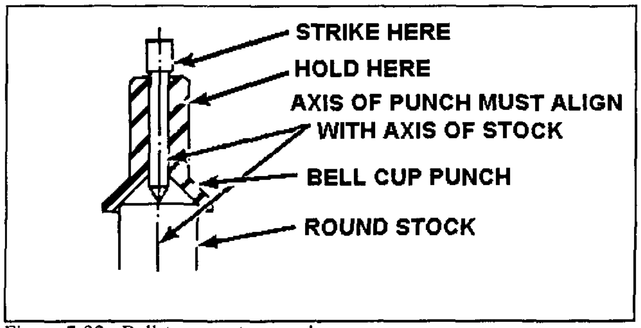


Figure 7-32. Bell-type center punch.

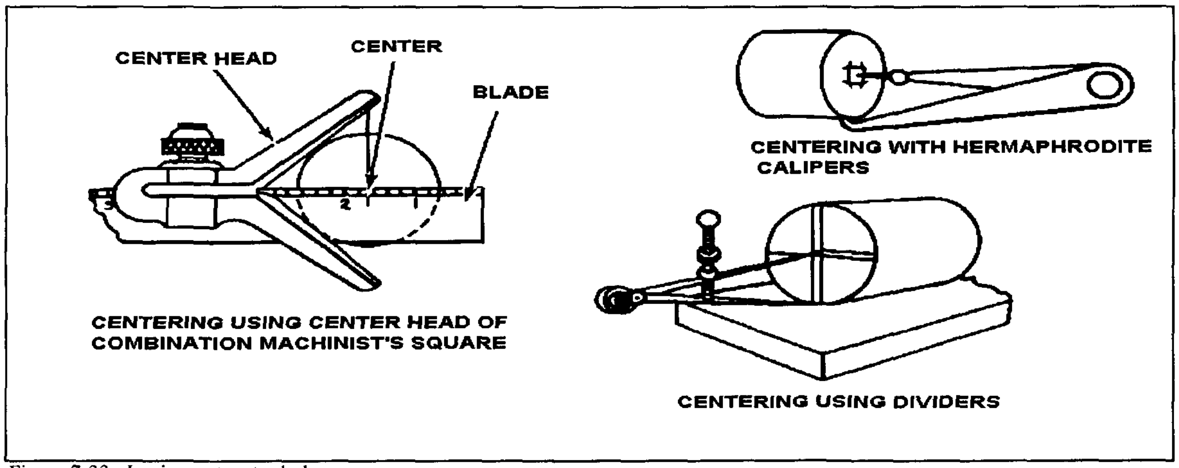


Figure 7-33. Laying outcenter holes.