Chapter 1

Benchwork

The term *benchwork* relates to work performed by the mechanic at the machinist's bench with hand tools rather than machine tools. It should be understood that the terms *benchwork* and *visework* mean the same thing; the latter, strictly speaking, is the correct term, as in most cases the work is held by the vise, while the bench simply provides an anchorage for the vise and a place for the tools. However, these terms are used almost equally. Today, work at the bench is not performed as much as formerly; the tendency, with the exception of scraping, is to do more and more benchwork with machines.

Operations that can be performed at the bench may be classed as follows:

- Chipping
- Sawing
- Filing
- Scraping

The Bench and Bench Tools

The prime requirements for a machinist's bench are that it should be strong, rigid, and of the proper width and height that the work can be performed conveniently. Correct height is important, and this will depend on the vise type used, that is, how far its jaws project above the bench. The location of the bench is important. It should be placed where there is plenty of light.

A great variety of tools is not necessary for benchwork. They may be divided into a few general classes:

- Vises
- Hammers
- Chisels
- Hacksaws
- Files
- Scrapers

Vises

By definition, a vise is a clamping device, usually consisting of two jaws that close with a screw or a lever, that is commonly attachable to a workbench; it is used for holding a piece of work firmly. There is a great variety of vises on the market, and they may be classed as follows:

- Blacksmith
- Machinist (plain, self-adjusting, quick-acting, or swivel)
- Combination
- Pipe

The machinist's vise shown in Figure 1-1 is usually provided on machine shop workbenches. Several types are provided; some of their features are parallelism, swivel action, and quick-acting jaws. These vises will withstand terrific abuse and are well adapted for a heavy and rough class of work.

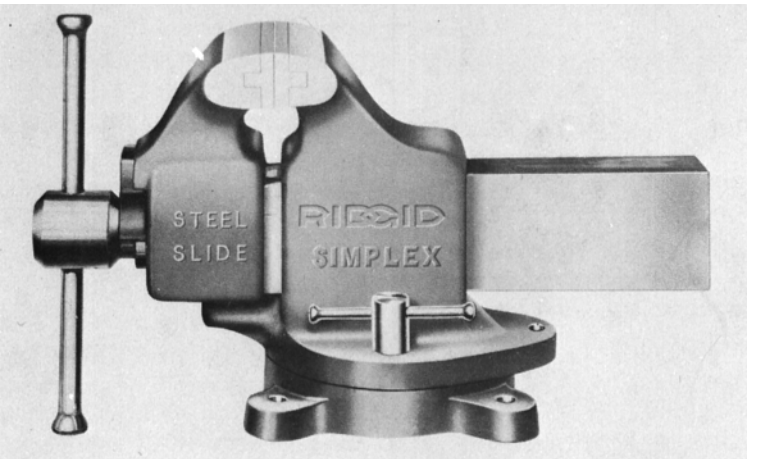


Figure 1-1 Machinist's vise. *(Courtesy Ridge Tool Company.)*

The combination vise shown in Figure 1-2 is well adapted for round stock and pipe. A regular pipe fitter's vise is shown in Figure 1-3. Vise jaws have faces covered with cross cuts in order to grip the work more firmly. It is evident that a piece of finished work held in such a manner would be seriously marred. This trouble may be avoided by using false jaws of brass or Babbitt metal, or by fastening leather or paper directly to the steel jaws.

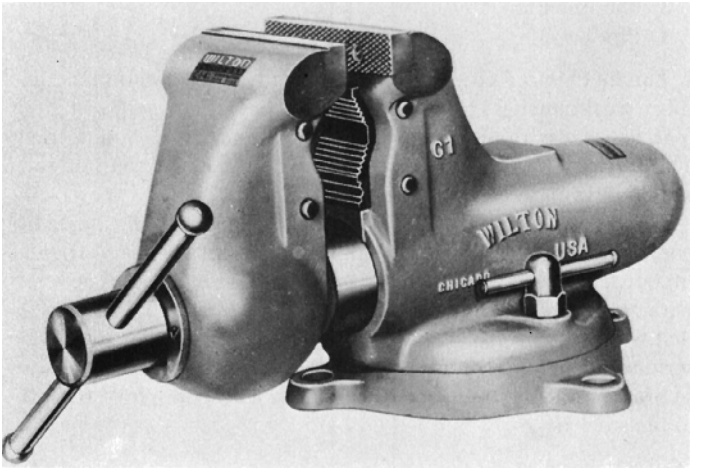


Figure 1-2 Combination vise. The inner teeth are for holding either pipe or round stock. *(Courtesy Wilton Tool Mfg. Co.)*

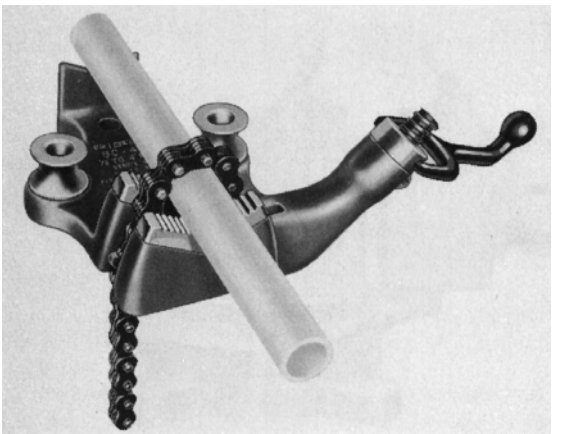


Figure 1-3 Pipe vise. *(Courtesy Ridge Tool Company.)*

Hammers

Hammers find frequent use in benchwork. Machinist's hammers may be classed with respect to the peen as follows:

- Ball peen
- Straight peen
- Cross peen

By definition, *peening* is the operation of hammering metal to indent or compress it in order to expand or stretch that portion of the metal adjacent to the indentation. These hammers are shown in Figure 1-4. The ball-peen hammer (Figure 1-4A), with its spherical end, is generally used for peening or riveting operations. For certain classes of work, the straight indentations of either the straight- or cross-peen hammers (Figure 1-4B and 1-4C) are preferable. A shaft or bar may be straightened by peening on the concave side.

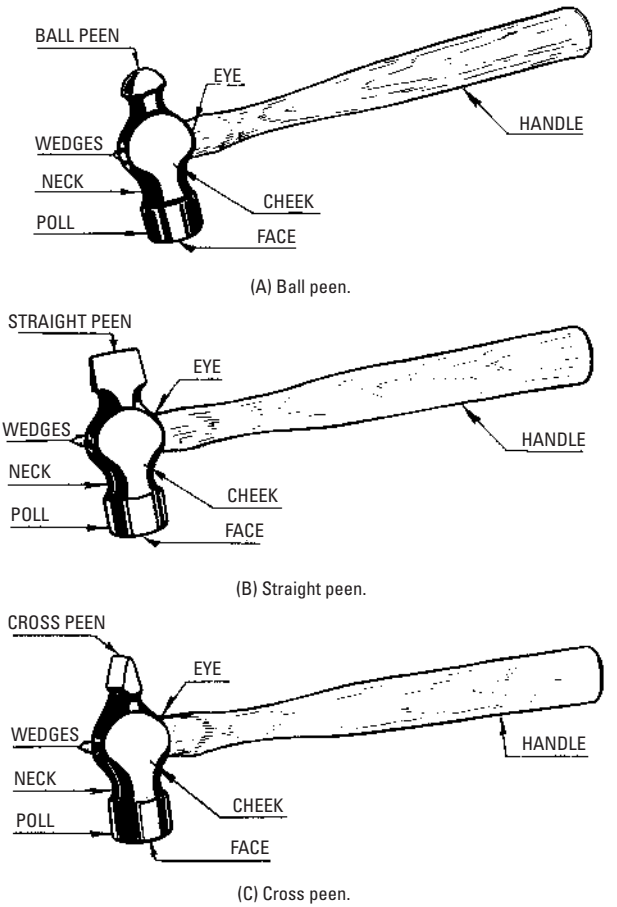


Figure 1-4 Machinist's hammers.

Chisels

The cold chisel is the simplest form of metal cutting tool. By definition, a chipping chisel is a hand tool made of heat-treated steel, with the cutting end shaped variously, for chipping metal when it is struck by a hammer.

The various types of chipping chisels are as follows:

- Flat
- Cape
- Diamond-point
- Round-nose

One of the first operations that a student or apprentice must learn in becoming a machinist is how to chip metal. This involves learning how to hold the chisel and how to use the hammer.

Flat Chisel

The work is placed firmly in the vise with the chisel held in the left hand. The chisel must be held firmly at the proper angle (Figure 1-5) to the work. The lower face of the chisel cutting edge acts as a guide, while the wedging action of the metal being chipped tends to guide the chisel in a straight line. The cutting face is the guide to hold the chisel at the correct angle, as shown in Figure 1-6. The cutting edge of the chisel is ground at an included angle of 60° to 70° (Figure 1-6A).

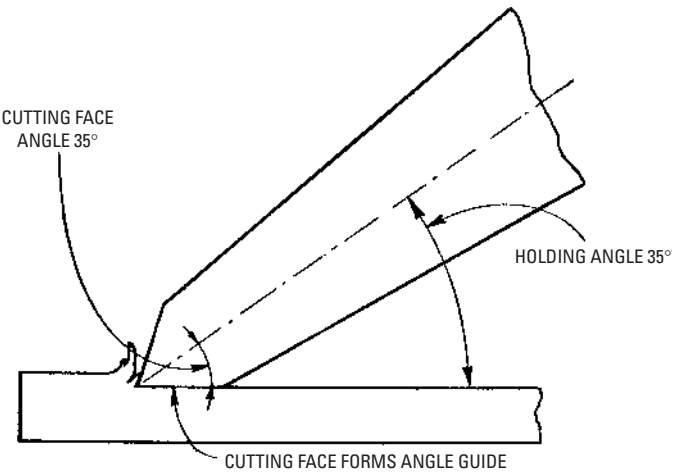


Figure 1-5 Detail of cutting end of cold chisel. Note the angle of application and the angle guide.

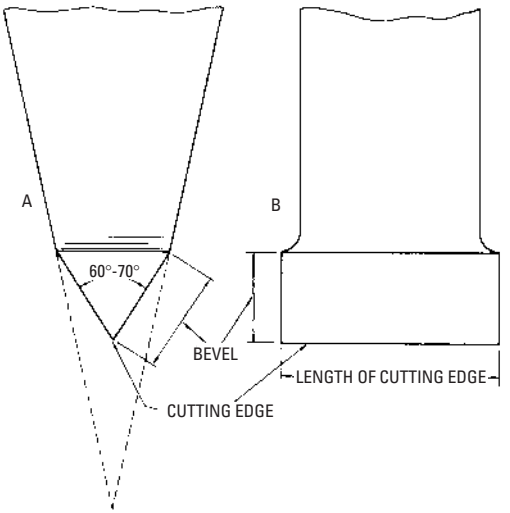


Figure 1-6 Cutting end of cold chisel showing bevel angle (A) and length of cutting edge (B).

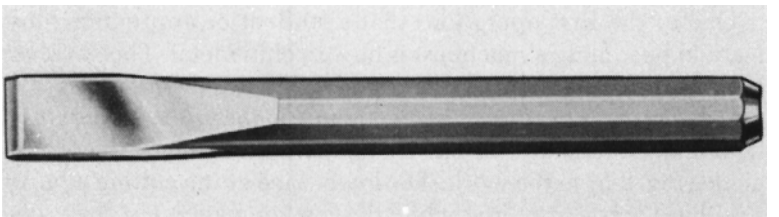


Figure 1-7 Cold chisel used in chipping operations. *(Courtesy Millers Falls Company.)*

The flat chisel is used for surfaces having less width than the castings and for all general chipping operations (Figure 1-7). The cutting edge is generally about one-eighth of an inch wider than the stock from which it is forged.

The beginning machinist learns to vary the chipping angle more or less as demanded by the nature of the work. The first exercise in chipping is usually a broad surface on which both the cold chisel and the cape chisel are used. First, grooves are cut in the piece to be chipped with the cape shield (Figure 1-8), and the raised portions are removed with a flat chisel (Figure 1-9).

In chipping, the worker should always chip toward the stationary jaw of the vise because its resistance to the blows of the hammer

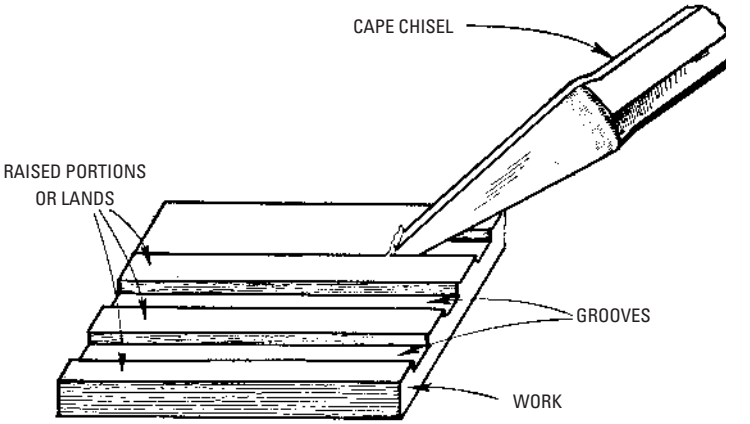


Figure 1-8 Cape chisel used to cut grooves.

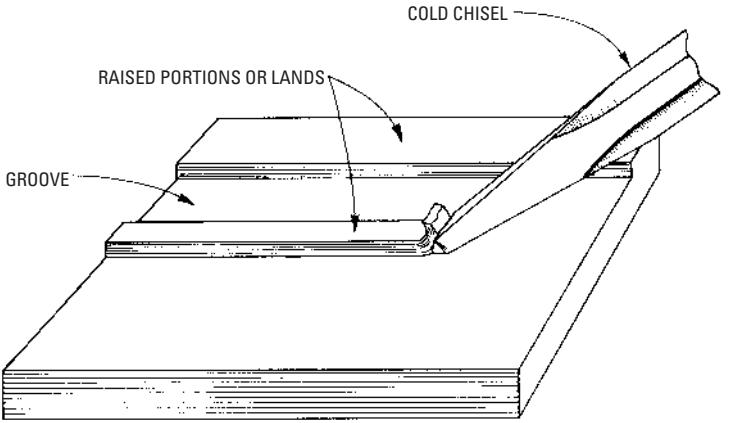


Figure 1-9 Using the cold chisel to remove *lands* in chipping a broad flat surface.

is greater. Start with a light chip, and watch only the cutting edge of the chisel. Chamfer the front and back edges of the work to avoid risk of breaking off the stock below the chipping line and to facilitate starting the chisel.

Use a 1-to 1¾-lb hammer for ordinary chipping work. Grasp the hammer near the end of the handle, with the fingers around the handle and the thumb projecting on top toward the striking end.

The chisel should be held firmly with the second and third fingers, and the little finger should be used to guide the chisel as required. The first finger and the thumb should be left slack; they are then in a state of rest, with the muscles relaxed. The fingers are less liable to become injured if struck with the hammer when relaxed than if struck when they were closed rigidly around the chisel. Reset the chisel to its proper position after each blow.

Cape Chisel

A cape chisel (Figure 1-10) is used to facilitate work in removing considerable metal from a flat surface, or to break up surfaces too wide to chip with a cold chisel alone. It is also used, along with other chisels, to cut keyways and channels.

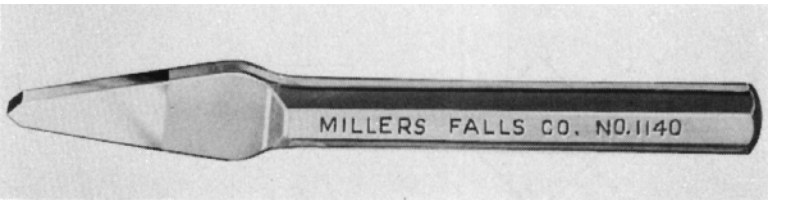


Figure 1-10 Cape chisel. *(Courtesy Millers Falls Company.)*

The cutting edge of the cape chisel is usually an eighth of an inch narrower than the shank. It is thin enough just behind the cutting edge to avoid binding in the slot. It is somewhat thicker in the plane at a right angle to the cutting edge.

Diamond-Point Chisel

Although the word "point" is universally used in place of "end," the term is a misnomer. The diamond end is obtained by drawing out the end of the stock and grinding the end at an angle less than 90° with the axis of the chisel, leaving a diamond-shaped point (Figure 1-11).

The diamond-point chisel (Figure 1-12) is used by diemakers for corner chipping, for correcting errors made while drilling holes, and for cutting holes in steel plates. By cutting a groove with this tool, following the shapes to be cut in the piece is much easier. The edges of holes made this way will be beveled, but they can be chipped square after the piece is removed.

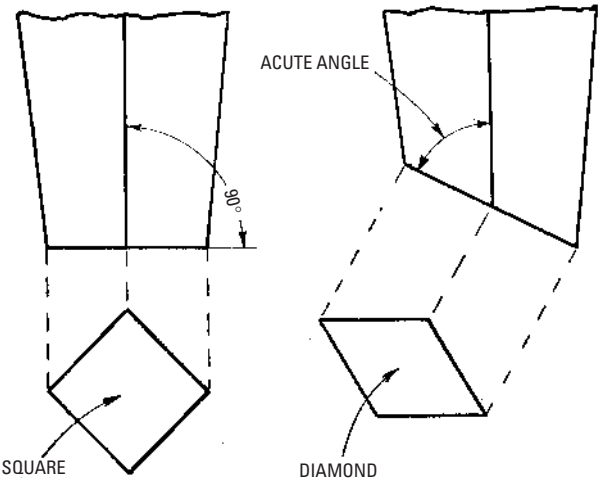


Figure 1-11 Detail of the cutting end of square and diamond-point chisels.

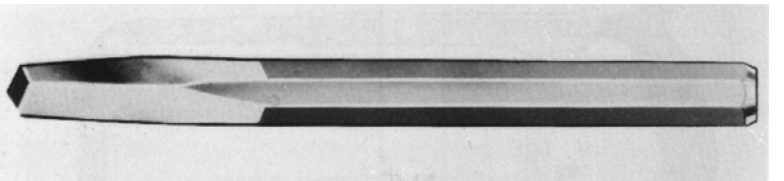


Figure 1-12 Diamond-point chisel. *(Courtesy Millers Falls Company.)*

Round-Nose Chisel

The round-nose chisel is sometimes called a *round-nose cape chisel* (Figure 1-13). The nose itself is cylindrical in section at the cutting end with tangential sides intersecting at the extremity. The tool is ground at an angle of 60° with its axis.

These chisels are called center chisels when they are used to "draw" the starting of drilling holes in order to bring them into concentricity with the drilling circles. They are also used on large round-bottomed channels and for cutting channels such as oil grooves.

The stock generally used for all the aformentioned forms of chisels is octagonal and of a good grade of tool steel, carefully forged, hardened, and tempered.

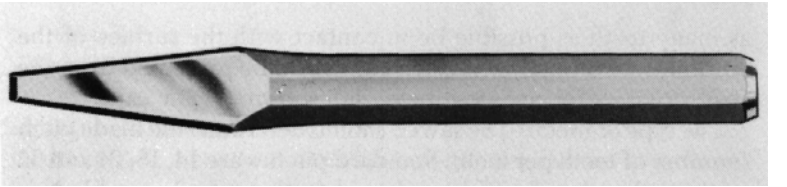


Figure 1-13 Round-nose cape chisel or round-nose chisel. *(Courtesy Millers Falls Company.)*

Hacksaws

The sawing of metal is one of the most common benchwork operations. Hand hacksaws are available with either a fixed frame or an adjustable frame. The adjustable frame hacksaw (Figure 1-14) can be changed to hold 8-inch, 10-inch, and 12-inch blades. Most blades are ½-inch wide and ¼-inch thick.

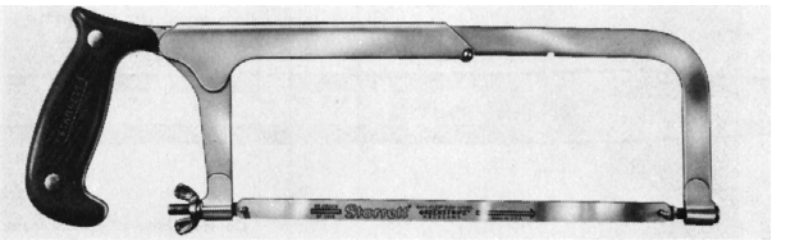


Figure 1-14 Adjustable frame hacksaw. *(Courtesy L. S. Starrett Company.)*

The workpiece must be held securely in a vise. The workpiece should be sawed near the vise jaws to prevent chattering. To hold nonrectangular-shaped pieces (Figure 1-15), clamp the work to allow as many teeth as possible to be in contact with the surface of the workpiece. Polished work surfaces should be protected from the steel vise jaws by covering them with soft metal jaw caps.

The type of metal to be sawed should determine the blade pitch (number of teeth per inch). Standard pitches are 14, 18, 24, and 32 teeth per linear inch. The number of teeth per inch on a blade is important because at least two teeth should be in contact with the work at all times (Figure 1-16).

To start a hacksaw cut, it is a good practice to guide the blade until the cut is well established. To start an accurate cut, use the thumb (Figure 1-17) as a guide and saw slowly with short strokes.

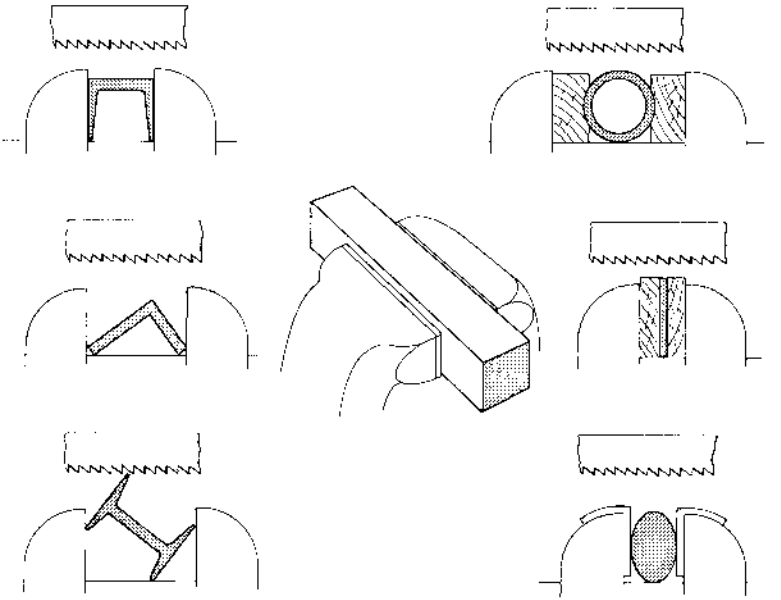


Figure 1-15 Holding work to be cut. *(Courtesy Disston, Inc.)*

As the cut deepens, grip the front end of the frame firmly and take a full-length stroke.

When sawing, stand facing the work with one foot in front of the other and approximately 12 inches apart, as shown in Figure 1-18. Pressure should be applied on the forward stroke and released on the return stroke because the blade cuts only on the forward stroke. Do not permit the teeth to slip over the metal as this dulls the teeth and may cause blade breakage. Once the *kerf* (the slot made by the blade) is established, the hacksaw should be moved at about 40 strokes per minute.

Files

Filing is a difficult operation for the beginner because it depends on the motion of the hands, without a means of guiding the tool, to move over the work in the correct direction. Proficiency is obtained by practice only when the proper methods are followed.

How to File

The correct position and method of holding the file are important. The work should be at the proper height—about level with the

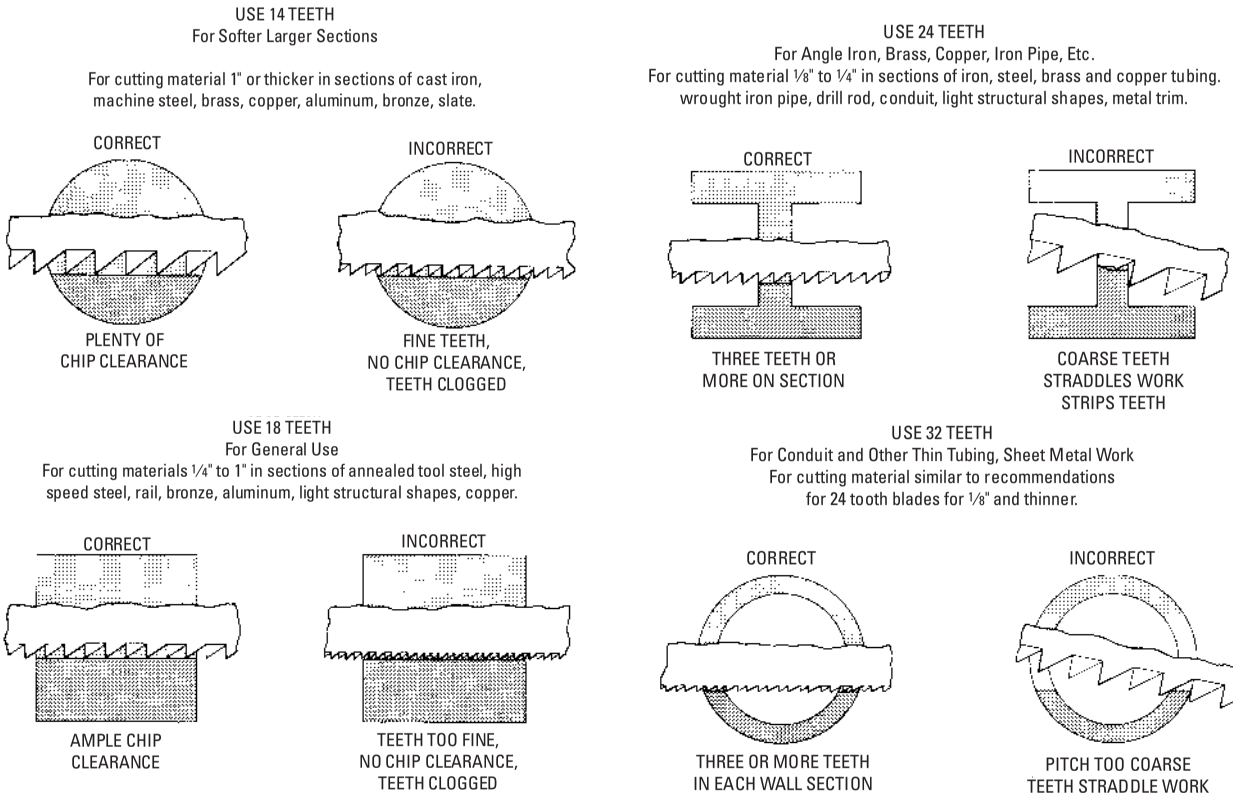


Figure 1-16 Hacksaw blade selection for various cutting operations. *(Courtesy Disston, Inc.)*

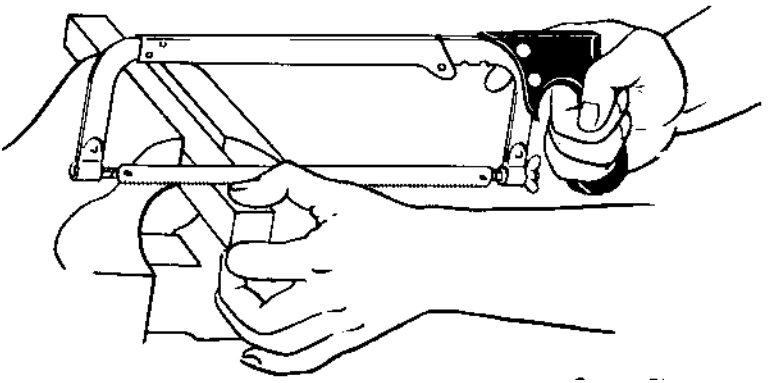


Figure 1-17 Starting a cut. *(Courtesy Disston, Inc.)*

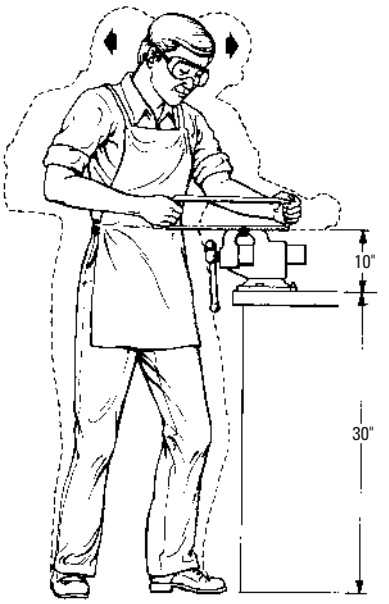


Figure 1-18 Proper stance for cutting. *(Courtesy Disston, Inc.)*

elbows on light work, and a little lower on heavy work (Figure 1-19). The feet should be about eight inches apart and at right angles to each other, the left foot being parallel with the file. Hold the file handle with the right hand-thumb on top and fingers below the handle.

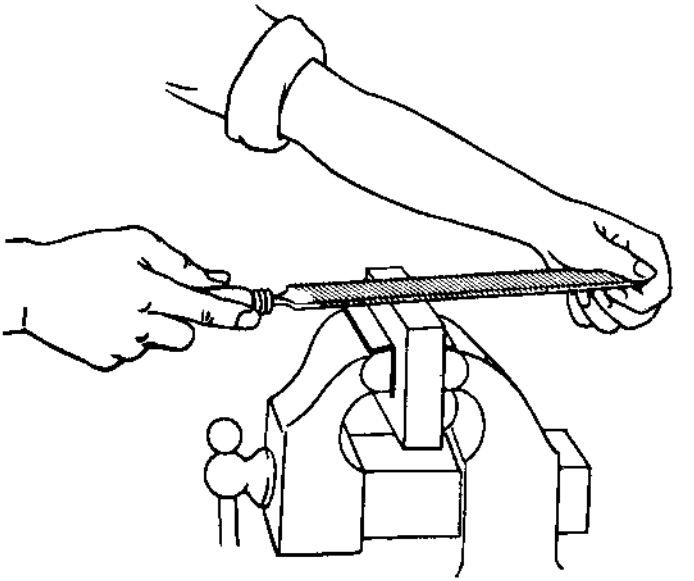


Figure 1-19 Correct position of hands and arms in filing. *(Courtesy Disston, Inc.)*

When filing, pressure should be exerted on the forward stroke only, because the teeth or cutting edges are pointed toward the end of the file. Pressure on the return stroke produces no cutting action, but tends only to dull the teeth. Figure 1-20 shows an incorrect position of the body when filing.

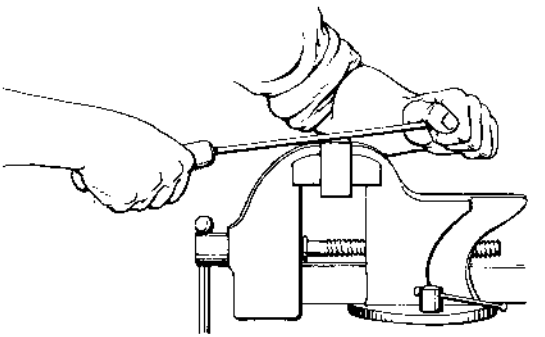


Figure 1-20 Incorrect position of body when filing.
(Courtesy Nicholson File Company.)

Drawfiling

When the file is grasped by the ends and moved sidewise across the work, the action is known as drawfiling (Figure 1-21). This produces a smooth finish on narrow surfaces and edges and is used on turned work to remove any tool marks. Drawfiling is light filing—used to produce a smooth surface (Figure 1-22). A second-cut or smooth file should be used; a single-cut file is better than a double-cut file because the single-cut is less likely to scratch the surface of the work.

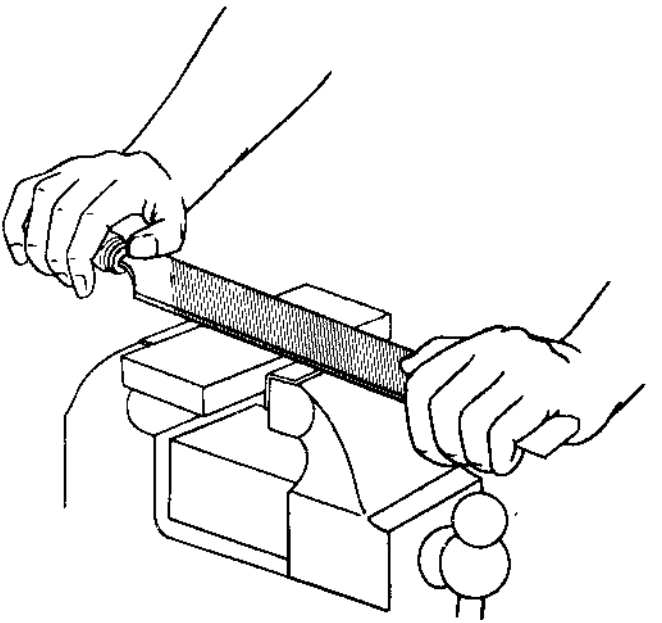


Figure 1-21 Drawfiling for producing a smooth surface. *(Courtesy Disston, Inc.)*

For most filing operations, begin with a coarse file and continue using successively finer grades of file, finishing with a smooth or dead-smooth file, according to the degree of finish desired (Figure 1-23).

Particles of metal, or pins, often remain in the teeth of the file, and they either reduce its cutting qualities or scratch the work. These particles can be removed by using either a stiff brush (Figure 1-24A) or a file card (Figure 1-24B) frequently for cleaning them from the file.

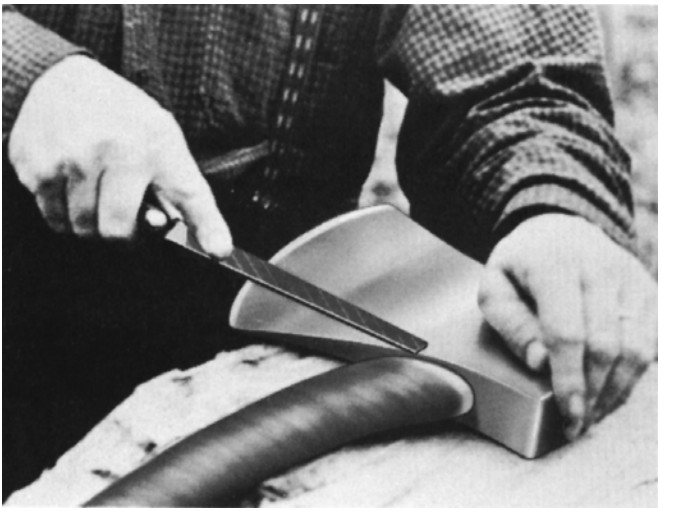


Figure 1-22 Using one hand to do light filing. *(Courtesy Nicholson File Company.)*

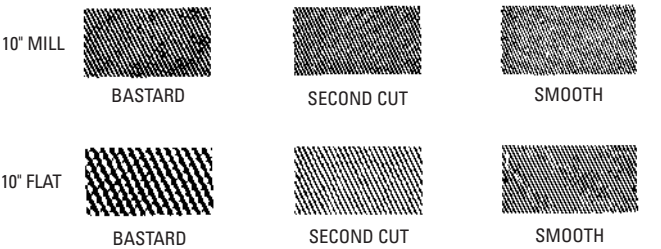


Figure 1-23 Standard file tooth cuts. *(Courtesy Simonds Saw & Steel Company.)*

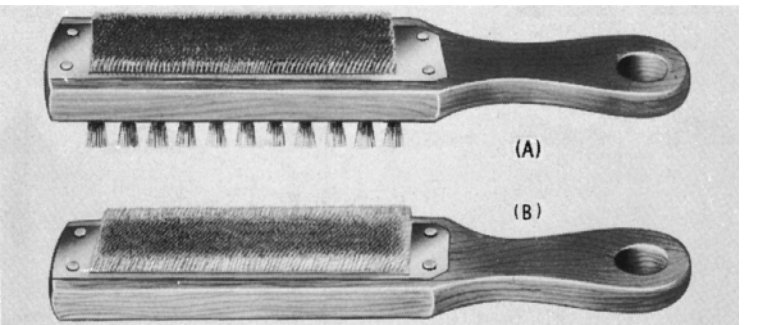


Figure 1-24 File cleaners: (A) file brush, (B) file card. *(Courtesy Nicholson File Company.)*

Cast iron should not be allowed to become greasy, as the file tends to slide without cutting into the metal. However, frequent *pinning* (clogging of the teeth with small slivers of metal) can be prevented by the use of oil when filing steel.

File Characteristics

A file differs from a chisel in that it has a large number of cutting points instead of a single cutting edge, and the file is driven by hand, rather than by a hammer. When a file is applied to a metal surface with a reciprocating motion, the teeth act as small chisels, each removing small chips.

Files have three distinguishing characteristics (Figure 1-25):

- *Length*—Always measured from the heel to the point, the tang not being included
- *Kind*—The shape or style
- *Cut*—Both the character and the relative degrees of coarseness of the teeth

Length

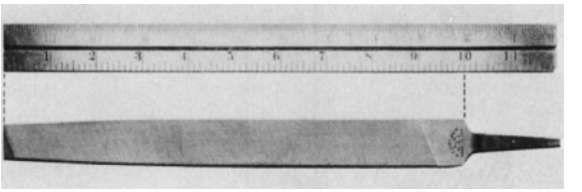
File lengths vary from 3 inches to 20 inches. Most machinist's files are from 4 to 6 inches in length (Figure 1-25A).

Kind

Many kinds of files are manufactured for many different purposes. Shapes of files in common use are mill, flat, hand, square, three-square, half-round, and round files (Figure 1-25B).

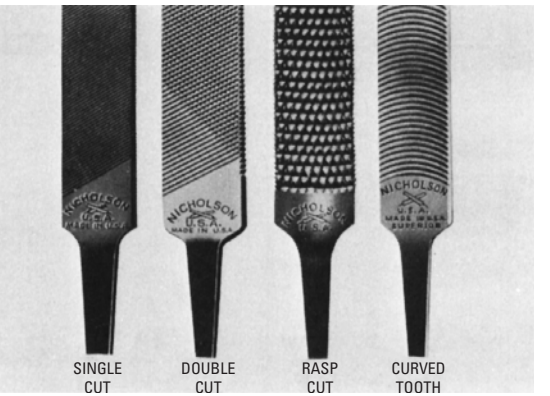
Cut

The teeth on a file are shaped to form a cutting edge similar to that of a tool bit, and they have both rake and a clearance angle. Four types of cuts are shown in Figure 1-25C. *Single-cut* files are made with a single set of teeth cut at an angle of 65° to 85°. They are usually used with light pressure to produce a smooth finish on a surface or to produce a keen edge on a knife or other cutting implement. *Double-cut* files are made with two sets of teeth that cross each other. One set is cut at approximately 45° and the other set at 70° to 80°. On a *rasp-cut* file, each tooth is short and is raised out of the surface by means of a punch. A *vixen-cut* file (or *curved-tooth* file) has a series of parallel, curved teeth, each extending across the file face. Most files for hand filing are from 10 to 14 inches long and have a pointed tang on one end on which wood or metal handles can be fitted for easy grasping.



(A) Length.

(B) Kind of shape.



(C) Cut.

Figure 1-25 File characteristics. *(Courtesy Nicholson File Company.)*

Machinist's files (Figure 1-26) are used throughout the industry wherever metal must be removed rapidly and finish is of secondary importance. They include flat, hand, round, half-round, square, pillar, three-square, warding, knife, and several less commonly known kinds of files. Most machinist's files are double-cut (Figure 1-27).

(A) All-purpose.

(B) Handy.

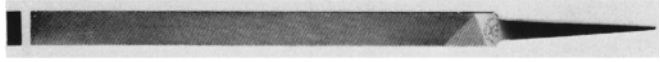
(C) Flat.

(D) Hand.

(E) Half-round.

(F) Round.

(G) Square.



(H) Pillar.

(I) Three-square.

(J) Warding.

(K) Knife.

Figure 1-26 Machinist's files. *(Courtesy Nicholson File Company.)*

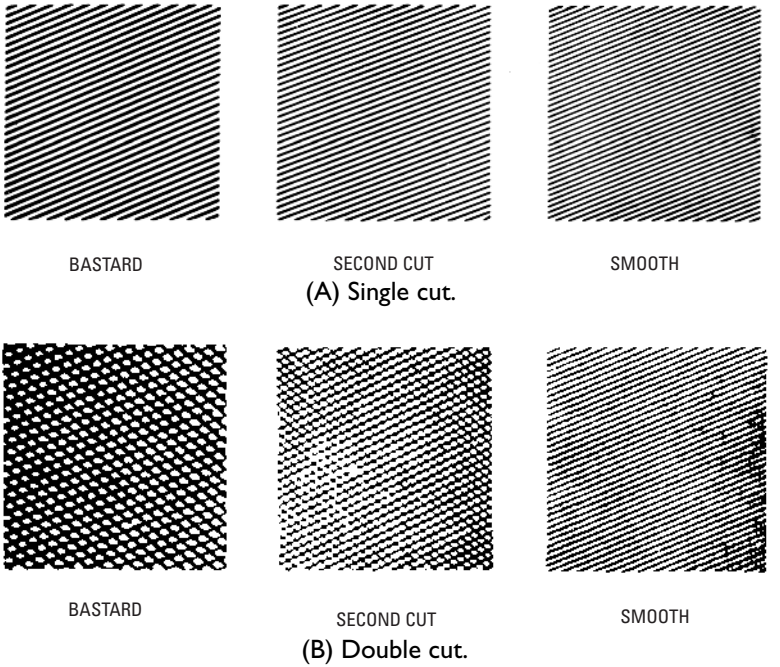


Figure 1-27 Single-cut and double-cut files. Each type has its own application. *(Courtesy Simonds Saw & Steel Company.)*

The cut (coarseness) of small files is usually designated by numbers as 00, 0, 1, 2, 3, 4, 5, 6, 7, and 8. The coarsest cut is 00, and 8 is the finest cut (Figure 1-28). The cut or coarseness in larger files is designated as rough, coarse, bastard, second-cut, smooth, and dead-smooth. These designations are relative and depend on the length of a file. A 14-inch bastard file is much coarser than a 6-inch bastard file (Figure 1-29.)

Scrapers

Scraping is the operation of correcting the irregularities of machined surfaces by means of scrapers (Figure 1-30) so that the finished surface is a plane surface. Although it is impossible to produce a true plane surface, scrapers are used to approach a plane surface, or for truing up a plane surface. Scrapers are also used for truing up circular surfaces such as bearings.

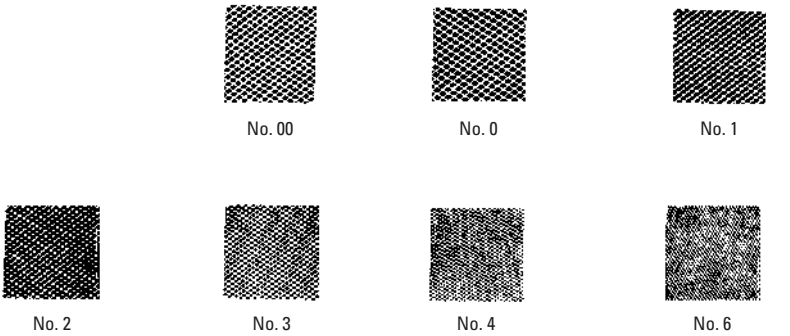


Figure 1-28 Small files are designated by numbers from 00 to 8. *(Courtesy Nicholson File Company).*

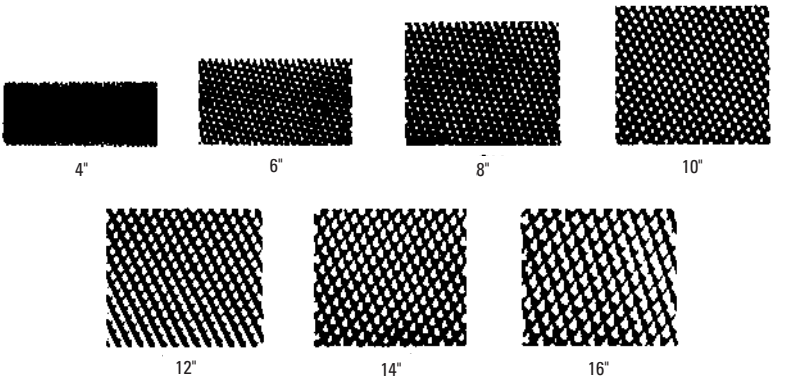


Figure 1-29 The coarseness varies for flat bastard files used by machinists. Length of the file determines coarseness. *(Courtesy Nicholson File Company.)*

How to Use a Scraper

In scraping operations (Figure 1-31), a surface plate is used to indicate irregularities or high spots. Any dust or grit should be wiped off the surface, and any burrs on the metal should be removed with a very fine file.

After thoroughly cleaning the surface plate, coat it with a marking material and rub the work over the surface plate a few times. High spots on the work will be indicated by the marking material that has been rubbed off. These high spots are removed by scraping. Continuing the process will bring up more high spots. After

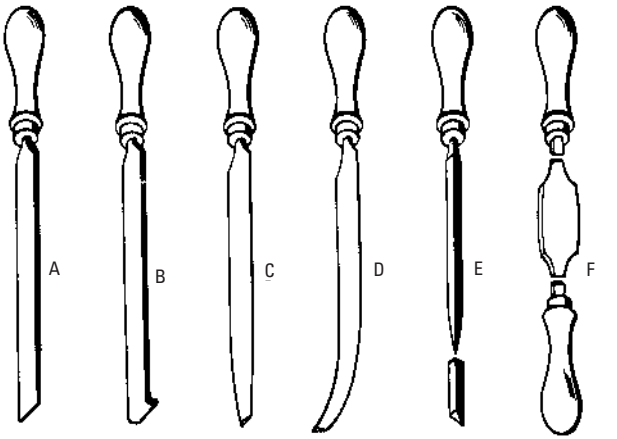


Figure 1-30 Typical scrapers: (A) flat or straight, (B) hook, (C) straight half-round, (D) curved half-round, (E) three-cornered or triangular, (F) double-handle.

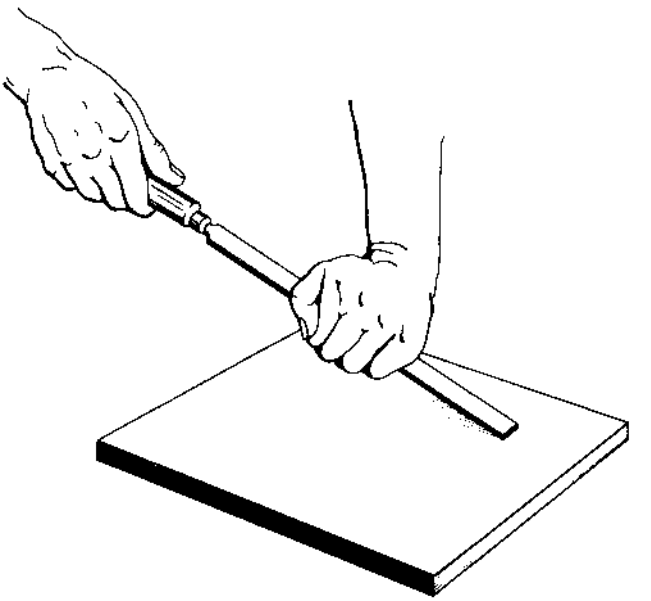


Figure 1-31 Correct method of holding a scraper.

repeated scraping and testing with the surface plate, the entire work surface will be covered with marking material, which indicates that the work is finished.

The correct use of the scraper is important. When a flat scraper is used, cutting is done on the forward stroke. Cutting is done on the return stroke when a hook scraper is used. Scraping requires a delicate touch. Less metal is removed by a scraper than by a file. The cutting operation, as done with scrapers, should be perfectly smooth and free from scratches.

The cutting edge of a scraper should be 3/32 of an inch thick and 1½ inches wide. The scraper should be ground on a grinding wheel and carefully honed on an oilstone. Scrapers are sometimes made from discarded files.

Scraper Classifications

Various forms of scrapers are used. The nature of the scraping operation determines the selection of the scraper. Scrapers may be classified as follows:

- Flat
- Hook (right-hand or left-hand)
- Half-round
- Triangular or three-cornered
- Two-handled
- Bearing

Scraping is also performed on round or curved surfaces, such as bearings. When an engine's main bearing has been trued up by scraping, the shaft will contact the bearing over its entire surface instead of making contact only at the high spots. Consequently, the bearing surface is presented, and the pressure is distributed over the entire bearing instead of being concentrated on the high spots.

Summary

Benchwork relates to work performed by the mechanic at the machinist's bench with hand tools rather than machine tools. The terms benchwork and visework mean the same thing. Visework, strictly speaking, is the correct term, as in most cases the work is held in a vise. Benchwork operations include chipping, sawing, filing, and scraping. Bench tools are the hammer, chisel, hacksaw, file, scraper, and vise.

The vise is a clamping device that has a couple of jaws that are used to hold a piece being worked on tightly in its grip. Vises are classified as blacksmith, machinist, combination, or pipe. The machinist vise is also classified as self-adjusting, quick-acting, plain, or swivel type. The jaws of the vise may be lined with brass or Babbitt metal or leather or paper to protect the piece being held rigid while the work is being done.

The machinist's hammer (ball-peen, straight-peen, or cross-peen) is suited only for the work it was designed to do. Ball-peen hammers are used for peening or riveting operations. But, for some types of straight work the straight peen is used.

Chisels are another of the hand tools that come in handy in metalwork and in the machine shop. Various types of chipping chisels are the flat, cape, diamond-point, and round-nose chisels. Chisels are used to chip metal. Holding the chisel correctly is very important in getting the job done.

The sawing of metal is one of the most important benchwork operations. Hand hacksaws are available with either a fixed frame or an adjustable frame. The work piece is held firmly in a vise while the work is being performed. It is very important that you use a hacksaw blade with a saw tooth fitted for the job. The hacksaw blade is made with 14, 18, 24, or 32 teeth per linear inch. The number of teeth is important because at least two teeth should be in contact with the work at all times.

Filing is a difficult operation for the beginner because it depends on the motion of the hands, without a means of guiding the tool, to move over the work in the correct direction. A lot of practice makes for a better filer. Small files are designated by numbers from 00 to 8. Drawfiling is the process of grasping the file by the ends and moving it sideways across the work. This produces a smooth finish on narrow surfaces and edges and is used on turned work to remove any tool marks.

Scraping is the operation of correcting the irregularities of machined surfaces by means of scrapers. It is very important to use the scraper correctly. Various forms of scrapers can be used by someone with a delicate touch to make a surface perfectly smooth. Scrapers are classified as flat, hook (right-hand, left-hand), half-round, triangular, two-handled, and bearing.

Review Questions

1. Name any five of the ten most popular machinist's files.

2. How many various forms of scrapers are used? Name them.

3. Name the three types of peen hammers and the four types of chisels.
4. Name the four types of bench vises.
5. Name five important bench tools.
6. Name the four hacksaw blade pitches.
7. How many hacksaw blade teeth should be in contact with the work piece?
8. What is the meaning of benchwork?
9. What are four operations that can be performed at the bench?
10. Name four types of chipping chisels.
11. What is drawfiling?
12. How does a file differ from a chisel?
13. What are the three distinguishing characteristics of files?
14. Why is scraping used on bearings?
15. Why does scraping take a delicate touch?