19 Shop Processes

19.1. Shop processes. An engineering draftsman must be thoroughly familiar with the fundamental shop processes before he is qualified to prepare drawings that will fulfill the requirements of the production shops. In preparing working drawings, he must consider each and every individual process involved in the production of a piece, and then specify the processes in terms that the shopman will understand. All too frequently, drawings that specify impractical methods and impossible operations are sent to the shops. Most of these impractical specifications are the result of a lack of knowledge, on the draftsman's part, of what can or cannot be done by skilled craftsmen using modern machines and tools.

Although an accurate knowledge of the shop processes can be acquired only through actual experience in the various shops, it is possible for an apprentice draftsman to obtain a working knowledge of the fundamental operations through study and observation. This chapter presents and explains the principal operations in the pattern shop, foundry, forge shop, and machine shop.

19.2. Castings. Castings are formed by pouring molten metal into a mold or cavity. In sand molding, the molten metal assumes the shape of the cavity that has been formed in a sand mold by ramming a prepared moist sand around a pattern and then removing the pattern. Although a casting shrinks somewhat in cooling, the metal hardens in the exact shape of the pattern used (Fig. 19.1).

A sand mold consists of at least two sections. The upper section, called the *cope*, and the lower section, called the *drag*, together form a box-shaped structure called a *flask*.

When large holes ($\frac{3}{4}''$ and over) or interior passageways and openings are needed in a casting, dry sand cores are placed in the cavity. Cores exclude the metal from the space they occupy and thus form desired openings. Large holes are cored in order to avoid an unnecessary shop operation. A dry sand core is formed by ramming a mixture of sand and a binding material into a core box that has been made in the pattern shop. To make a finished core rigid, the coremaker places it in a core oven where it is baked until it is hard.

The molder when making a mold inserts in the sand a sprue stick that he removes after the cope has been rammed. This resulting hole, known as the *sprue*, conducts the molten metal to the *gate*, which is a passageway cut to the cavity. The adjacent hole called the *riser* provides an outlet for excess metal.

19.3. The pattern shop. The pattern shop prepares patterns of all pieces that the foundry is to cast. Although special pattern drawings are frequently submitted, the pattern maker ordinarily uses a drawing of the finished piece that the draftsman has prepared for both the pattern shop and the machine shop. The finish marks on such a drawing are just as important to him as to the machinist, for he must allow, on each surface to be finished, extra metal, the amount of which depends upon the method

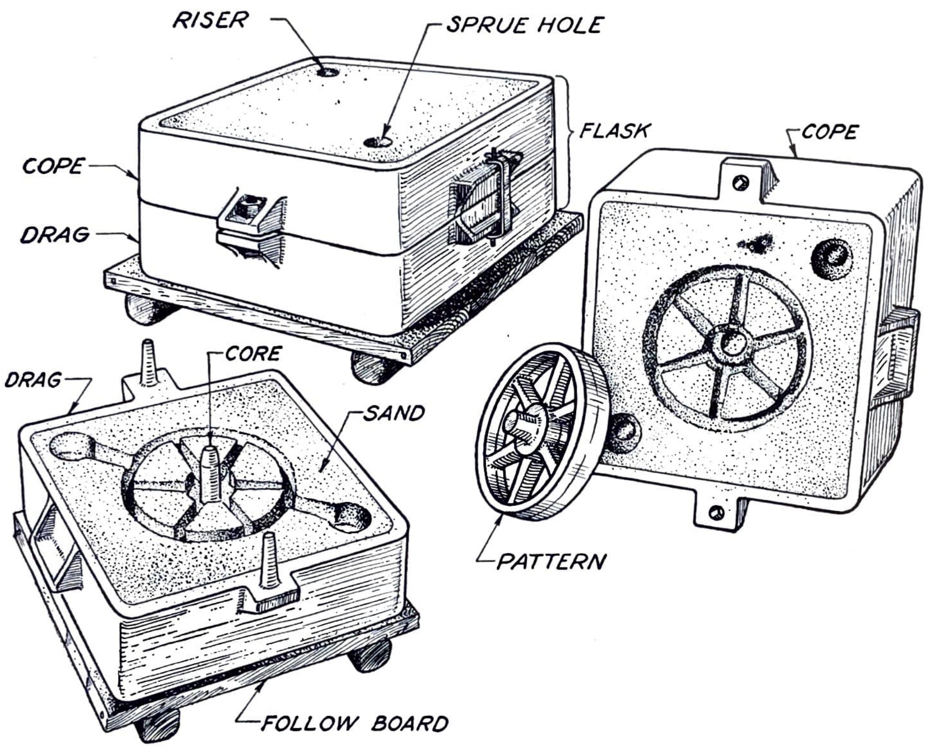


Fig. 19.1. Sand Mold.

of machining and the size of the casting. In general, this amount varies from $\frac{1}{16}''$, in very small castings, to as much as $\frac{3}{4}''$, in large castings.

It is not necessary for the draftsman to specify on his drawing the amount to be allowed for shrinkage, for the pattern maker has available a "shrink rule," which is sufficiently oversize (approximately $\frac{1}{8}''$ per foot) to take care of the shrinkage.

A pattern usually is first constructed of light strong wood, such as white pine or mahogany, which, if only a few castings are required, may be used in making sand molds. In quantity production, however, where a pattern must be used repeatedly, the wooden one will not hold up, so a metal pattern (aluminum, brass, and so on) is made from it and is used in its place.

Every pattern must be constructed in such a way that it can be withdrawn from each section of the sand mold. If the pattern consists of two halves (split), the plane of separation should be so located that it will coincide with the plane of separation of the cope and the drag (Fig. 19.1). Each portion of the pattern must be slightly tapered, so that it can be withdrawn without leaving a damaged cavity. The line of intersection, where the dividing plane cuts the pattern, is called the *parting line.* Although this line is rarely shown on a drawing, the draftsman should make certain that his design will allow the pattern maker to establish it. Ordinarily, it is not necessary to specify the slight taper, known as *draft,* on each side of the parting line, for the pattern maker assumes such responsibility when constructing the pattern.

A "filled-in" interior angle on a casting is called a *fillet,* to distinguish it from a rounded exterior angle, which is known as a *round* (Fig. 19.2). Sharp interior angles are avoided for two reasons: They are difficult to cast; and they are likely to be potential points of failure because the crystals of the cooling metal arrange themselves at a sharp corner in a weak pattern. Fillets are formed by nailing quarter rounds of wood or strips of leather into the sharp angles, or by filling the angles with wax.

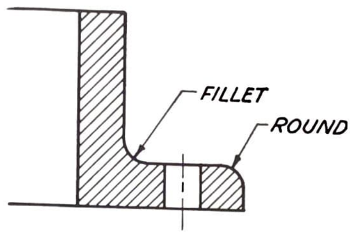


Fig. 19.2. Fillets and Rounds on a Casting.

19.4. The foundry. Although a draftsman is not directly concerned with the foundry, since the pattern maker takes his drawing and prepares all patterns and core boxes for the molder, it is most important that he be familiar with the operations in making a sand mold and a casting. Otherwise, he will find it difficult to prepare an economical design, the cost of which depends upon how simple it is to mold and cast.

19.5. Die casting. Die casting is an inexpensive method for producing certain types of machine parts, particularly those needing no great strength, in mass production. The castings are made by forcing molten metal or molten alloy into a cavity between metal dies in a die-casting machine. Parts thus produced usually require little or no finishing.

19.6. The forge shop. Many machine parts, especially those that must have strength and yet be light, are forged into shape, the heated metal being forced into dies with a drop hammer. Drop forging, since heated metal is made to conform to the shape of a cavity, might be considered a form of casting. However, because dies are difficult to make and are expensive, this method of production is used principally to make parts having an irregular shape that would be costly to machine and could not be made from casting material. Forgings are made of a high-grade steel. Dies are made by expert craftsmen who are known simply as diemakers.

Generally, special drawings, giving only the dimensions needed, are made for the forge shop.

19.7. Standard stock forms. Many types of metal shapes, along with other materials that are used in the shops for making parts for structures, are purchased from manufacturers in stock sizes. They are made available from the stock department, where rough stock, such as rods, bars, plates, sheet metal, and so on, is cut into sizes desired by the machine shop.

19.8. The machine shop. In general, the draftsman is more concerned with machine-shop processes than with the processes in other shops, as all castings and forgings that have been prepared in accordance with his drawings must receive their final machining in the machine shop. Since all machining operations must be considered in the design and then properly specified, a draftsman must be thoroughly familiar with the limitations as well as the possibilities of such common machines as the lathe, drill press, boring machine, shaper, planer, milling machine, and grinder. An explanation of the operation and capabilities of each machine will be given in the following sections.

19.9. The lathe. Many common operations, such as turning, facing, boring, reaming, knurling, threading, and so on, may be performed with this widely used machine. In general, however, it is used principally

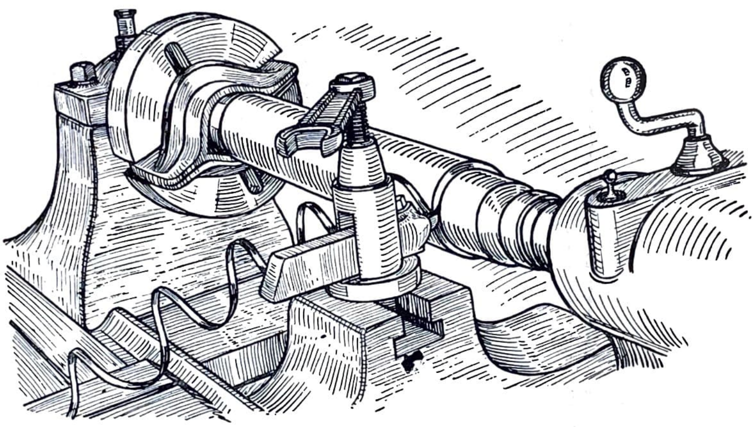


Fig. 19.3. Lathe Operation—Turning.

for machining (roughing-out) cylindrical surfaces to be finished on a grinding machine. Removing metal from the exterior surfaces of cylindrical objects is known as turning and is accomplished by a sharp cutting tool that removes a thin layer of metal each time it travels the length of a cylindrical surface on the revolving work (Fig. 19.3). The piece, which is supported in the machine between two aligned centers, known as the *dead center* and the *live center*, is caused to rotate about an axis by power transmitted through a lathe dog, chuck, or a face plate. The work revolves against the cutting tool, held in a tool post, as the tool moves parallel to the longitudinal axis of the piece being turned. Cutting an interior surface is known as *boring* (Fig. 19.4). A note is not necessary on a drawing to indicate that a surface is to be turned on a lathe.

When a hole is reamed, it is finished very accurately with a fluted reamer of the exact required diameter. If the operation is performed on a lathe, the work revolves as the nonrotating reamer is fed into the hole by turning the handwheel on the tail stock. (See Fig. 19.5.)

Screw threads may be cut on a lathe by a cutting tool that has been ground to the shape required for the desired thread. The thread is cut as the tool travels parallel to the axis of the revolving work at a fixed speed (Fig. 19.6).

Knurling is the process of roughening or embossing a cylindrical surface. This is accomplished by means of a knurling tool containing knurl rollers that press into the surface of the work as it is fed across them (Fig. 19.7).

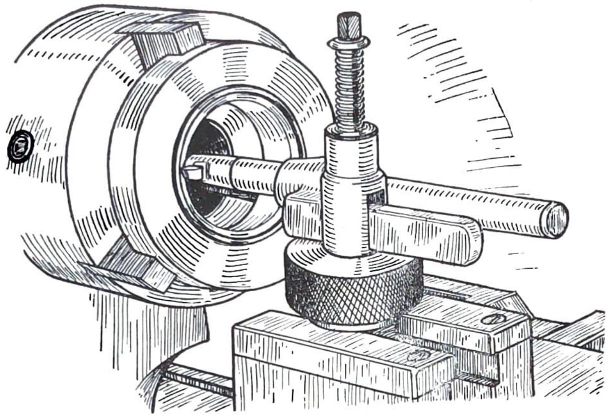


Fig. 19.4. Boring on a Lathe.

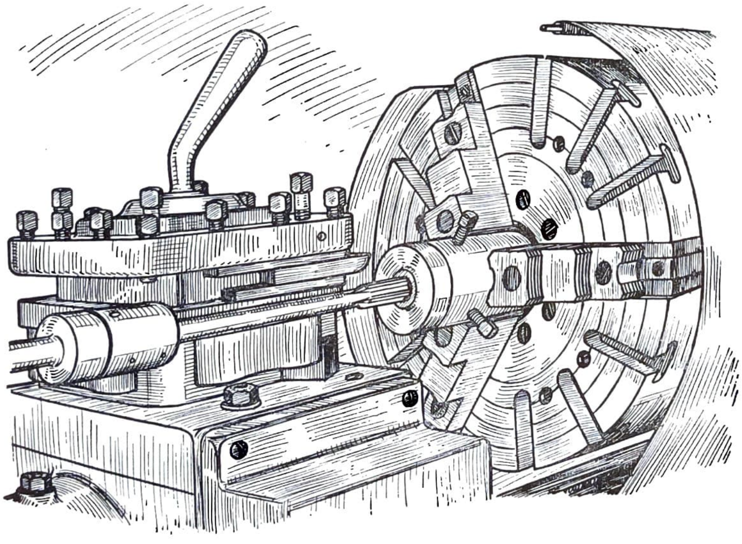


Fig. 19.5. Reaming on a Lathe.

19.10. The drill press. A drill press is a necessary piece of equipment in any shop because, although it is used principally for drilling, as the name implies (Fig. 19.8), other operations, such as reaming, counterboring, countersinking, and so on, may be performed on it by merely using the proper type of cutting tool. The cutting tool is held in position in a chuck and is made to revolve, through power from a motor or line shafting, at a particular speed suitable for the type of metal being drilled. The most flexible drill press, especially for large work, is the radial type, which is so designed that the spindle is mounted on a movable arm that

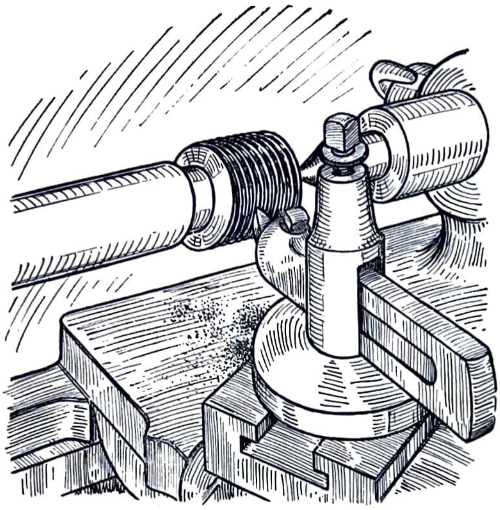


Fig. 19.6. Cutting Threads on a Lathe.

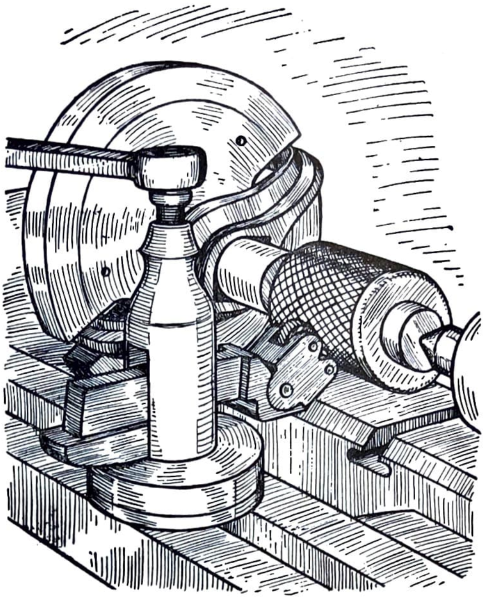


Fig. 19.7. Knurling.

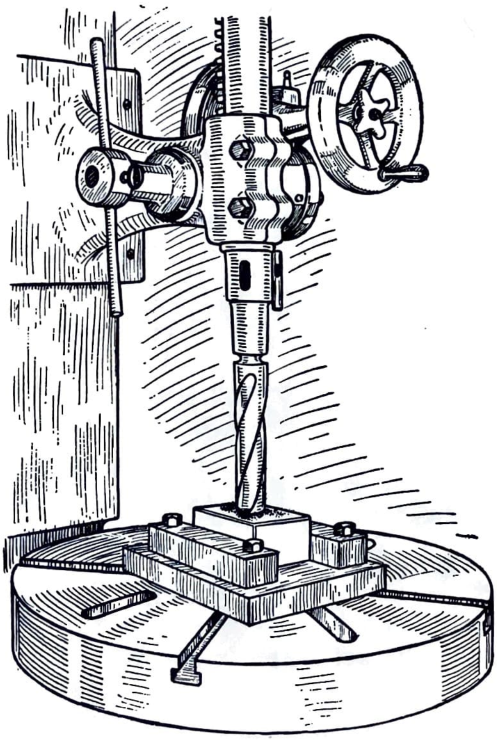


Fig. 19.8. A Drill Press.

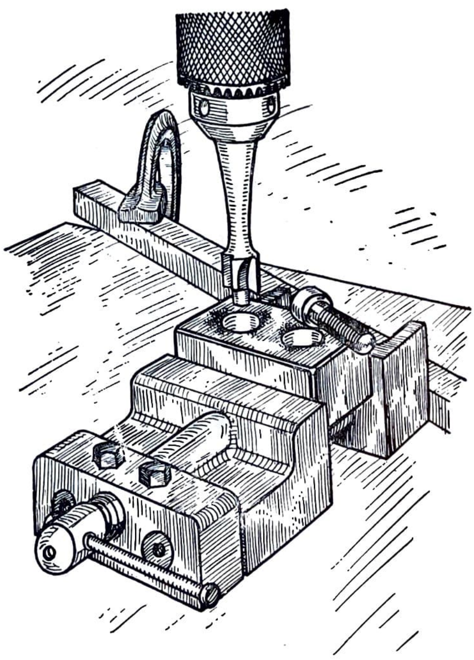


Fig. 19.9. Counterboring on a Drill Press.

can be revolved into any desired position for drilling. With this machine, holes may be drilled at various angles and locations without shifting the work, which may be either clamped to the horizontal table or held in a drill vise or drill jig. The ordinary type of drill press without a movable arm is usually found in most shops along with the radial type. A multi-spindle drill is used for drilling a number of holes at the same time.

Figure 19.9 shows a setup on a drill press for performing the operation of counterboring. A counterbore is used to enlarge a hole to a depth that will allow the head of a fastener, such as a fillister-head cap screw, to be brought to the level of the surface of the piece through which it passes. A counterbore has a piloted end having approximately the same diameter as the drilled hole.

Figure 19.10 shows a setup for the operation of countersinking. A countersink is used to form a tapering depression that will fit the head of a flat-head machine screw or cap screw and allow it to be brought to the level of the surface of the piece through which it passes.

A plug tap is used to cut threads in a drilled hole (Fig. 19.11).

A spotfacer is used to finish a round spot that will provide a good seat for the head of a screw or bolt on the unfinished surface of a casting. Figure 19.12 shows various cutting tools commonly used for forming holes and cutting threads.

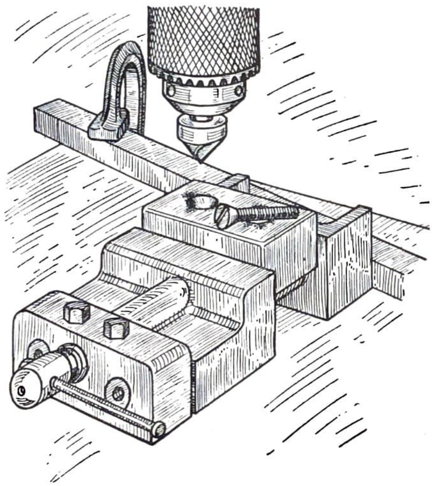


Fig. 19.10. Countersinking on a Drill Press.

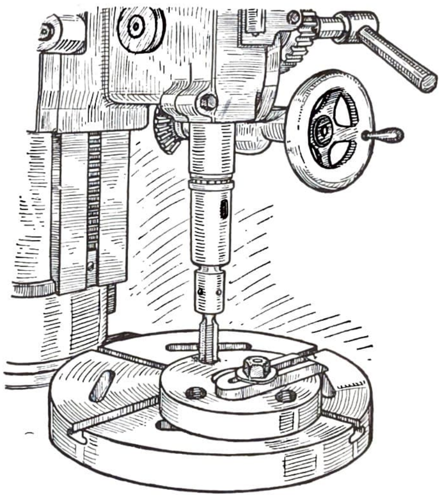


Fig. 19.11. Tapping on a Drill Press.

19.11. Hand reaming. A hole may be finished to an accurate size by hand reaming, as shown in Fig. 19.13. The reamer in this illustration is of a special type known as a *line reamer*.

19.12. Boring (Fig. 19.14). Boring is the operation of enlarging a circular hole for accuracy in roundness or straightness, and may be accomplished on a lathe, drill press, milling machine, or boring mill. When the hole is small and of considerable length, the operation may be performed on a lathe. If the hole is large, the work is usually done on a boring mill, of which there are two types—the vertical and the horizontal. On a vertical boring machine, the work is fastened on a horizontal revolving table, and the cutting tool or tools, which are stationary, advance vertically into it as the table revolves. On a horizontal boring machine, the tool revolves and the work is stationary.

19.13. The milling machine. A milling machine is used for finishing plane surfaces and for milling gear teeth, slots, keyways, and so on. In finishing a plane surface, a rotating circular cutter removes the metal for a desired cut as the work, fastened to a moving horizontal bed, is auto-

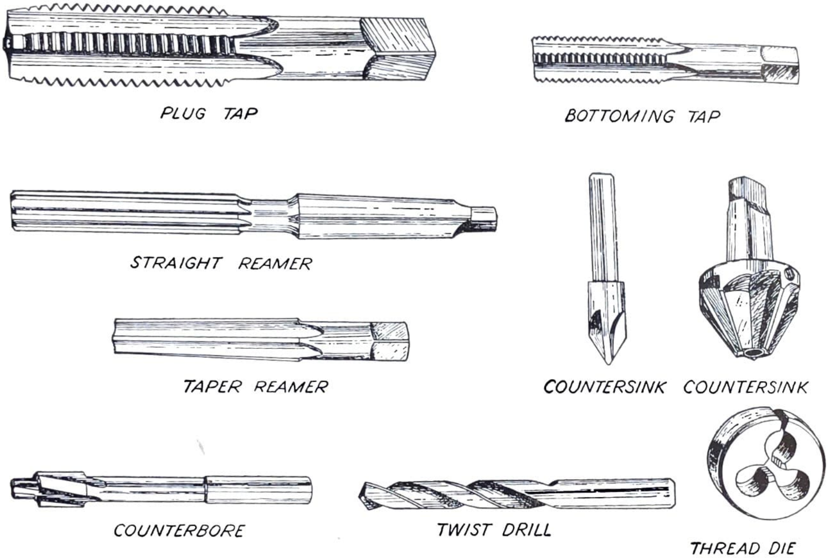


Fig. 19.12. Various Cutting Tools.

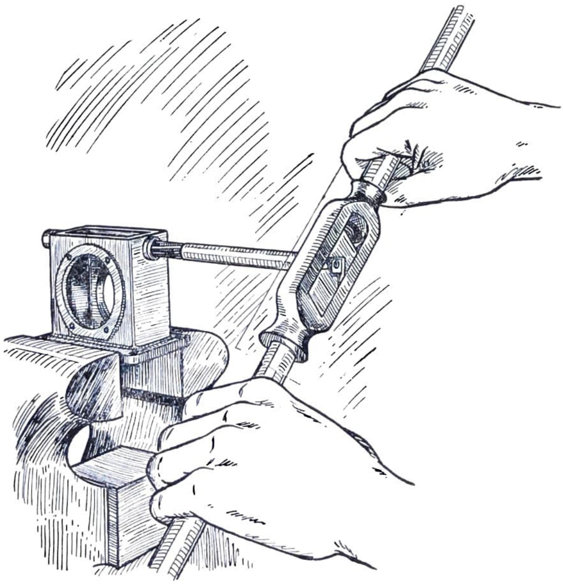


Fig. 19.13. Hand Reaming.

matically fed against it. Several types of milling cutters are shown in Fig. 19.15.

Figure 19.16 shows a setup for milling gear teeth in a gear blank. Note the form of this particular type of cutter.

19.14. The shaper (Fig. 19.17). A shaper is used for finishing small plane surfaces and for cutting slots and grooves. In action, a fast-moving reciprocating ram carries a tool across the surface of the work, which is fastened to an adjustable horizontal table. The tool cuts only on the forward stroke.

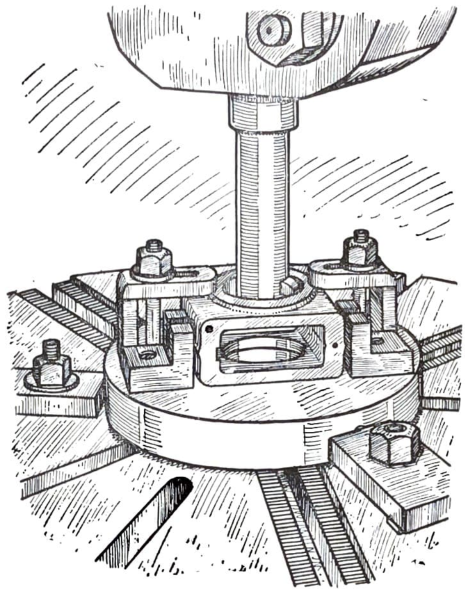


Fig. 19.14. Boring on a Boring Mill.

19.15. The planer. The planer is a machine particularly designed for cutting down and finishing large flat surfaces. The work is fastened to a long horizontal table that moves back and forth under the cutting tool. In action, the tool cuts as the table moves the surface against it. Unlike the cutter on the shaper, it is stationary except for a slight movement laterally for successive cuts.

19.16. The grinding machine. A grinding machine has a rotating grinding wheel that, ordinarily, is either an emery wheel (fine or coarse)

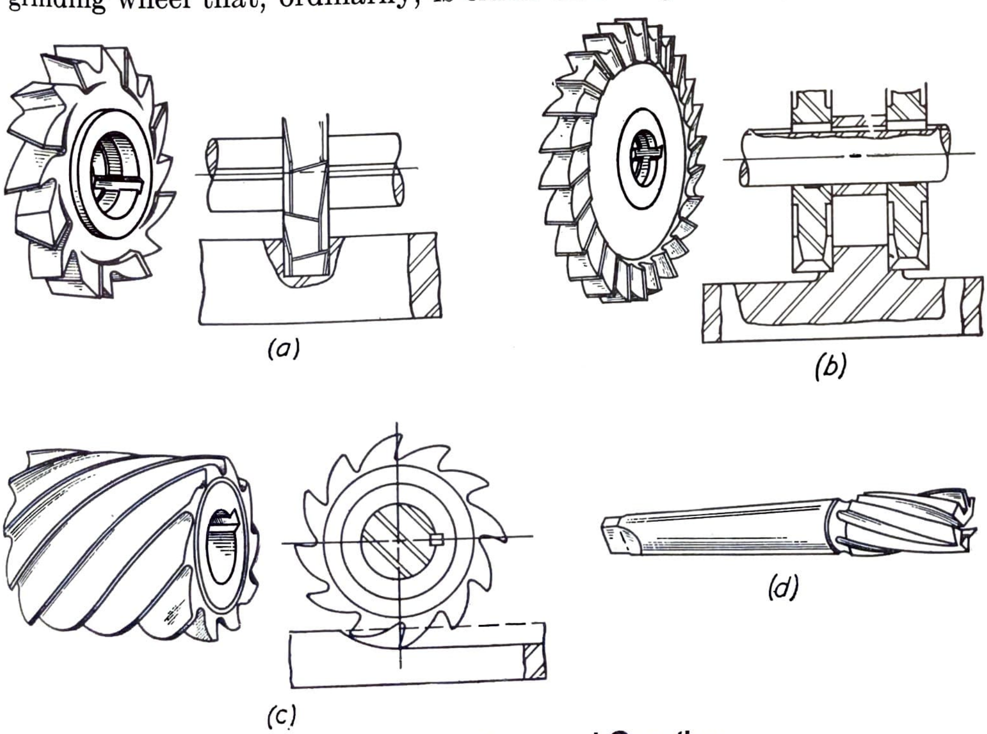


Fig. 19.15. Milling Cutters and Operations.

or some type of high-speed wheel made of carborundum. Grinding consists in bringing the surface to be ground into contact with the wheel. Although grinding machines are often used for "roughing" and for grinding down projections and surfaces on castings, their principal use, as far as a draftsman is concerned, is for the final finishing operation to bring a

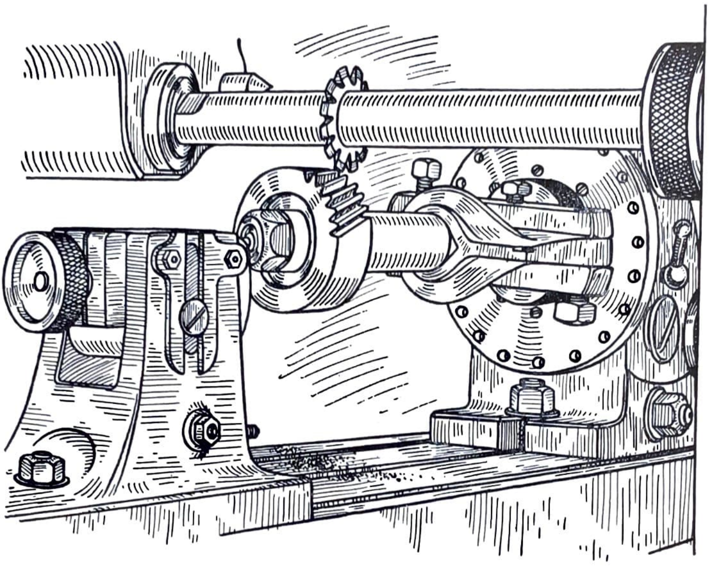


Fig. 19.16. Cutting Gear Teeth on a Milling Machine.

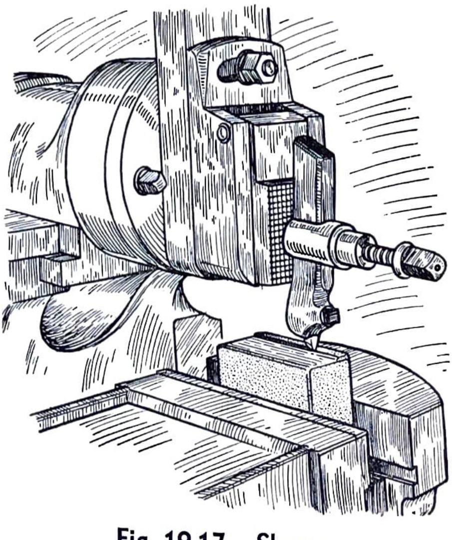
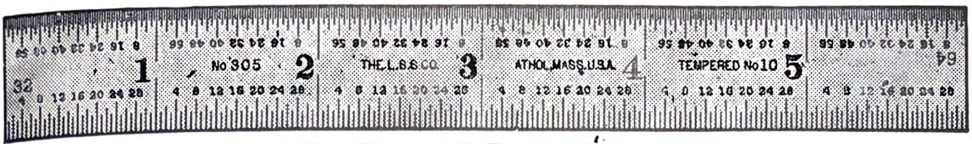


Fig. 19.17. Shaper.

piece of work down to accurate dimensions. Internal grinders are available for various purposes.

19.17. Polishing. Polishing consists of bringing a ground surface into contact with a revolving disc of leather or cloth, thus producing a lustrous smoothness that would be impossible to obtain by using even the finest grinding wheel. The operation is specified on a drawing by a note, "polish" or "grind and polish."



Quick Reading with Decimal Equivalents

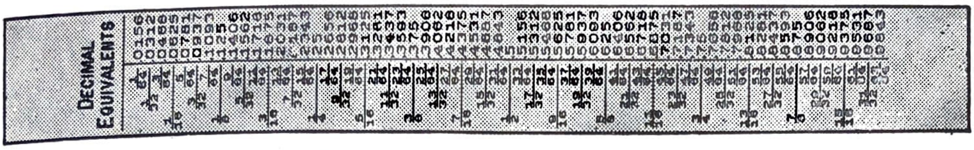
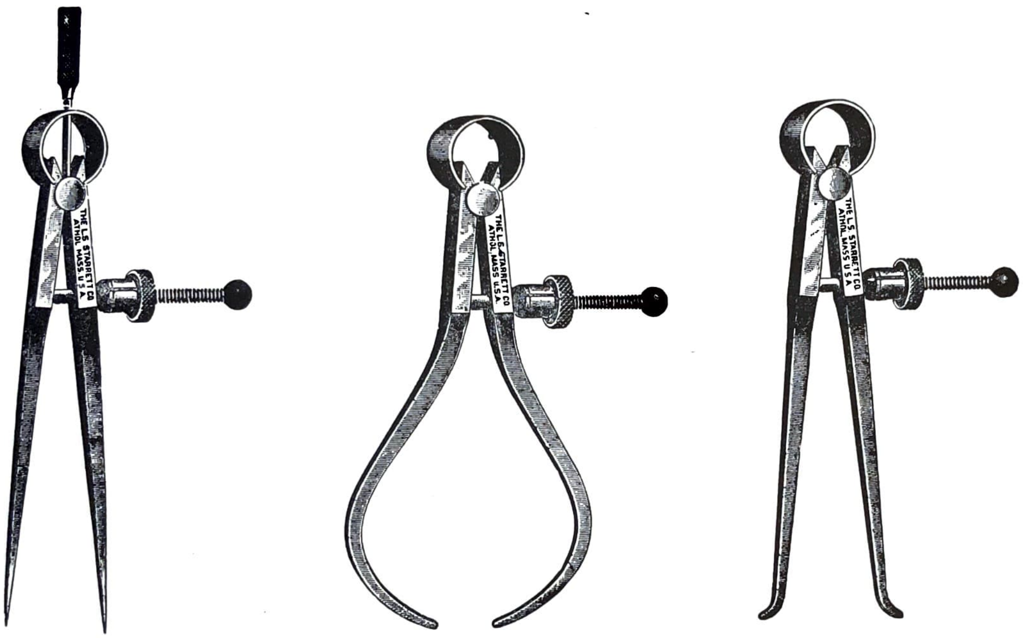


Fig. 19.18. The Steel Rule.



Dividers

Outside Calipers

Inside Calipers

Fig. 19.19. Calipers.

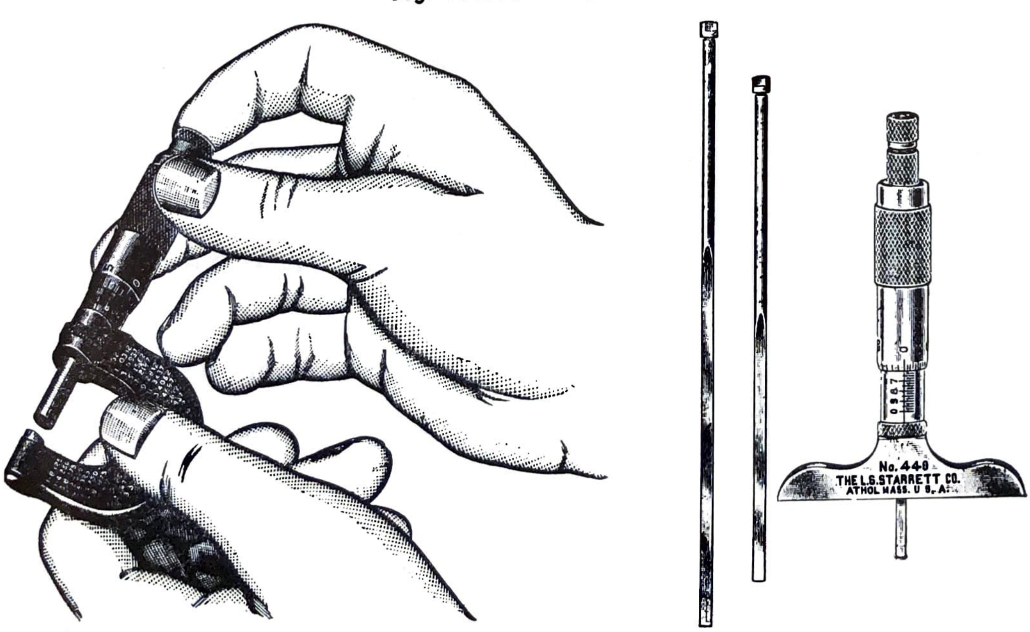


Fig. 19.20. Micrometers.

19.18. Broaching. A broach is a tool used to cut keyways and to form square, rectangular, hexagonal, or irregular-shaped holes. It is a hard, tempered steel shaft with serrated cutting edges that enlarge a drilled, punched, or cored hole to a required shape. Broaches are either pushed or pulled through the work. A special broaching machine is used for pulling broaches. Some form of press, hydraulic or otherwise, is required for push broaches.

19.19. Jigs and fixtures. Often, when an operation must be performed many times in making a part in quantities on a general machine, one of two devices, a *jig* or a *fixture*, may be used to facilitate production and insure accuracy without making repeated measurements. Although both jigs and fixtures fulfill the same general purpose, there is a distinguishing difference between them. A jig, for example, holds the work as it guides the tool and, ordinarily, is not fixed to the machine. A fixture, on the other hand, is rigidly fastened to a machine and holds the work in position without acting as a guide for the cutting tools.

Since most large manufacturing concerns have special departments for designing jigs and fixtures, the ordinary draftsman is not directly concerned with these auxiliary devices when he is preparing working drawings.

19.20. Special production machines. In large industrial concerns, most mechanical parts are made on specialized machines by semiskilled operators. A discussion of even a few of these, however, is beyond the scope of a general drawing text in which each subject is limited to a few pages. Since most specialized mass-production machines operate on the same general principles as the general-purpose machines, a young engineering draftsman should be able to determine their limitations and capabilities through observation, if he has a general knowledge of such machines as the lathe, shaper, drill press, milling machine, and so on. No prospective designer or draftsman should ever forego an opportunity to observe special production machines. He must have a thorough understanding of all shop machines and methods, if his drawings are to be satisfactory for the shops.

19.21. Measuring tools. Figures 19.18, 19.19, and 19.20 show a few of the measuring tools commonly available in shops. When great accuracy is not required, calipers are used (Fig. 19.19). The outside calipers are suited for taking external measurements, as for example from a shaft. They are adjusted to fit the piece, and then the setting is applied to a rule to make a reading. The inside calipers have out-turned toes, which fits them for taking internal measurements, as for example in measuring either a cylindrical or a rectangular hole. When extreme accuracy is required, some form of micrometer calipers may be used (Fig. 19.20).