Unit 24. Die Casting

Well over a million tons of nonferrous metals—aluminum, zinc, magnesium, and brass—went to market in the form of die castings this year.

They made their appearance in a great variety of end products created by virtually the full spectrum of metal-consuming industries.

Die-casting production is entering the million-ton stage, with ferrous alloys becoming prominent in the picture.

A high standard of living would not be economically possible if it were not for die castings. Household appliances, automobiles, small tools, and electric motors—these things and many more are all made possible by the die-casting industry.

Die casting can be defined as *the process of forcing metal, by pressure—hydraulic or pneumatic—into a metal die or mold.* The pressures, which range from 80 to 40,000 psi (pounds per square inch) are held until the solidification of the metal occurs.

Die-casting machines may be classified as (1) hot-chamber and (2) cold-chamber. 24–1.

HOT-CHAMBER PROCESS

In the hot-chamber process, the melting pot is included with the machine. 24–2. The molten metal is forced into the mold by means of a plunger or compressed air. 24–3 (Page 126).

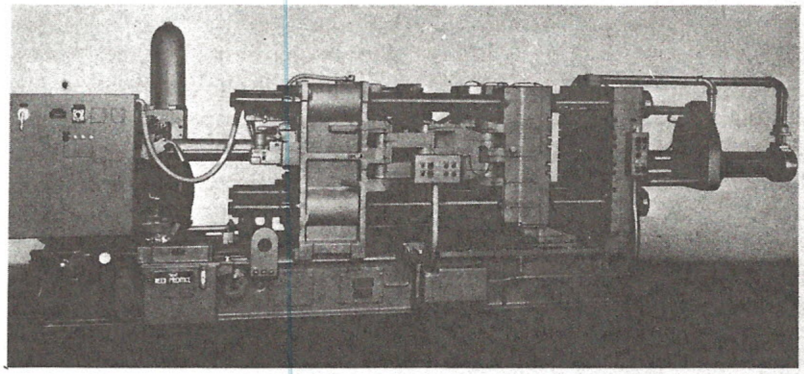
Both the metal plunger and the die mechanism are hydraulically operated in the plunger type machine.

The plunger operates in one end of a gooseneck casting which is submerged in the molten metal. The metal is introduced by gravity into the gooseneck. After the molten metal is ladled into the machine the rest of the operations are automatic. The downstroke of the plunger creates pressure which causes the metal to be forced along into the die cavity. Upon solidification of the metal, the pressure is relieved and the dies are opened. The finished casting is ejected by knockout pins.

The operating pressures in this machine range from 5,600 to 22,000 psi.

Process Details

Air operated machines are equipped with a gooseneck cast-

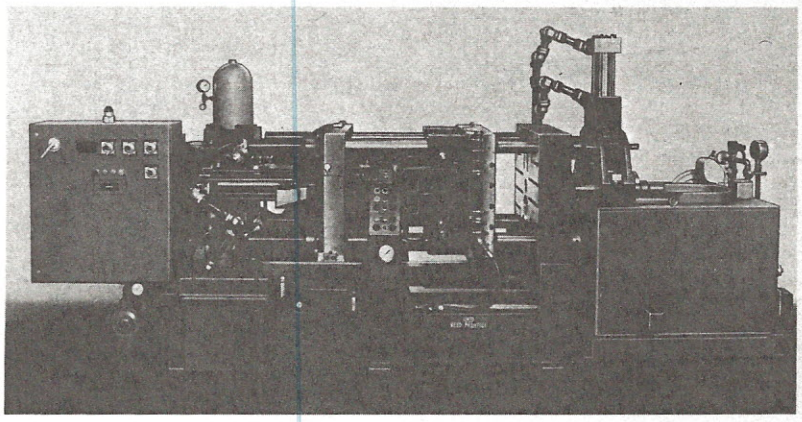


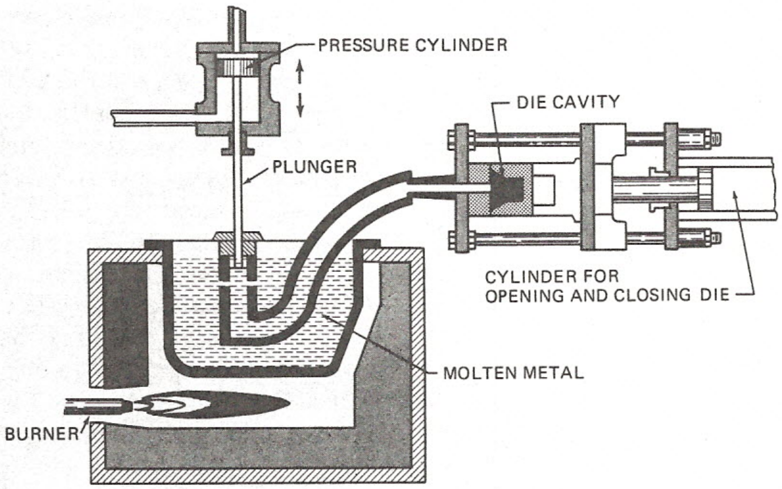
Reed-Prentice Div., Package Machinery Co.

24–1. 600-ton, cold-chamber, die-casting machine.

24–2. 400-ton, hot-chamber, die-casting machine.

Reed-Prentice Div., Package Machinery Co.





24-3. The hot-chamber or plunger type die-casting machine is used primarily for casting zinc alloys. The melting pot is built into the machine and the cylinder that leads to the die chamber always contains molten metal.

ing that is operated by a lifting device. 24-4. The start of the casting operation begins with the gooseneck being lowered into the molten metal where, as just noted, it is filled through the nozzle by gravity. The raising mechanism lifts the gooseneck until it comes into contact with the opening of the die cavity and locks itself into position for the casting operation. Compressed air is then admitted into the die, where solidification takes place. After the metal solidifies, the air pressure is released and the gooseneck returns to its original position to receive more metal. The dies are opened and the casting is ejected. The operation is then repeated. Air pressures range from 80 to 600 psi.

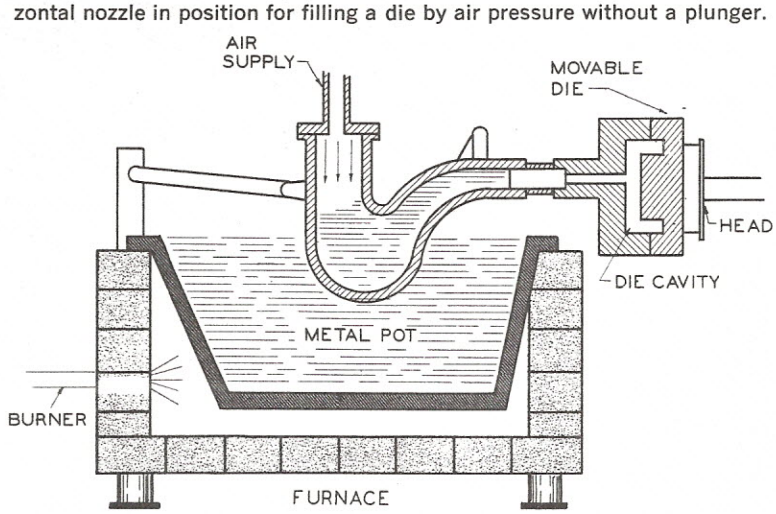
COLD-CHAMBER PROCESS

1. One style of cold-chamber, die-casting machine consists of cylindrical pressure chamber, generally operated hydraulically, that conveys pressure to a ram or piston. In sequence, the dies are closed and a predetermined amount of molten metal is ladled into the cylinder. The plunger is actuated and forces the metal into the closed sections of the die. 24-5. After the metal solidifies, the cores are removed, the dies opened, and the casting is ejected from the stationary half of the die. A cold-chamber machine may be used for making castings of aluminum, magnesium, or brass. From 100 to 150 pieces per hour can be produced by this method.

2. Another style of cold-chamber machine uses metal in a semiliquid or plastic state, which permits the operation at a lower temperature than if using molten metal. 24-6. Longer die life is obtained. The process reduces the high temperature required to heat such metals as brass and bronze, which have a higher melting temperature than either aluminum or zinc. Overheating of dies is eliminated by being able to use the metal in a semiliquid state, and less die damage occurs. The dies are water cooled to protect them from overheating.

The metal is ladled by hand to the compression chamber. It will be noted that the compres-

24-4. Cross section of a pneumatic die-casting machine, having a horizontal nozzle in position for filling a die by air pressure without a plunger.



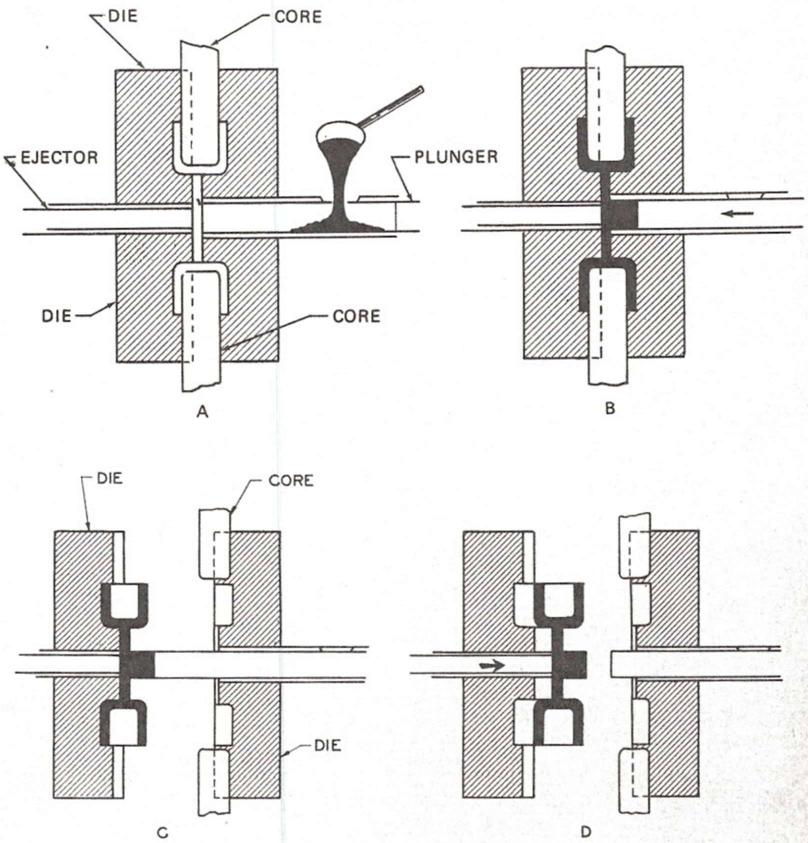
sion chamber is part of the die. Metal is poured into this chamber at the upper part of the die and forced under pressure into the die cavity. The ram is moved out, the dies open, and the casting is ejected.

The sprue and excess metal are removed in the finishing operation.

DIE-CASTING DIES

A die for die casting is normally made in two parts. One part is the front cover portion; the other serves to eject the metal. Each is equipped with dowel pins or other device to align the two parts, much like a split pattern. The two die sections meet at the parting line and are joined by a locking mechanism when in the closed position. In cooling, the casting shrinks onto core pins and projections which are attached to the ejector portion of the die. When the molten metal has cooled, the ejector plate in the movable part of the die is advanced sufficiently to force the casting from the cavity. The casting falls clear, and the cycle of operations is repeated.

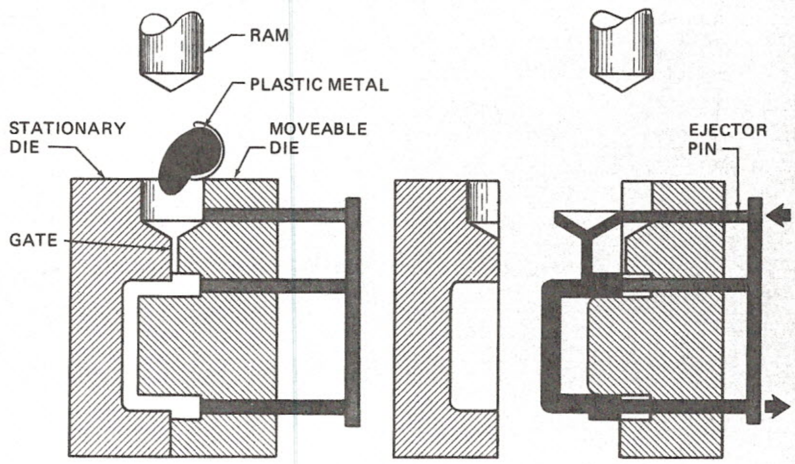
Dies may be classified as follows: (1) single-cavity die, (2) multiple-cavity die, (3) combination, used with (4) a unit die. A *single-cavity* die produces one casting per cycle of operation. In large production runs a *multiple-cavity* die is used to produce several castings at the same time. A *combination* die has cavities of two or more different shapes which are cast at the same time. A *unit die holder* holds several die elements at the same time.



New Jersey Zinc Co.

24–5. (A) Ladling molten metal into cold chamber. (B) After molten metal is forced into die. (C) Cores are withdrawn, die opened, and plunger advanced to eject piece. (D) Plunger withdrawn and ejector advanced to force gate of castings from ejector half of die.

24–6. Die-casting machine designed to use metal in a semi-liquid or plastic state, showing compression chamber in dies.



ials as cast iron,
nds on the metal
arts with internal
up) are placed in
:avity are usually
as parting com-
:chanical ejectors
serve as thermal

e molten metal is
re opened and the
oys and cast iron.
:ss has advantages
n rates. Although
low because the

This can be ap-
first develops in a
r ornamental and
l frc he molds,
only necessary

ito the mold cavity
re *pouring*) process
ity by air pressure.
ble plunger is also
ss is generally used
ical products). The

sting. The molten
00 and 100,000 psi
art unless clamped
ımping force. There
ld-chamber.
ich traps a certain
es of about 2000 psi
cast by this process.
ı the life of various

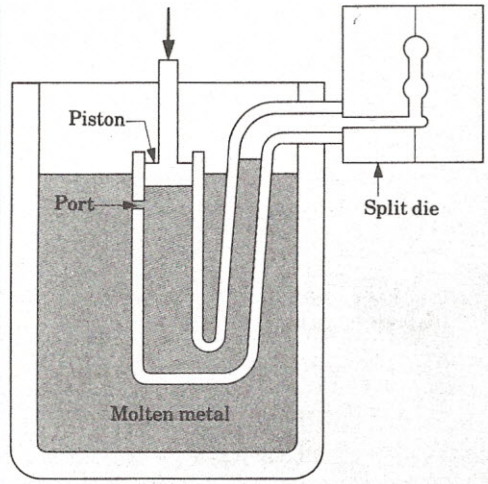


FIGURE 5.23 Hot-chamber die-casting process, generally used with low-melting-point alloys such as lead, tin, and zinc. The pressure of the liquid metal in the die may be on the order of 2000 psi (15 MPa).

In the *cold-chamber* process (Fig. 5.24), the injection cylinder (shot chamber) is filled by ladle with molten metal and the metal is forced into the die cavity at pressures as much as 10 times that in the hot-chamber process. High-melting-point alloys of aluminum, magnesium, and copper are cast by this process.

Die casting has the advantages of high production rates with good strength, high quality of parts, and good surface details and dimensional accuracy. Equipment costs are somewhat high (Fig. 5.25) but labor costs are generally low. One part made by die casting is shown in Fig. 5.26. Properties and typical applications of die casting alloys are given in Table 5.4.

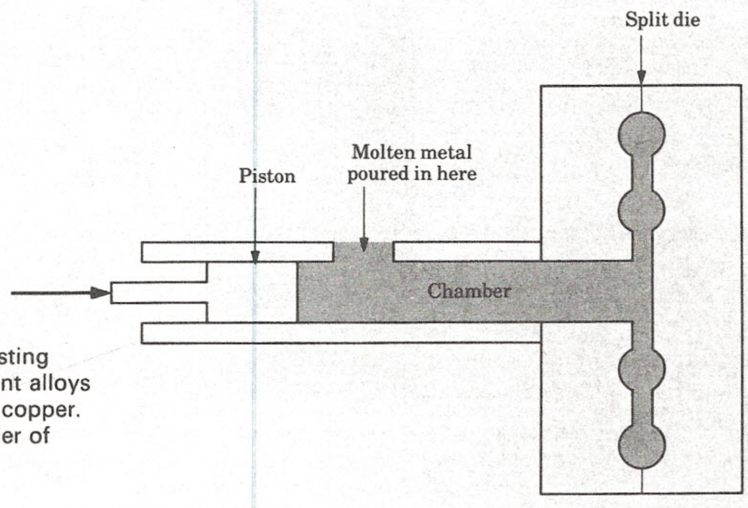


FIGURE 5.24 Cold-chamber die-casting process, used with high-melting-point alloys such as aluminum, magnesium, and copper. The pressures are as much as an order of magnitude higher than those in the hot-chamber process.

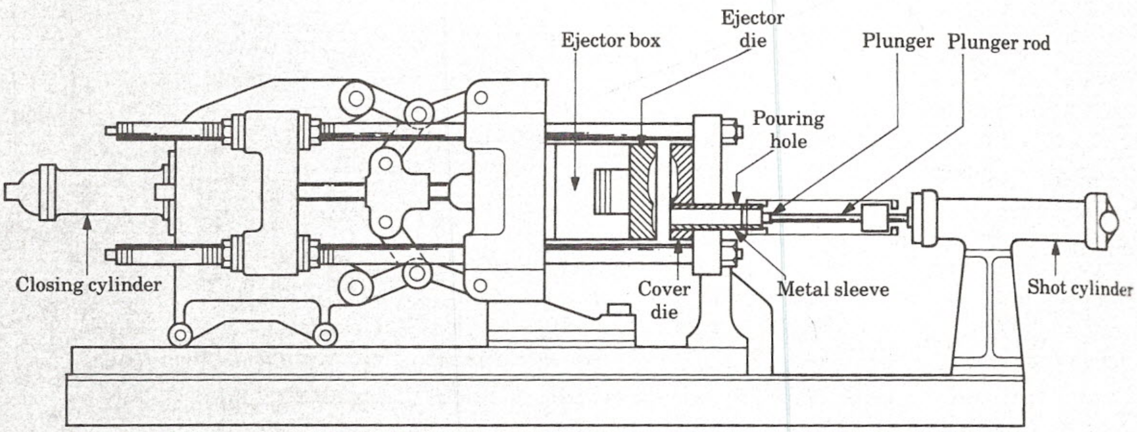


FIGURE 5.25 Schematic illustration of a die-casting machine. These machines are large compared to the size of the casting, because of the high forces required to keep the two halves of the die closed under the pressure of the molten metal in the die cavities.

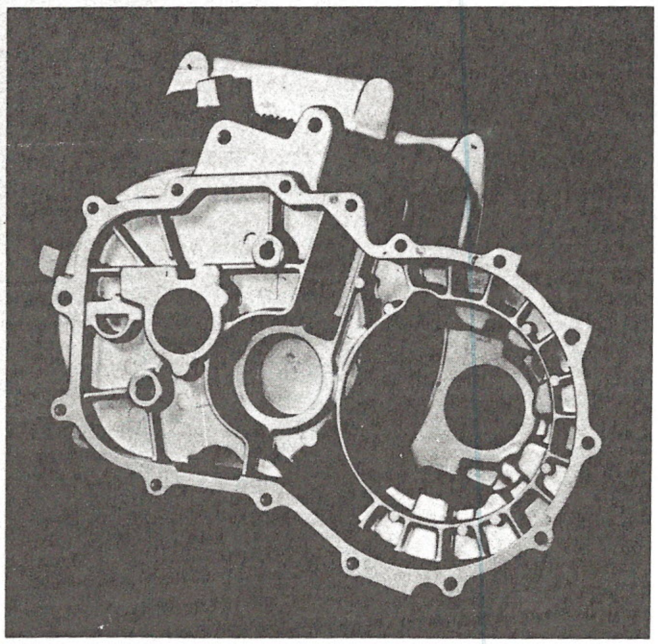


FIGURE 5.26 An example of a housing made by die casting. Note the fine detail and complex shape of the part that has been cast in one piece. *Source:* Courtesy of J. J. Kolar, American Die Casting Institute.

5.8 CENTR

forging cannot be entirely formed by one blow because of the limitations of directions in which the metal can be forced at one time. Therefore the operations are divided into a number of steps and each step changes the form of the part until the final desired shape is obtained. Many products cannot be completely formed on one set of dies, and therefore it may be necessary to use more than one set of dies to secure the final shape.

Steam hammers range in capacity from 500 to 50,000 pounds and are usually of double housing design. 31–4. Most steam hammers today are double acting and considerably more energy can be obtained at the die from a steam hammer than with a board or gravity drop hammer.

Action of Board Drop Hammer

Board drop hammers are still in use. Many, however, are being replaced by air lift, gravity drop hammers or powered hammers.

The force of gravity is employed in the board drop hammer. 31–5. The ram is raised to striking position by means of boards, the lower ends of the boards are wedged into the ram. The upper ends pass between one or two pairs of rolls. With the two rolls, in a pair, rotating in opposite directions, the boards and ram are raised when the rolls move together. As the ram reaches the top, the rolls separate and the boards are released.

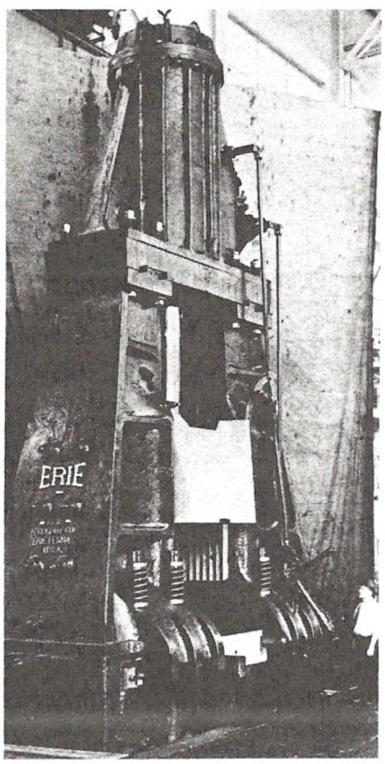
The ram is operated by a treadle, which, when depressed, causes the ram to fall. 31–6. As long as the treadle is held down, the board drop hammer will automatically deliver blows at a uniform rate. The force of the blow can be varied by changing the distance of the fall, by unclamping and moving the dogs on the front rod. The force of the blows is determined entirely by the weight of the ram, or falling weight, which in most commercial forging plants is between 600 and 6,500 pounds.

Piston-Lift Action

The piston-lift hammer uses compressed air or steam to lift the ram, then lets it fall by gravity similar to the board drop hammer. The ram is lifted by a

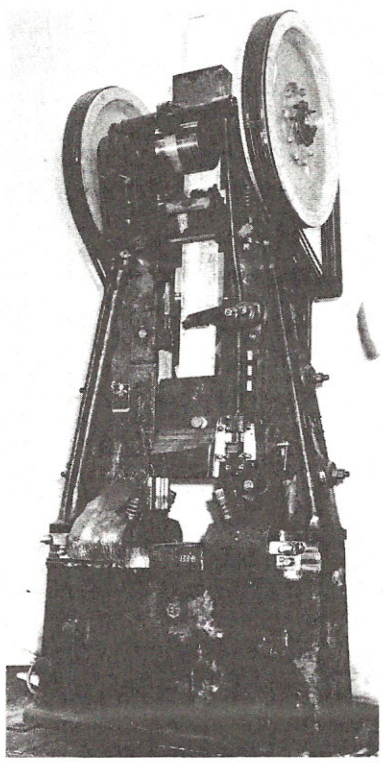
31–4. A 50,000-pound steam drop hammer.

Erie Foundry Co.



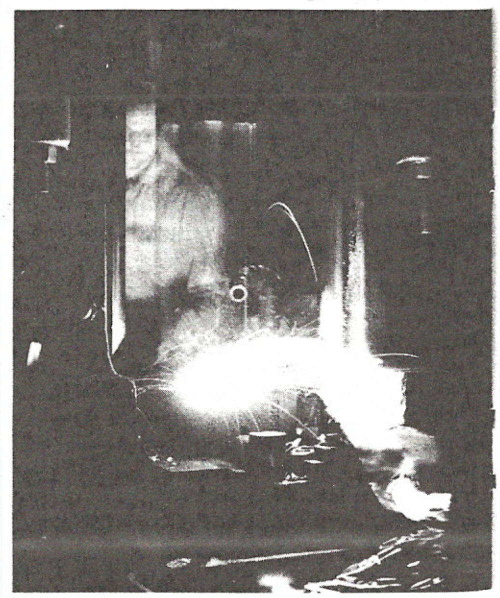
31–5. A 1,500-pound "FV" board drop hammer.

Erie Foundry Co.



31–6. This ram is operated by treadle.

Crescent Niagara Corp.



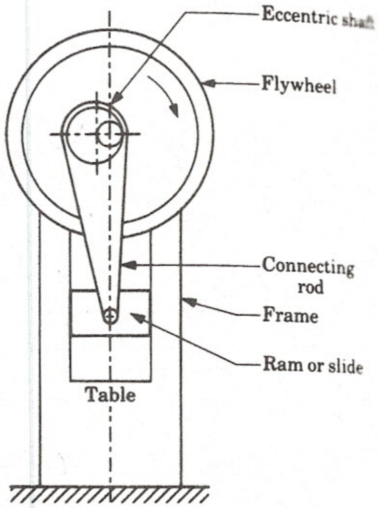


FIGURE 6.39 Schematic illustration of a mechanical press with an eccentric drive. Rotary motion is translated into reciprocating motion. The clutch and brake for this press are located on the eccentric shaft.

Mechanical Presses
Mechanical presses are *stroke limited.* They are basically crank or eccentric types (Fig. 6.39), with speeds varying from a maximum at the center of the stroke to zero at the bottom. The force available depends on the stroke position and becomes extremely high at the bottom dead center. Thus, proper setup is essential to avoid breaking the dies or the equipment. The largest mechanical press has a capacity of 12,000 tons (120 MN).

Screw Presses
Screw presses (Fig. 6.40) derive their energy from a flywheel. The forging load is transmitted through a vertical screw. These presses are *energy limited* and can be used for many forging operations. They are particularly suitable for producing small quantities, for parts requiring precision (such as turbine blades), and for control of ram speed. The largest screw press has a capacity of 16,000 tons (160 MN).

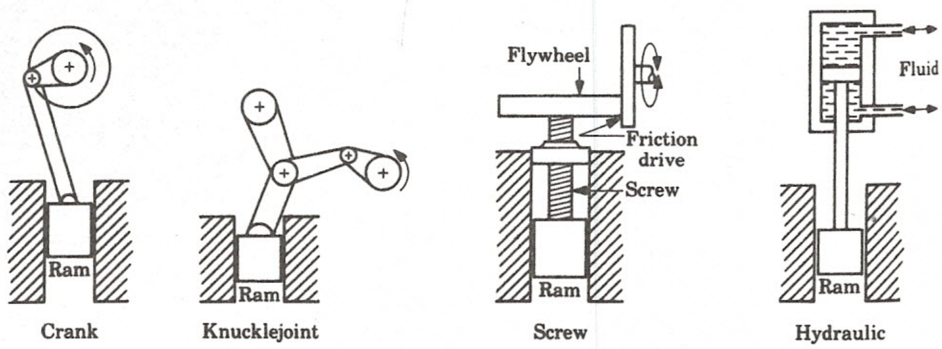
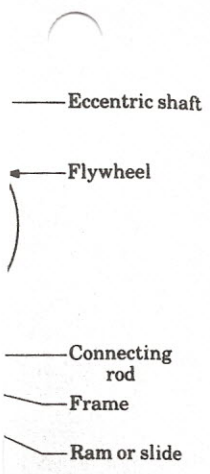
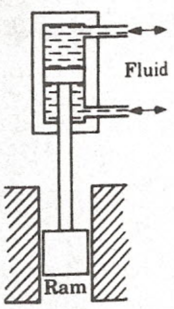


FIGURE 6.40 Schematic illustration of various types of presses used in metalworking. The choice of the press is an important factor in the overall operation.



or eccentric types
of the stroke to
ition and becomes
essential to avoid
has a capacity of

he forging load is
imited and can be
r producing small
and for control of
60 MN).



Hydraulic

d in metalworking.
l.

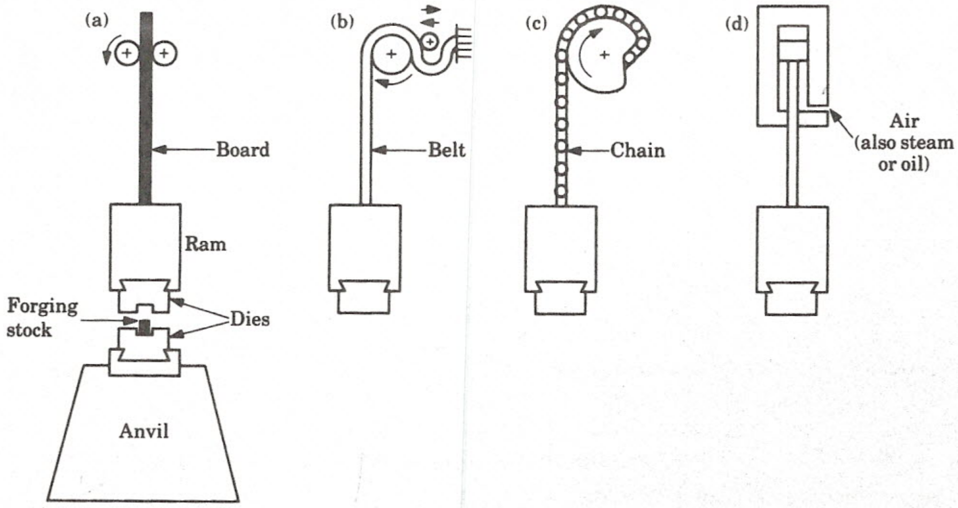


FIGURE 6.41 Schematic illustration of various types of gravity-drop hammers. (a) Board drop. (b) Belt drop. (c) Chain drop. (d) Air drop. *Source:* After T. Altan.

Hammers

Hammers (Fig. 6.41) derive their energy from the potential energy of the ram, which is then converted to kinetic energy; thus they are *energy limited.* The speeds are high; therefore the low forming times minimize the cooling of the hot forging, thus allowing the forging of complex shapes, particularly with thin and deep recesses. To complete the forging, several blows may have to be made on the part. In power hammers (developed in the 1830s) the ram is accelerated in the downstroke by steam or air, in addition to gravity. The highest energy available in hammers is 850,000 ft · lb (1.15 MN · m).

Counterblow Hammers

Counterblow hammers have two rams that simultaneously approach each other to forge the part. They are generally of the mechanical–pneumatic or mechanical–hydraulic type. These machines transmit less vibration to the foundation. The largest counterblow hammer has a capacity of 900,000 ft · lb (1.2 MN · m).

Equipment Selection

The selection of forging equipment depends on such factors as the size and complexity of the forging, the strength of the material and its sensitivity to strain rate, and the degree of deformation required. As a guideline, presses are generally preferred for aluminum, magnesium, beryllium, bronze, and brass. Hammers are preferred for copper, steels, titanium, and refractory alloys. Production rate is also a consideration in equipment selection. The number of strokes per minute ranges from a few for hydraulic presses to as much as 300 for power hammers. (See also Table 6.9.)

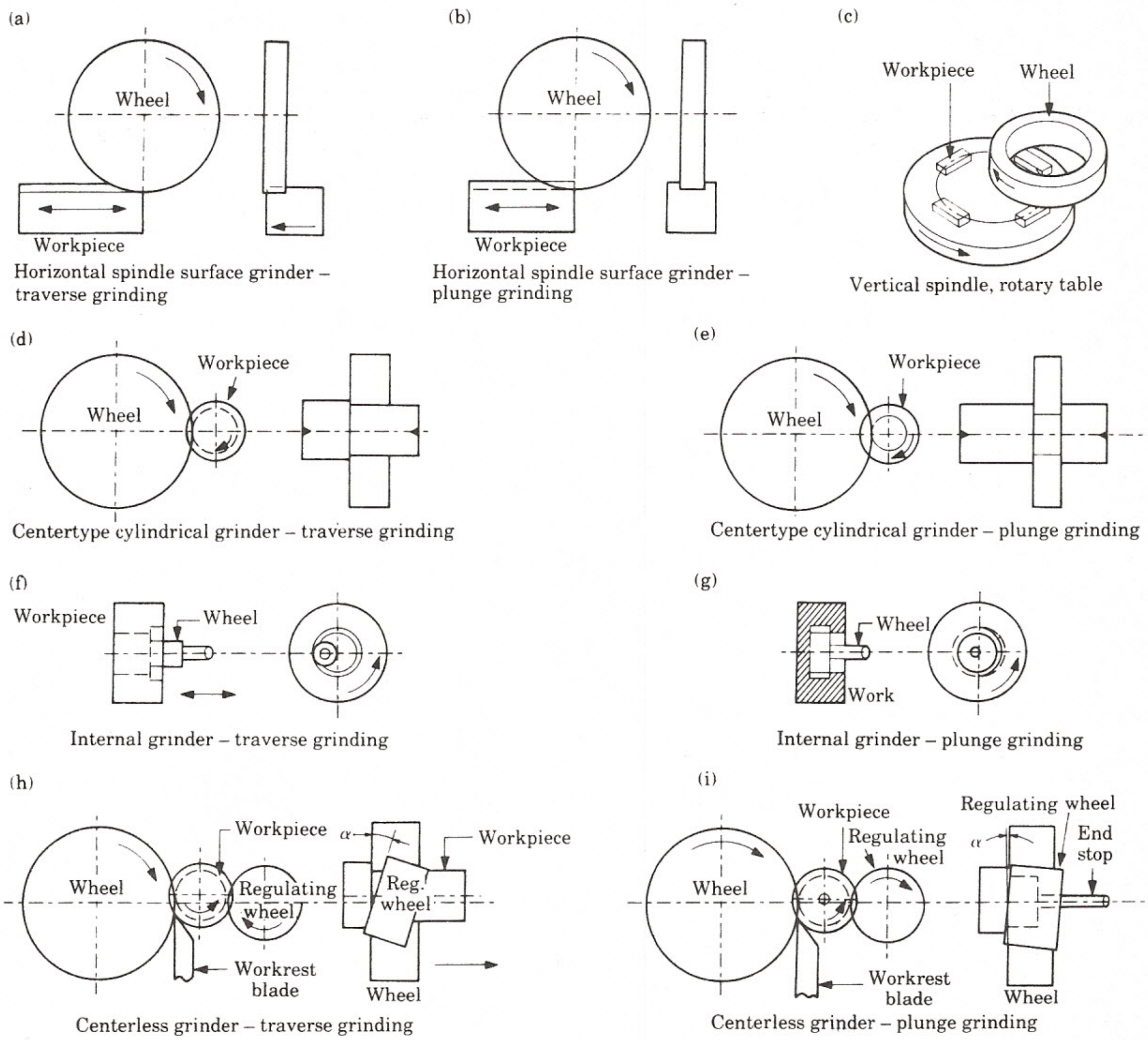
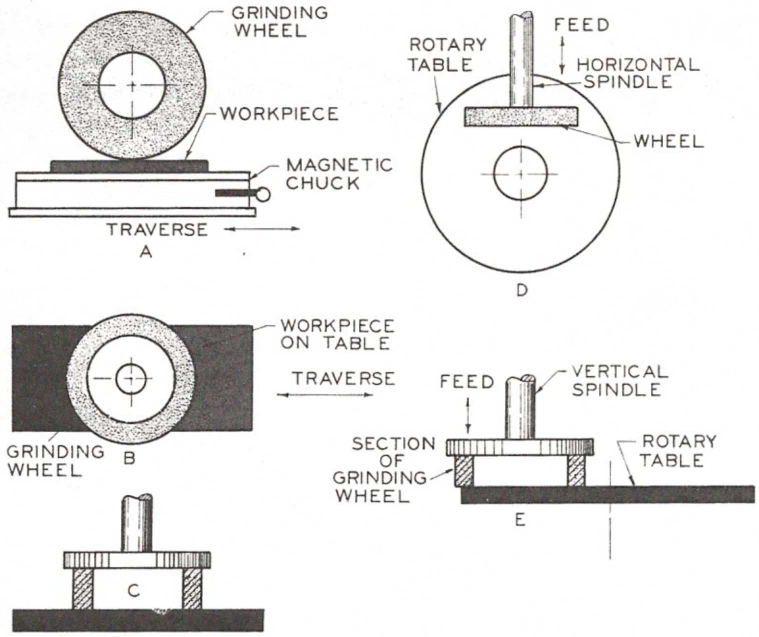


FIGURE 9.11 Schematic illustration of various grinding operations. Grinding is a versatile and important finishing operation, although it can also be used for large-scale removal operations. *Source:* Adapted from *Machinability Data Handbook*, 3d ed., 1980, Metcut Research Associates Inc.

A great variety of grinders is available for different operations. Because of the precision generally required in grinding, special machines have been built with numerous features for automatic loading of the workpieces, clamping, cycling, and wheel dressing.



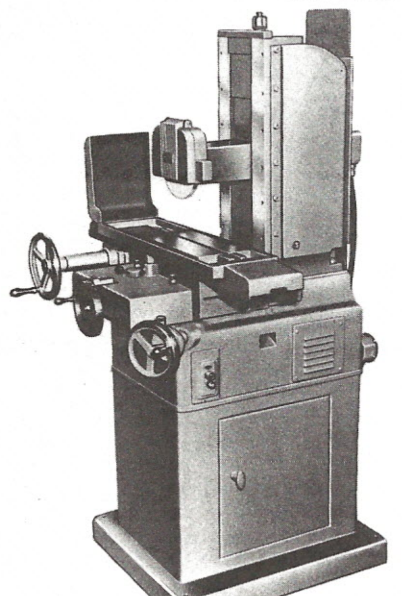
77–2(A). Common types of surface grinding machines: (A) horizontal spindle—reciprocating table, (B) vertical (top view of machine) spindle—reciprocating table (C) bottom view of (B), (D) horizontal spindle—rotating table, and (E) vertical spindle—rotating table.

Grinders are available with either hand feed, power feed, or both. 77–2(B). The power feed for both cross-feed or longitudinal feed may be either a mechanical-type or a hydraulically operated feed mechanism. 77–3. The grinding wheel may be fed in a vertical direction with a hand-wheel generally graduated in 0.0002″ for accurate adjustment. Both the transverse and longitudinal movements can be controlled by limit dogs.

In the majority of surface grinding operations, the workpiece is held on a *magnetic chuck,* which is fast to apply, easy to use, and will hold a large number of small pieces in place for grinding. 77–4. Only magnetic materials can be held by direct contact. However, parts

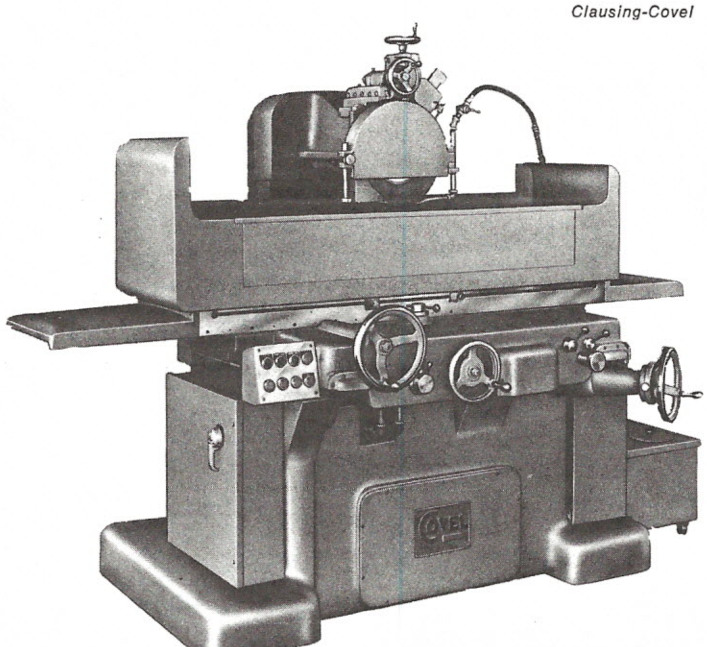
77–2(B). Hand-feed surface grinder.

Clausing-Covel



77–3. Hydraulic type surface grinder.

Clausing-Covel



9.5.1 GRINDING OPERATIONS AND EQUIPMENT

Surface Grinding

Surface grinding is performed with a horizontal-spindle or a vertical-spindle wheel where a number of parts can be ground at the same time. It is one of the most common grinding operations (Fig. 9.13).

The workpiece is secured on a magnetic chuck, which is attached to the work table. A straight wheel (Type 1, Fig. 9.14a) is mounted on a horizontal spindle. Grinding is done with the table reciprocating in the longitudinal direction and feeding laterally after each stroke (cross feed).

The size of a surface grinder is identified by the dimensions of the surface that can be ground on that machine. In addition to the design shown in Fig. 9.13, other designs include grinders with vertical spindles (using cup wheels [Fig. 9.14d]), and rotary tables for grinding a number of pieces in one operation (Fig. 9.11).

Cylindrical Grinding

In this operation (see Fig. 9.11), the external cylindrical surface and the shoulders of a workpiece are ground. Examples include crankshafts, axles, spindles, and rolls for rolling mills. Threads and workpieces with two or more diameters (*plunge grinding*) are also ground on these machines. In cylindrical grinding the workpiece reciprocates along its axis, although for large and long workpieces the grinding wheel reciprocates. The latter design is called a *roll grinder*.

Cylindrical grinders are identified by the maximum diameter and length of the workpiece that can be ground. In universal grinders, both the workpiece and the wheel axis can be swiveled around a horizontal plane, thus permitting the grinding of tapered shafts and similar parts.

Internal Grinding

In this operation a small wheel grinds the inside diameter of the part, such as bearing races or bushings. The workpiece is held inside a rotating chuck in the headstock and the wheel rotates at 30,000 rpm or higher. Internal grinders also have features whereby the headstock can be swiveled on a horizontal plane to grind tapered holes.