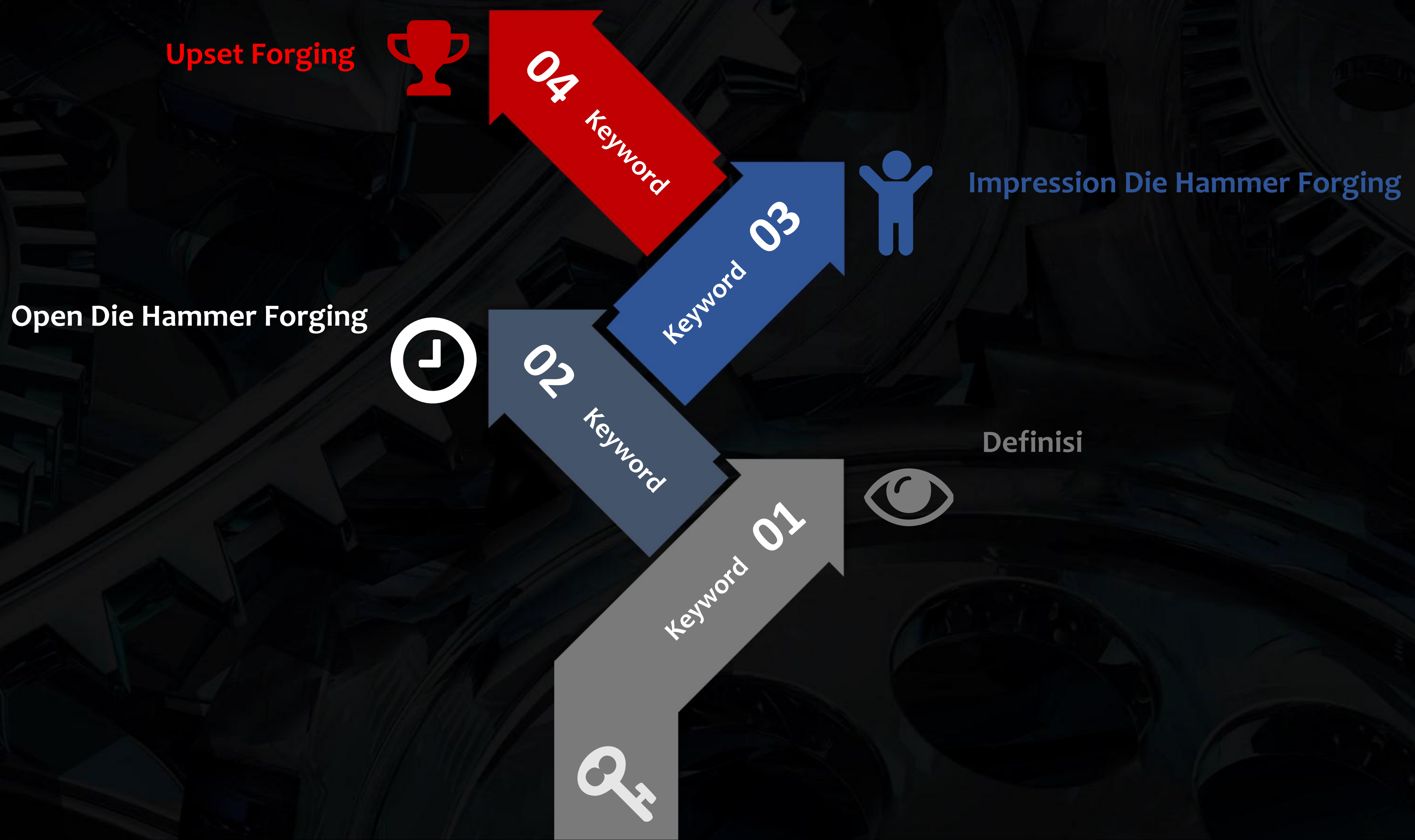
FORGING

KONTEN



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Forging is a term applied to a family of processes that induce plastic deformation through localized compressive forces applied through dies. The equipment can take the form of hammers, presses, or special forging machines. While the deformation can be performed in all temperature regimes (hot, cold, warm, or isothermal), most forging is done with workpieces above the recrystallization temperature.

Forging is clearly the oldest known metalworking process. From the days when prehistoric peoples discovered that they could heat sponge iron and beat it into a useful implement by hammering with a stone, forging has been an effective method of producing many useful shapes. Modern forging is simply an extension of the ancient art practiced by the armor makers and immortalized by the village blacksmith. High-powered hammers and mechanical presses have replaced the strong arm and the hammer, and tool steel dies have replaced the anvil. Metallurgical knowledge has supplemented the art and skill of the craftsman, as we seek to control the heating and handling of the metal. Parts can range in size from ones whose largest dimension is less than 2 cm (1 in.) to others weighing more than 170 metric tons (450,000 lb).

OPEN DIE HAMMER FORGING (1)

In concept, *open-die hammer forging* is the same type of forging done by the blacksmith of old, but massive mechanical equipment is now used to impart the repeated blows. The metal is first heated to the proper temperature using a furnace or electrical induction heating. An impact is then delivered by some type of mechanical hammer. The simplest industrial hammer is a *gravity drop* machine, where a free-falling ram strikes the workpiece, and the energy of the blow is varied by adjusting the height of the drop. Most forging hammers now employ some form of energy augmentation, however, where pressurized air, steam, or hydraulic fluids are used to raise and propel the hammer. Higher striking velocities are achieved, with more control of striking force, easier automation and the ability to shape pieces up to several tons. *Computer-controlled hammers* can provide blows of differing impact speed (energy) for different products or each of the various stages of a given operation. Their use can greatly increase the efficiency of the process and also minimize the amount of noise and vibration, which are the most common outlets for the excess energy not absorbed in the deformation of the workpiece. Figure 16-9 shows a large double-frame hammer along with a labeled schematic.

Open-die forging does not fully control the flow of metal. To obtain the desired shape, the operator must orient and position the workpiece between blows. The hammer may contact the workpiece directly, or specially shaped tools can be inserted to assist in making concave or convex surfaces, forming holes, or performing a cutoff operation. Manipulators may be used to position larger workpieces, which may weigh several tons. While some finished parts can be made by this technique, open-die forging is usually employed to preshape metal in preparation for further operations. For example, consider parts like turbine rotors and generator shafts with dimensions up to 20 m (70 ft) in length and up to 1 m (3 ft) in diameter. Open-die forging induces oriented plastic flow and

OPEN DIE HAMMER FORGING (2)

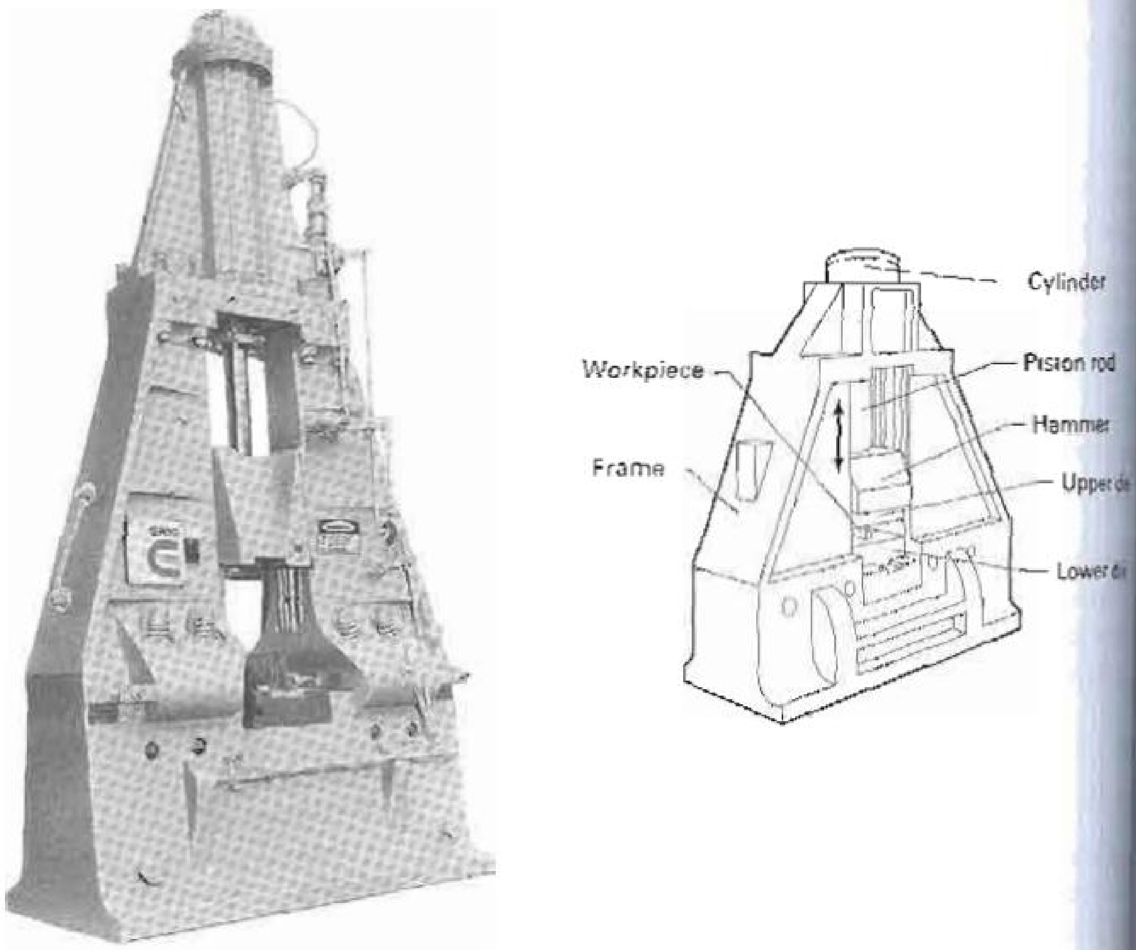

FIGURE 16-9 (Left) Double-frame drop hammer. *(Courtesy of Erie Press Systems, Erie, PA.)* (Right) Schematic diagram of a forging hammer.

OPEN DIE HAMMER FORGING (3)

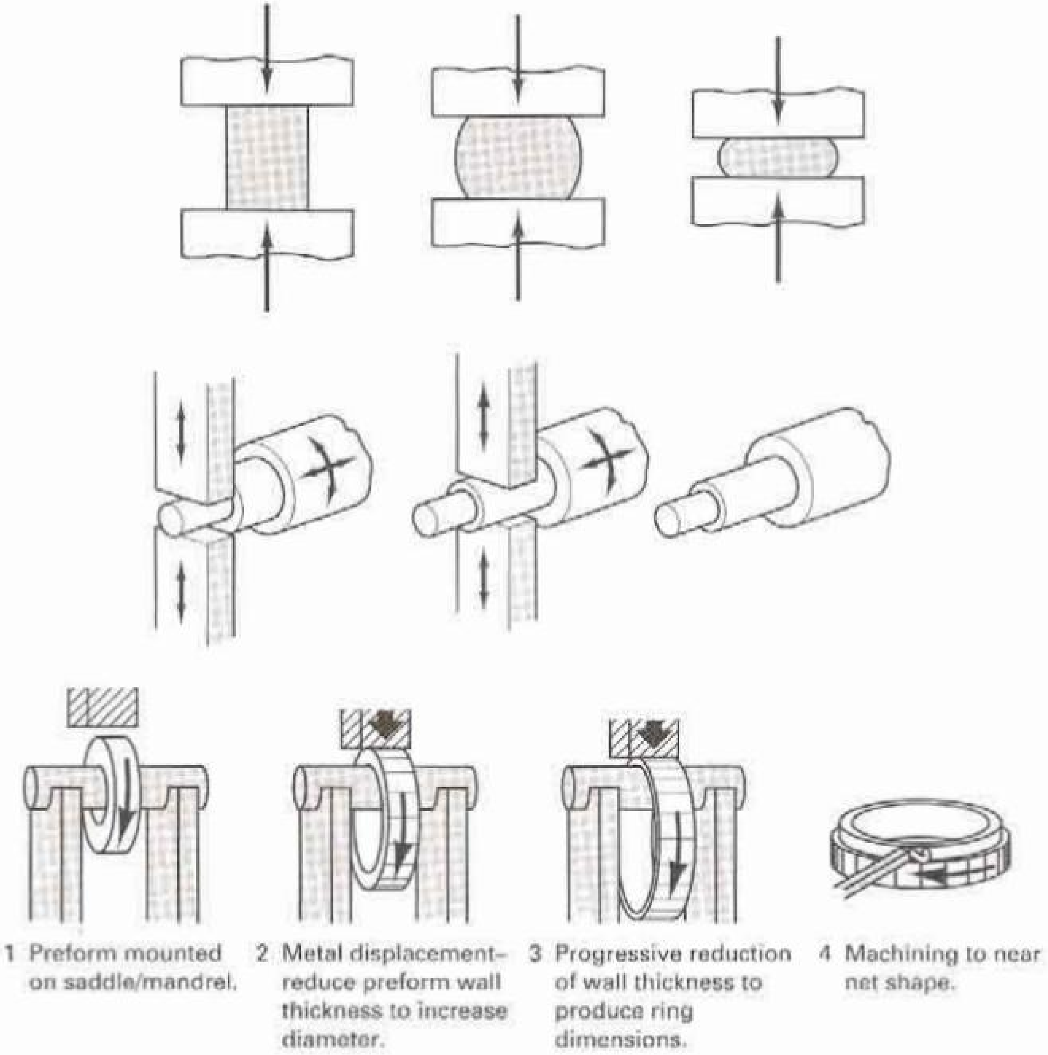

FIGURE 16-10 (Top) Illustration of the unrestrained flow of material in open-die forging. Note the barrel shape that forms due to friction between the die and material. (Middle) Open-die forging of a multidiameter shaft. (Bottom) Forging of a seamless ring by the open-die method. *(Courtesy of Forging Industry Association, Cleveland, OH.)*

Break Time

15 Minutes

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IMPRESSION DIE HAMMER FORGING (1)

Open-die hammer forging (or smith forging, as it has been called) is a simple and flexible process, but it is not practical for large-scale production. It is a slow operation, and the shape and dimensional precision of the resulting workpiece is dependent on the skill of the operator. As shown in Figure 16-11, *impression-die* or *closed-die forging* overcomes these difficulties by using shaped dies to control the flow of metal. Figure 16-12 shows a typical set of multicavity dies. The upper piece attaches to the hammer and the lower piece to the anvil. Heated metal is positioned in the lower cavity and struck one

or more blows by the upper die. The hammering causes the metal to flow and completely fill the die cavity. Excess metal is squeezed out along the parting line to form a *flash* around the periphery of the cavity. This material cools rapidly, increases in strength, and, by resisting deformation, effectively blocks the formation of additional flash. By trapping material within the die, the flash then ensures the filling of all of the cavity details. The flash is ultimately trimmed from the part in a final forging operation.

In *flashless forging*, also known as true closed-die forging, the metal is deformed in a cavity that provides total confinement. Accurate workpiece sizing is required since complete filling of the cavity must be ensured with no excess material. Accurate workpiece positioning is also necessary, along with good die design and control of lubrication. The major advantage of this approach is the elimination of the scrap generated during flash formation, an amount that is often between 20 and 45% of the starting material.

Most conventional forgings are impression-die with flash and are produced in dies with a series of cavities, where one or more blows of the hammer are used for each step in the sequence. The first impression is often an *edging*, *fullering*, or *bending* impression to distribute the metal roughly in accordance with the requirements of the later cavities. Edging gathers material into a region, while fullering moves material away. Intermediate impressions are for *blocking* the metal to approximately its final shape, with generous corner and fillet radii. For small production lots, the cost of further cavities may not be justified, and the blocker-type forgings are simply finished by machining. More often, the final shape and size are imparted by an additional forging operation in a *final* or *finisher impression*, after which the flash is trimmed from the part. Figure 16-12 shows an example of these steps and the shape of the part at the conclusion of each. Since every part is shaped in the same die cavities, each mass-produced part is a close duplicate of all the others.

IMPRESSION DIE HAMMER FORGING (2)

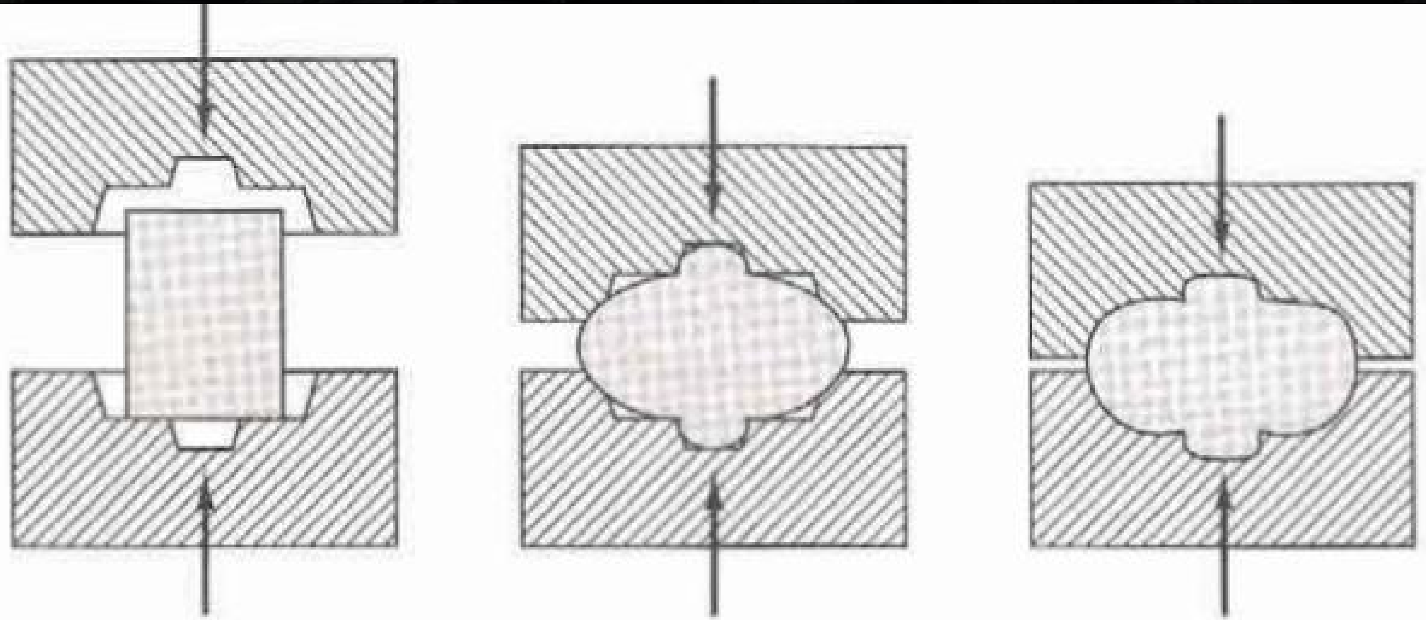

FIGURE 16-11 Schematic of the impression-die forging process, showing partial die filling and the beginning of flash formation in the center sketch and the final shape with flash in the right-hand sketch.

IMPRESSION DIE HAMMER FORGING (3)

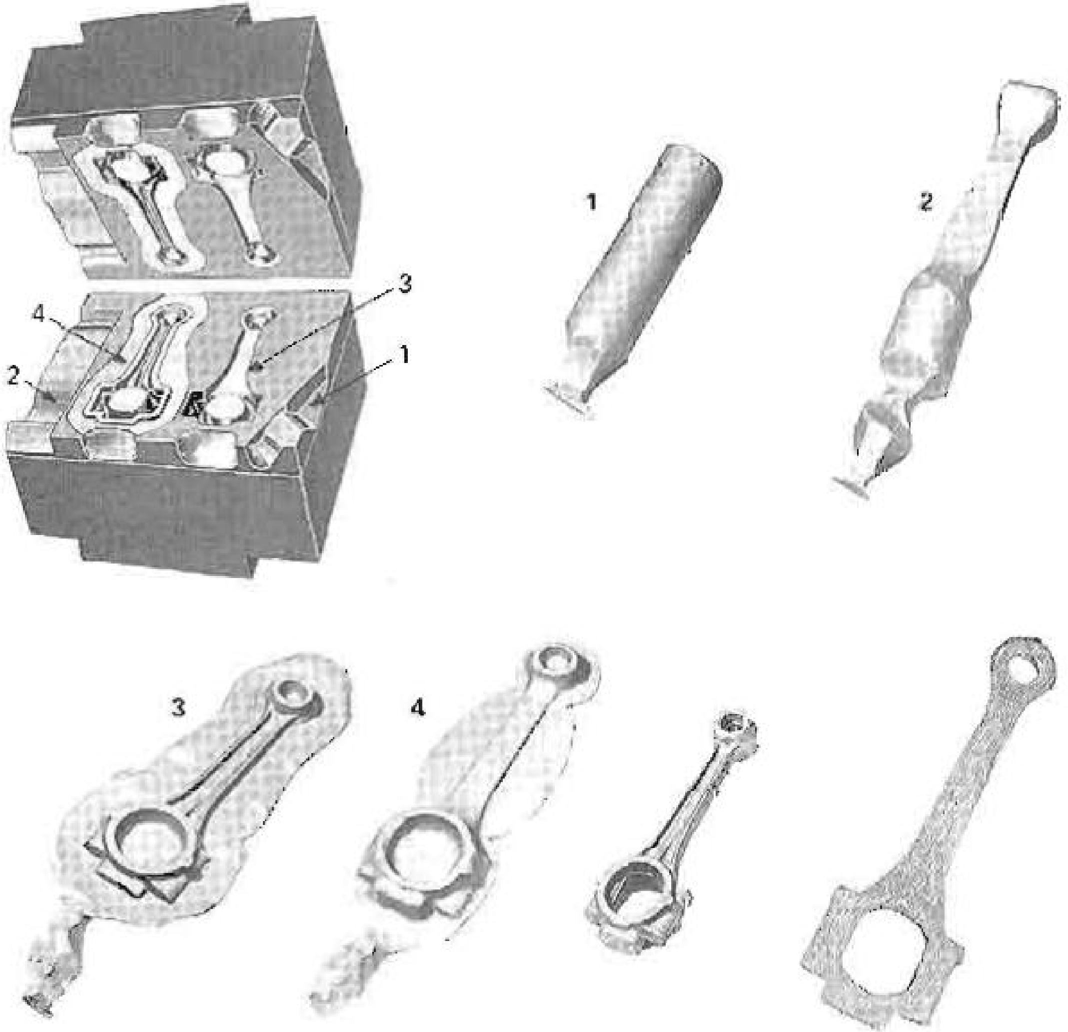

FIGURE 16-12 Impression drop-forging dies and the product resulting from each impression. The flash is trimmed from the finished connecting rod in a separate trimming die. The sectional view shows the grain flow resulting from the forging process *(Courtesy of Forging Industry Association, Cleveland, OH)*

UPSET FORGING (1)

Upset forging involves increasing the diameter of a material by compressing its length. Because of its use with a myriad of fasteners, it is the most widely used of all forging processes when evaluated in terms of the number of pieces produced. Parts can be upset forged both hot and cold, with the operation generally being performed on special high-speed machines. The forging motion is usually horizontal, and the workpiece is rapidly moved from station to station. While most operations start with wire or rod, some machines can upset bars up to 25 cm (10 in.) in diameter.

Upset forging generally employs split dies that contain multiple positions or cavities, as seen in the typical die set of Figure 16-16. The dies separate enough for the bar to advance between them and move into position. They are then clamped together and a heading tool or ram moves longitudinally against the bar, upsetting it into the cavity. Separation of the dies then permits transfer to the next position or removal of the product. If a new piece is started with each die separation and an operation is performed in each cavity simultaneously, a finished product can be made with each cycle of the machine. By including a shearing operation as the initial piece moves into position, the process can operate with continuous coil or long-length rod as its incoming feedstock.

Upset-forging machines are often used to form heads on bolts and other fasteners as well as to shape valves, couplings, and many other small components. The upset region can be on the end or central portion of the workpiece, and the final diameter may be up to three times the original. The following three rules, illustrated in Figure 16-17, should be followed when designing parts that are to be upset forged:

1. The length of unsupported metal that can be gathered or upset in one blow without injurious buckling should be limited to three times the diameter of the bar.
2. Lengths of stock greater than three times the diameter may be upset successfully provided that the diameter of the upset is not more than 1 times the diameter of the bar.
3. In an upset requiring stock length greater than three times the diameter of the bar and where the diameter of the cavity is not more than 1 times the diameter of the bar (the conditions of rule 2), the length of unsupported metal beyond the face of the die must not exceed the diameter of the bar.

TUPSET FORGING (2)

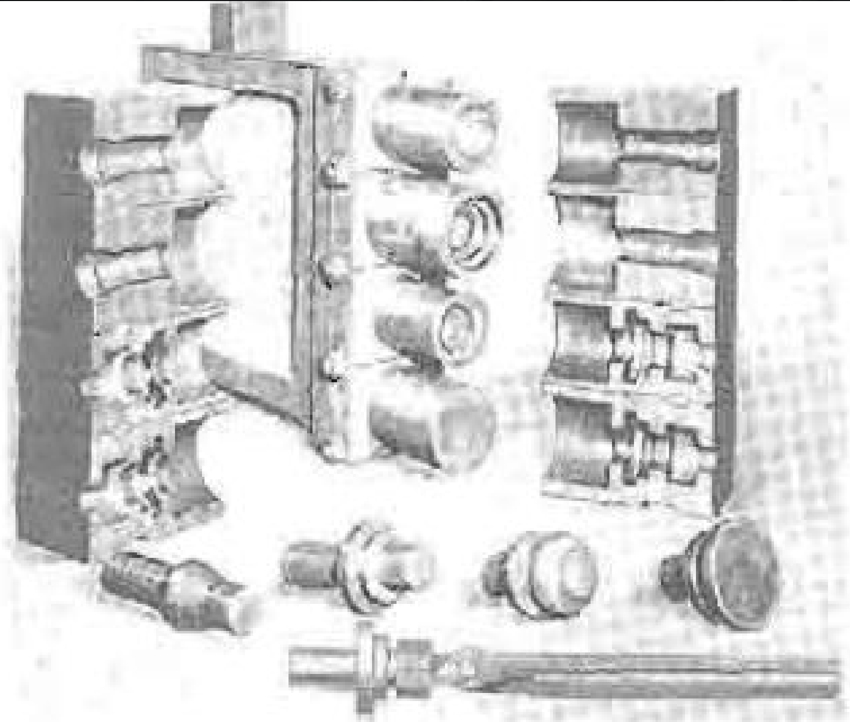

FIGURE 16-16 Set of upset-forging dies and punches. The product resulting from each of the four positions is shown along the bottom. *(Courtesy of Ajax Manufacturing Company Euclid, OH.)*

TUPSET FORGING (3)

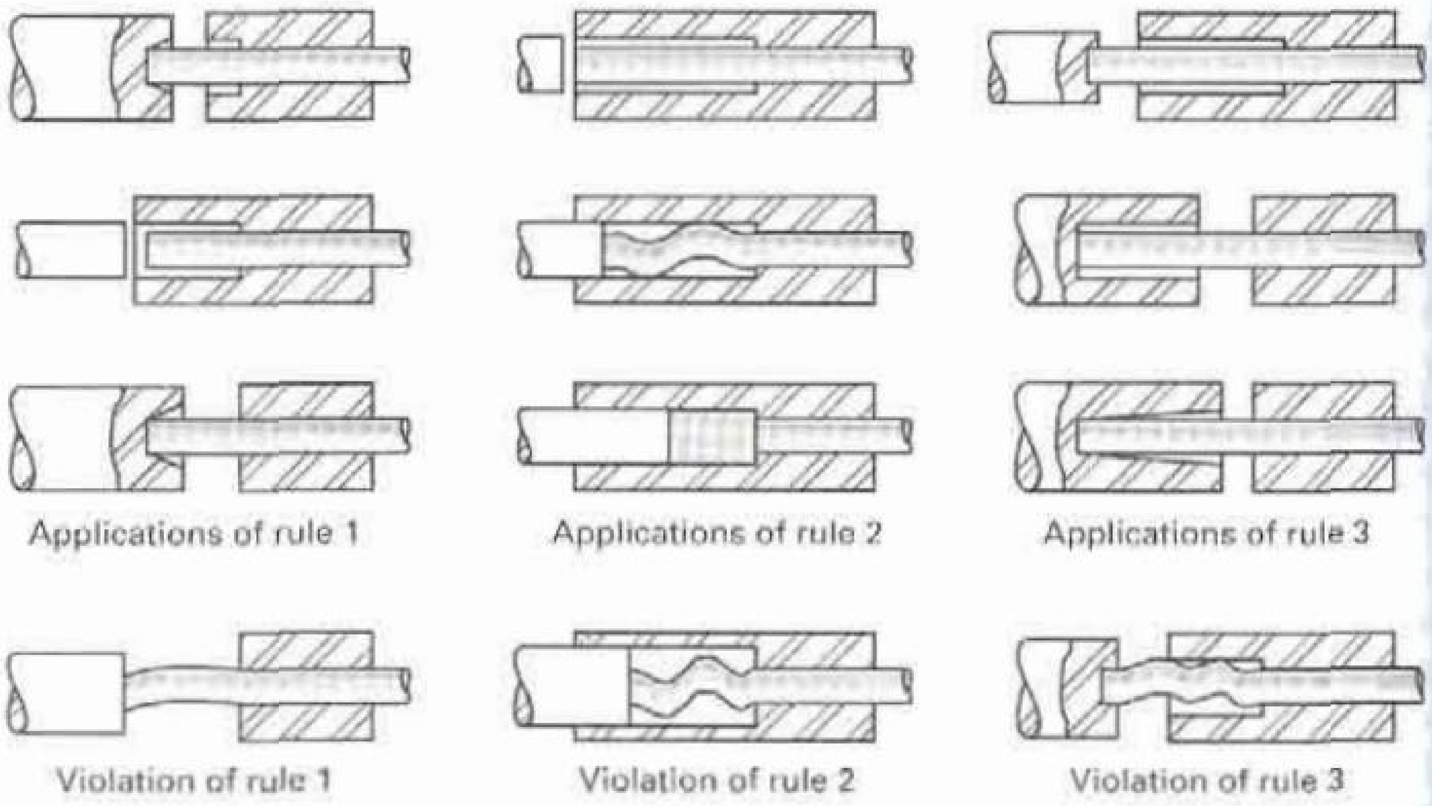

FIGURE 16-17 Schematics illustrating the rules governing upset forging. *(Courtesy of National Machinery Company, Tiffin, OH.)*

TERIMA KASIH

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