

METAL FORMING PROCESS

Overview of Metal Forming

Metal forming can be classified as

- **Bulk deformation processes** – generally characterized by significant deformations and massive shape changes; and the surface area-to-volume of to work is relatively small.
 - Forging
 - Extrusion
 - Rolling
 - Wire and bar drawing
- **Sheet metal forming process**
 - Bending operations
 - Deep or cup drawing
 - Shearing processes
 - Miscellaneous

Bulk Deformation Processes

- Forging
- Extrusion
- Rolling
- Wire and bar drawing

Forging

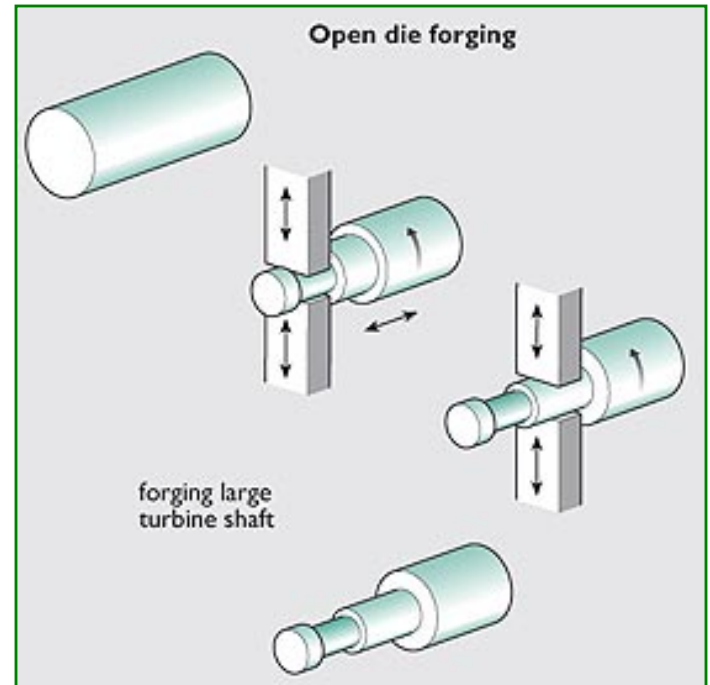
Forging is a deformation process in which the work is compressed between two dies, using either impact or gradual pressure to form the part. Today, forging is an important industrial process used to make a variety of high-strength components for automotive, aerospace, and other applications. These components include engine crankshafts and connecting rods, gears, aircraft structural components, and jet engine turbine parts. In addition, steel and other basic metals industries use forging to establish the basic forms of large components that are subsequently machined to final shape and dimensions.

Forging is carried out in many different ways. One way to classify forging is by working temperature. Most forging operations are performed hot or warm, owing to the significant deformation demanded by the process and the need to reduce strength and increase ductility of the work metal. However, cold forging is also very common for certain products. The advantage of cold forging is the increased strength that results from strain hardening of the component.

Either impact or gradual pressure is used in forging. The distinction derives more from the type of equipment used than differences in process technology. A forging machine that applies an impact load is called a forging hammer, while one that applies gradual pressure is called a forging press. Another difference among forging operations is the degree to which the flow of the work metal is constrained by the dies. By this classification there are **three types of forging operations like (i) Open-die forging, (ii) Impression or Close die forging and (iii) Flashless Forging.**

Open-Die Forging

- Most forging processes begin with open die forging. Open die forging is hot mechanical forming between flat or shaped dies in which the metal flow is not completely restricted. The stock is laid on a flat anvil while the flat face of the forging hammer is struck against the stock. The equipment may range from the anvil and hammer to giant hydraulic presses.
- Open-die hot forging is an important industrial process. Shapes generated by open-die operations are simple; examples include shafts, disks, and rings. In some applications, the work must often be manipulated (for example, rotating in steps) to effect the desired shape change. Open-die forging process is shown in the following Figure.



Open-Die Forging

- The skill of the human operator is a factor in the success of these operations. An example of open-die forging in the steel industry is the shaping of a large, square cast ingot into a round cross section. Open-die forging operations produce rough forms, and subsequent operations are required to refine the parts to final geometry and dimensions.
- An important contribution of open-die hot forging is that it creates favorable grain low and metallurgical structure in the metal. Operations classified as open-die forging or related operations include **fullering, edging, and cogging**, as shown in the next diagrams.

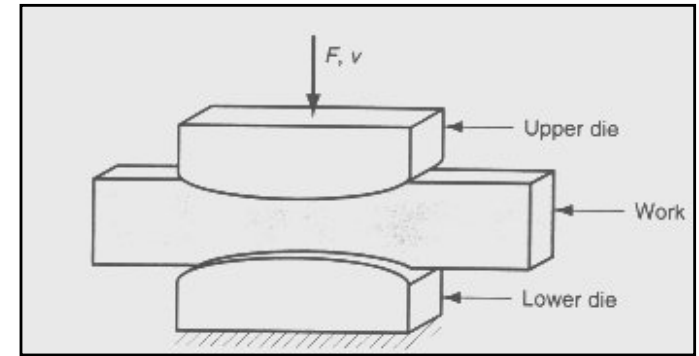
Open-Die Forging

Fullering is a forging operation performed to reduce the cross section and redistribute the metal in a workpart in preparation for subsequent shape forging.

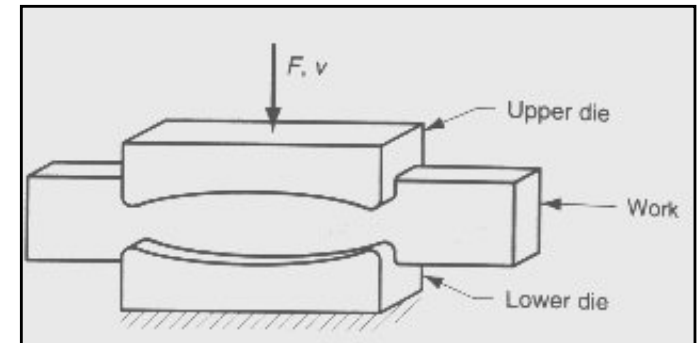
It is accomplished by dies with convex surfaces. Fullering die cavities are often used designed into multicavity impression dies so that the starting bar can be rough formed before final shaping.

Edging is similar to fullering, except that the dies have concave surfaces.

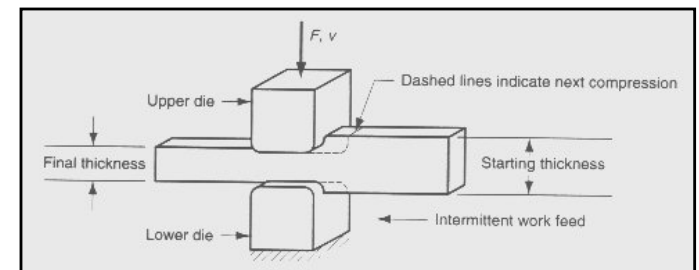
A **cogging** operation consists of a sequence of forging compressions along the length of a workpiece to reduce cross section and increase length. It is used in the steel industry to produce blooms and slabs from cast ingots. It is accomplished using open dies with flat or slightly contoured surfaces. The term *incremental forging* is sometimes used for this process.



Fullering



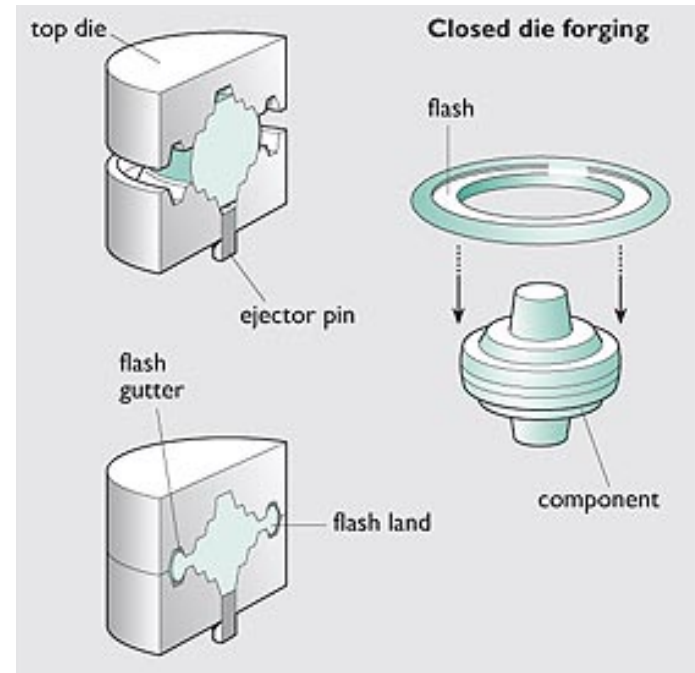
Edging



Cogging

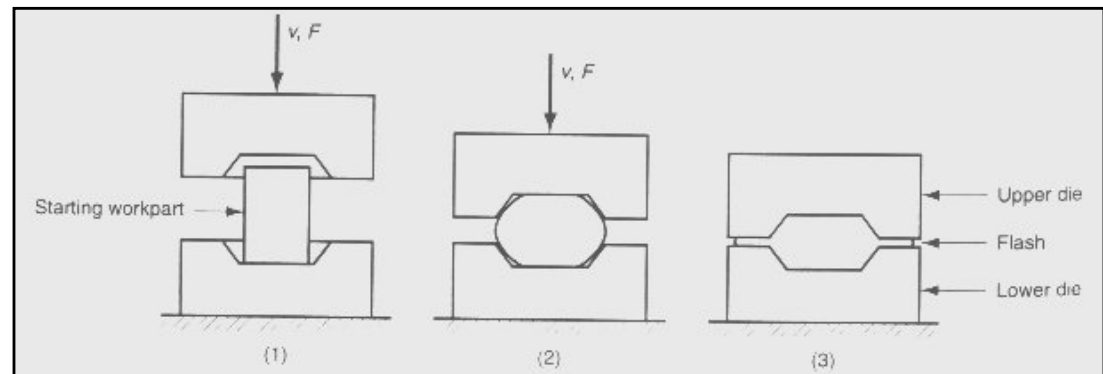
Impression or Close Die Forging

In *impression-die forging*, sometimes called **closed die forging**, the die surfaces contain a shape or impression that is imparted to the work during compression, thus constraining metal flow to a significant degree as shown in following Figure. **In this type of operation, a portion of the work metal flows beyond the die impression to form flash and must be trimmed off later.** The process is shown in the following Figure as a three step sequence. The raw workpiece is shown as a cylindrical part similar to that used in the previous open-die operation.



Impression die forging

Sequence in impression die forging:
(1) just prior to initial contact with **raw workpiece** (2) **partial compression** and (3) **final die closure, causing flash to form in gap between die plates**

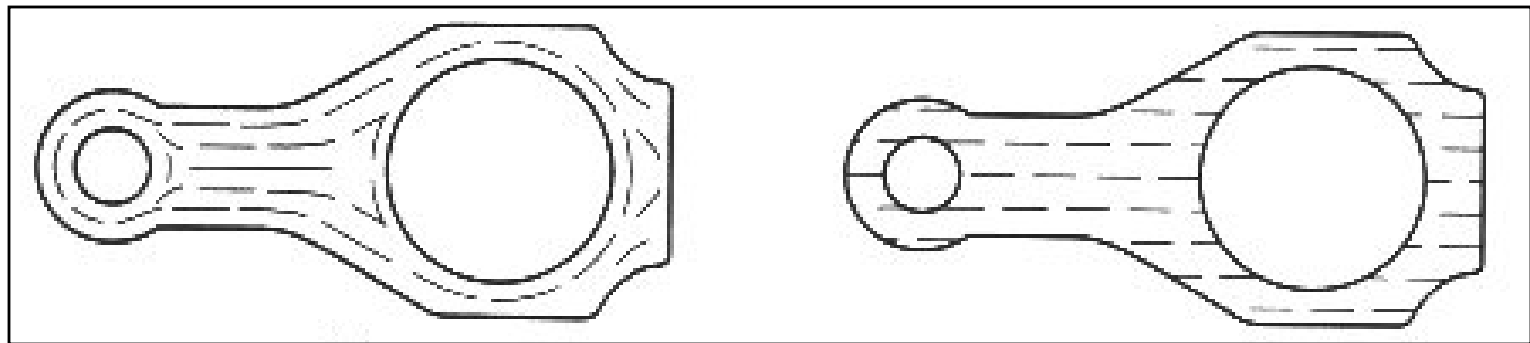


Impression or Close Die Forging

- As the die closes to its final position, flash is formed by metal that flows beyond the cavity and into the small gap between the die plates. Although this flash must be cut away from the part in a subsequent trimming operation, it actually serves an important function in impression-die forging.
- As the flash begins to form in the die gap, friction resists continued flow of metal into the gap, thus constraining the bulk of the work material to remain in the die cavity. In hot forging, metal flow is further restricted because the thin flash cools quickly against the die plates, thereby increasing its resistance to deformation.
- Restricting metal flow in the gap causes the compression pressures on the part to increase significantly, thus forcing the material to fill the sometimes intricate details of the die cavity to ensure a high-quality product.
- Several forming steps are often required in impression die forging to transform the starting blank into the desired final geometry. Separate cavities in the die are needed for each step.
- The beginning steps are designed to redistribute the metal in the workpart to achieve a uniform deformation and desired metallurgical structure in the subsequent steps. The final steps bring the part to its final geometry. In addition, when drop forging is used, several blows of the hammer may be required for each step.

Impression or Close Die Forging

- When impression-die drop forging is done manually, as it often is, **considerable operator skill is required under adverse conditions to achieve consistent results.**
- Impression-die forging is not capable of close tolerance work and **machining is often required to achieve the accuracy needed.**
- The basic geometry of the part is obtained from the forging process, with machining performed on those portions of the part that require finishing (for example, holes, threads, and surfaces that mate with other components). The advantages of forging, compared to machining the part completely, are higher production rates, conservation of metal, greater strength, and favorable grain orientation of the metal results from forging.
- A comparison of the grain flow in forging and machining is shown in the following **Figure**.



(a) Forging

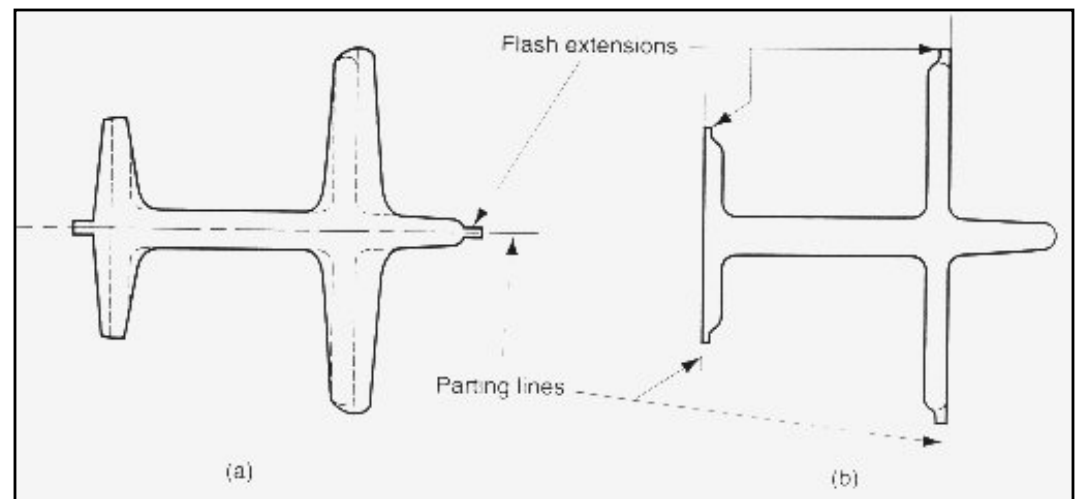
(b) Machining

Grain orientation in forging

Impression or Close Die Forging

- Improvements in the technology of impression-die forging have resulted in the capability to produce forgings with thinner sections, more complex geometries, and drastic reductions in draft requirements on the dies, closer tolerances, and the virtual elimination of machining allowances.
- Forging processes with these features are known as *precision forging*.
- Common work metals used for precision forging include aluminum, and titanium. A comparison of precision forging and conventional forging is shown next.
- Note that precision forging in this example does not eliminate flash, although it reduces it. Some precision forging operations are accomplished without producing flash.
- Depending on whether or not machining is required to finish the part geometry, precision forgings are properly classified as *near net shape* or *net shape* processes.

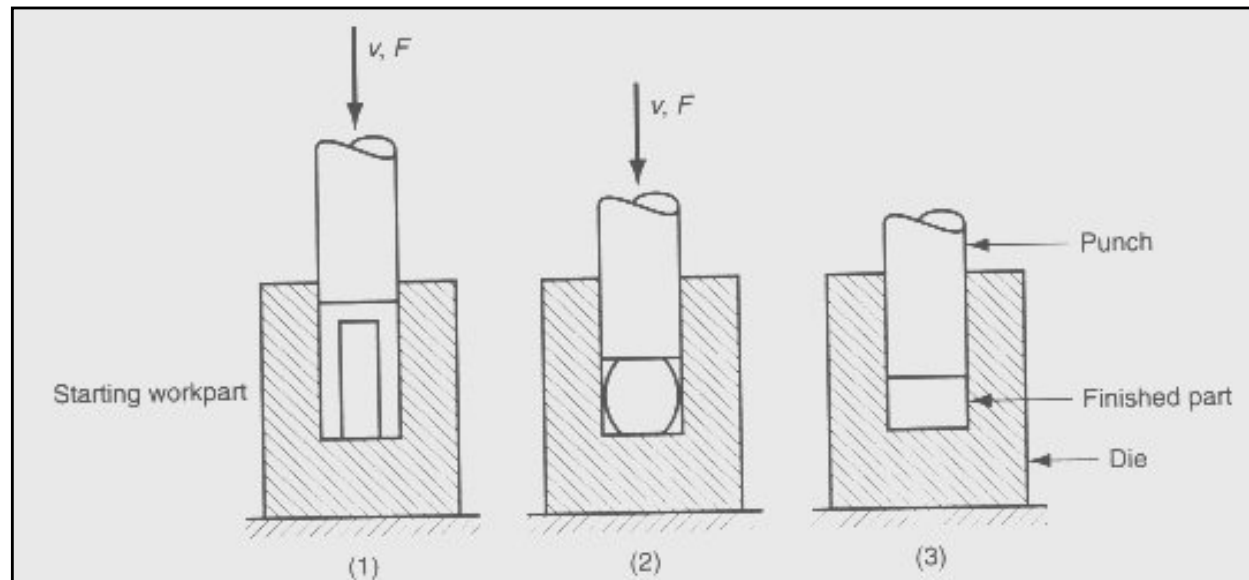
Cross section of (a) conventional and (b) precision forgings. Dashed line in (a) indicates subsequent machining required to make the conventional forging equivalent in geometry to the precision forging. In both cases flash extensions must be trimmed.



Flashless Forging

Flashless forging is sometimes called **closed-die forging in industry terminology**. However, there is a technical distinction between impression-die forging and true closed-die forging. The distinction is that in closed-die forging the raw workpiece is completely contained within the die cavity during compression, and no flash is formed. This process is shown in the following **figure**. Flashless forging imposes requirements on process control that are more demanding than impression-die forging. Most important is that the work volume must equal the space in the die cavity within a very close tolerance. If the starting blank is too large, excessive pressures may cause damage to the die or even the press. If the blank is too small, the cavity will not be filled. Because of the special demands made on flashless forging, the process lends itself best to part geometries that are usually simple and symmetrical and to work materials such as aluminum and magnesium and their alloys. Flashless forging is often classified **as a precision forging process**.

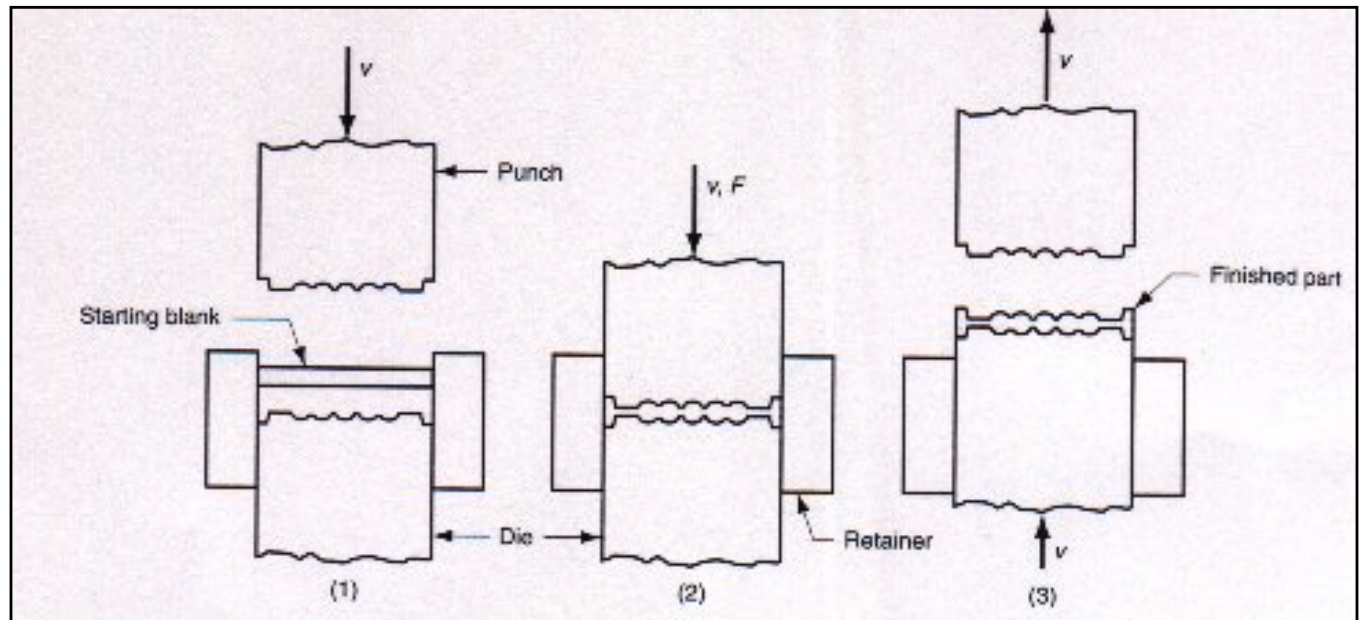
Flashless forging: (1) just before initial contact with work piece (2) partial compression and (3) final punch and die closure. v =velocity & F =applied force



Flashless Forging

- **Coining** is a special application of flashless forging in which fine details in the die are impressed into the top and bottom surfaces of the workpart.
- There is **little flow of metal in coining**; yet the pressures required to reproduce the surface details in the die cavity are high.
- A common application of coining, of course, is in the minting of coins as shown on the next slide.
- The **process is also used to provide good surface finish and dimensional accuracy on various workparts made** by other operations.

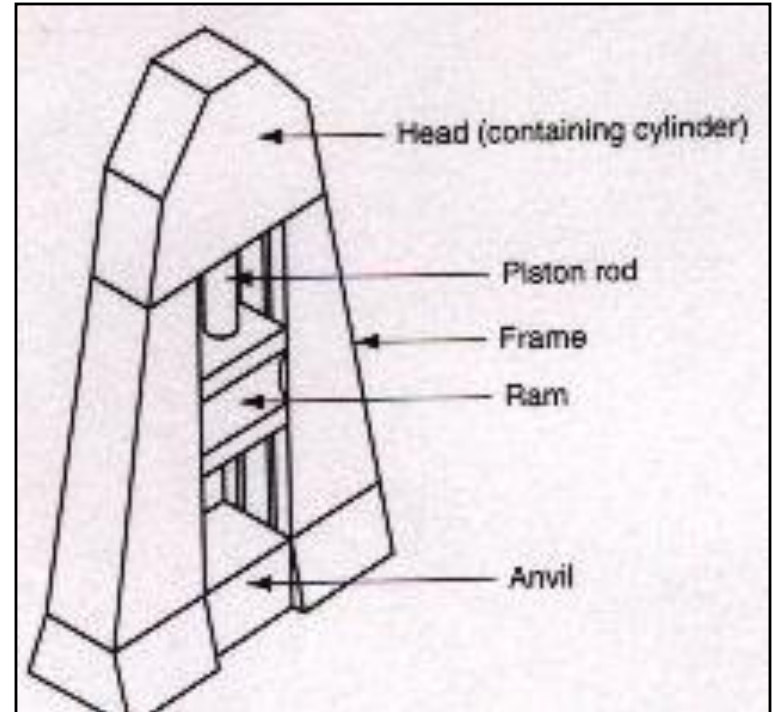
Coining operation: (1) start of cycle (2) compression stroke and (3) ejection of finished part



Forging Hammers, Presses & Dies

Equipment used in forging consists of forging machines, classified as hammers and presses, and forging dies, which are the special tooling used in these machines. In addition, auxiliary equipment is needed, such as furnaces to heat the work, mechanical devices to load and unload the work, and trimming stations to cut away the flash in impression-die forging.

Forging Hammers: Forging hammers operate by applying an impact load against the work. The term drop hammer is often used for these machines, owing to the means of delivering impact energy. Drop hammers are most frequently used for impression-die forging. The upper portion of the forging die is attached to the ram, and the lower portion to the anvil. In the operation, the work is placed on the lower die, and the ram is lifted and then dropped. When the upper die strikes the work, the impact energy causes the part to assume the form of the die cavity. Several blows of the hammer are often required to achieve the desired change in shape.



Drop hammer for impression die forging

Forging Hammers, Presses & Dies

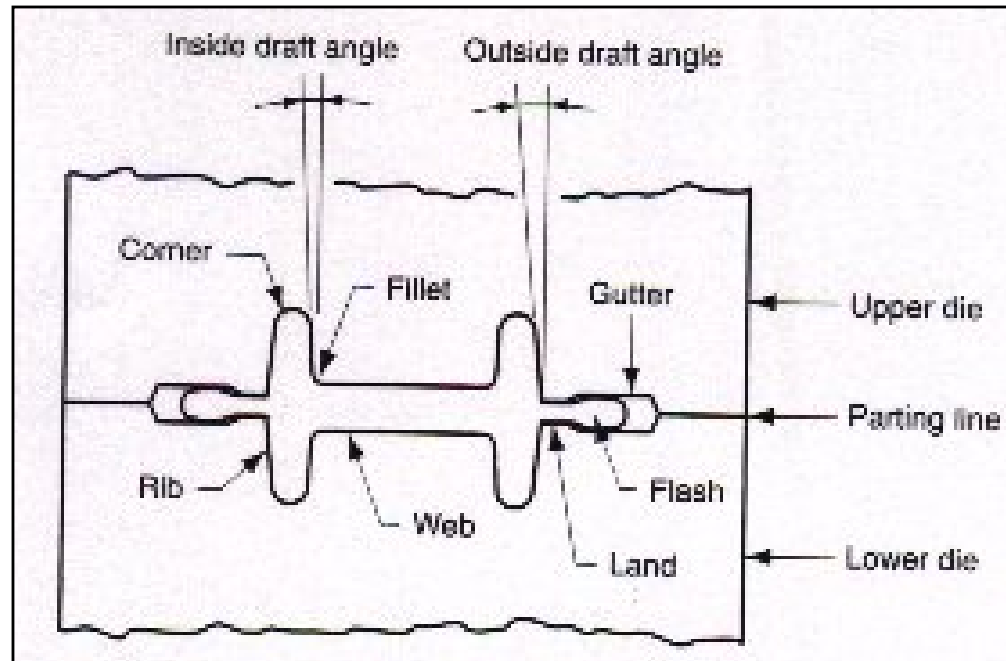
Drop hammers can be classified as **gravity drop hammers** and **power drop hammers**. **Gravity drop hammers** achieve their energy by the falling weight of a heavy ram. The force of the blow is determined by the height of the drop and the weight of the ram.

Power drop hammers accelerate the ram by pressurized air or steam. One disadvantage of the drop hammers is that a large amount of the impact energy is transmitted through the anvil and into the floor of the building. This results in a great deal of vibration for the surrounding area.

Forging Presses: Presses apply gradual pressure, rather than sudden impact, to accomplish the forging operation. Forging presses include **mechanical presses**, **hydraulic presses**, and **screw presses**. **Mechanical presses** typically operate by means of eccentrics, cranks, or knuckle joints, which convert the rotating motion of a drive motor into the translational motion of the ram. These mechanisms are very similar to those used in stamping presses. Mechanical presses typically achieve very high forces at the bottom of the forging stroke. **Hydraulic presses** use a hydraulically driven piston to actuate the ram. **Screw presses** apply force by a screw mechanism that drives the vertical ram. Both screw drive and hydraulic drive operate at relatively low ram speeds and can provide a constant force throughout the stroke. These machines are therefore suitable for forging (and other forming) operations that require a long stroke.

Forging Hammers, Presses & Dies

Forging Dies: Proper die design is important in the success of a forging operation. Parts to be forged must be designed based on knowledge of the principles and limitations of this process. The purpose of the next slides is to describe some of the terminology and guidelines used in the design of forgings and forging dies. Design of open dies is generally straightforward since the dies are relatively simple in shape. The following details apply to impression dies and closed dies. The following Figure shows some of the terminology in an impression die.



Terminology for a conventional impression die forging

Forging Hammers, Presses & Dies

Parting line: The parting line is the plane that divides the upper die from the lower die. Called the flash line in impression-die forging, it is the plane where the two die halves meet. Its selection by the designer affects grain flow in the part, required load, and flash formation.

Draft: Draft is the amount of taper on the sides of the part required to remove it from the die. The term also applies to the taper on the sides of the die cavity. Typical draft angles are 30 on aluminum and magnesium parts and 50 to 70 on steel parts. Draft angles on precision forgings are near zero.

Webs and ribs: A web is a thin portion of the forging that is parallel to the parting line, while a rib is a thin portion that is perpendicular to the parting line. These part features cause difficulty in metal flow as they become thinner.

Fillet and corner radii: Fillet and corner radii are shown in the diagram. Small radii tend to limit metal flow and increase stresses on the die surfaces during forging.

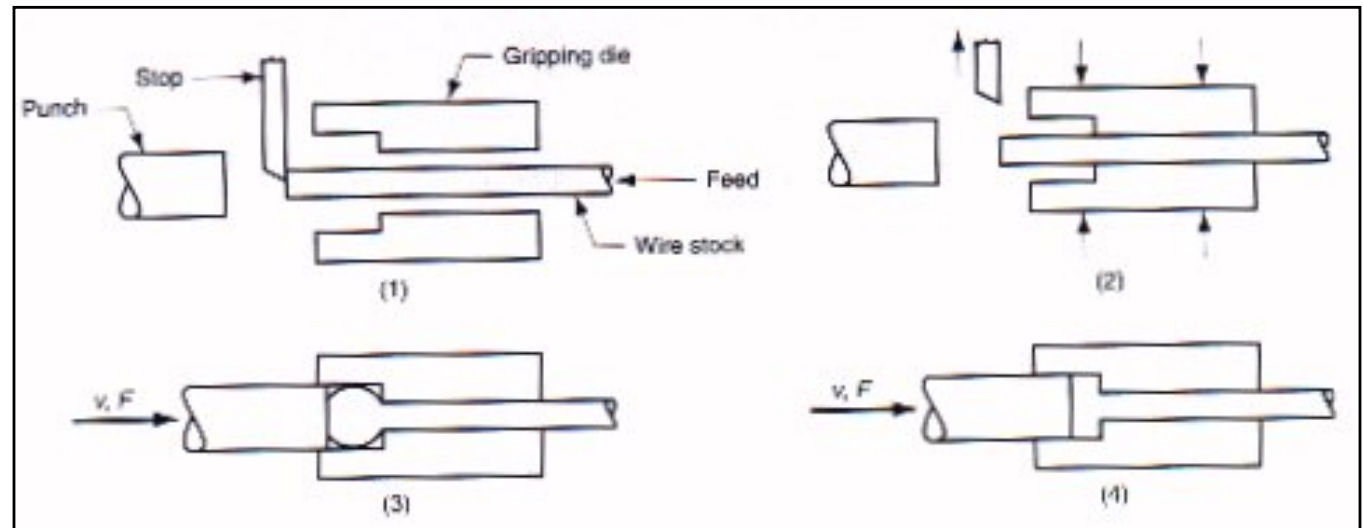
Flash: Flash formation plays a critical role in impression-die forging by causing pressure buildup inside the die to promote filling of the cavity. This pressure buildup is controlled by designing a flash land and gutter into the die as shown. The land determines the surface area along which lateral flow of metal occurs, thereby controlling the pressure increase inside the die. The gutter permits excess material to escape without causing the forging load to reach extreme values

Other Forging & Related Operations

In addition to the conventional forging operations previously outlined, other metal forming operations are closely associated with forging.

Upsetting and Heading: Upsetting (also called *upset forging*) is a deformation operation in which a cylindrical workpart is increased in diameter and reduced in length. However, as an industrial operation, it can also be performed as closed-die forging, as shown in the previous slide. Upsetting is widely used in the fastener industry to form the heads of nails, bolts, and similar hardware products. In these applications, the term *heading* is often used to denote the operation.

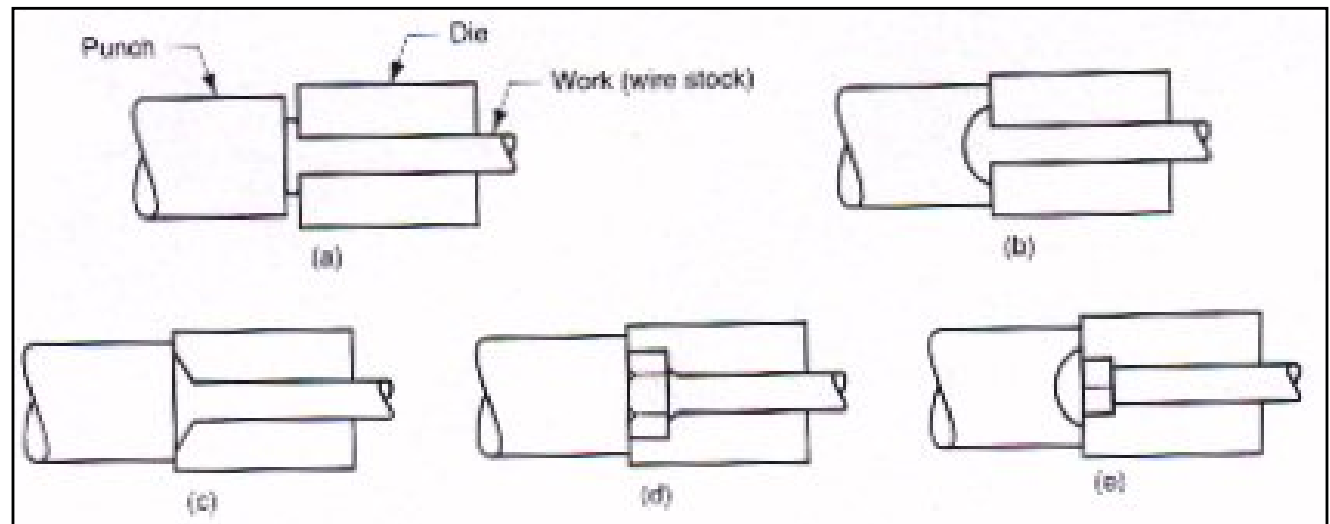
An upset forging operation to form a head on a bolt: (1) wire stock is fed to the stop (2) gripping dies close on the stock and the stop is retracted (3) punch moves forward and (4) bottoms to form the head



Other Forging & Related Operations

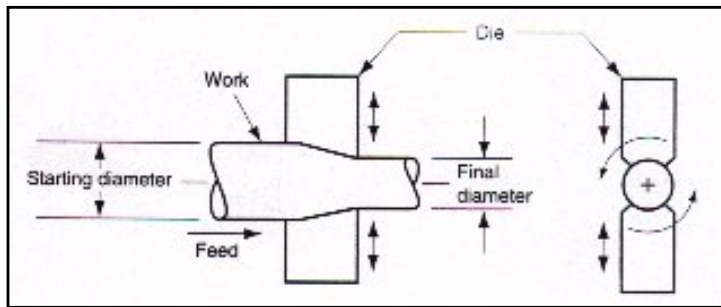
The following Figure illustrates a variety of heading applications, indicating various possible die configurations. Owing to these types of applications, more parts are produced by upsetting than any other forging operation. It is performed as a mass production operation - **cold, warm, or hot** - on special upset forging machines, called **headers or formers**. These machines are usually equipped with horizontal slides as in conventional forging hammers and presses. Long wire or bar stock is fed into the machines, the end of the stock is upset forged, and then the piece is cut to length to make the desired hardware item. For bolts and screws, thread rolling is used to form the threads. There are limitations on the amount of deformation that can be achieved in upsetting, usually defined as the maximum length of the stock to be forged. The maximum length that can be upset in one blow is three times the diameter of the starting stock. Otherwise, the metal bends or buckles instead of compressing properly to fill the cavity.

Heading operation: (a) heading a nail using a open die (b) round head formed by punch (c) and (d) heads formed by die and (e) carriage bolt head formed by punch and die

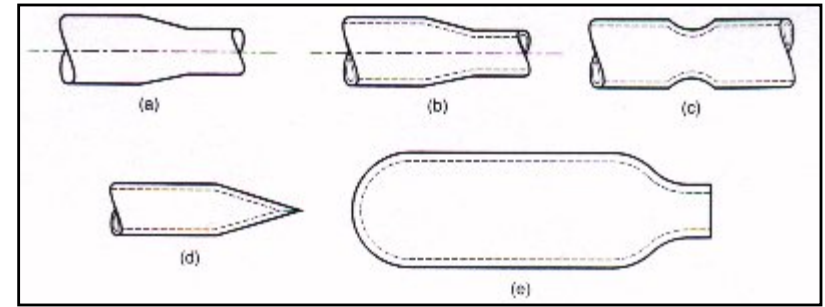


Other Forging & Related Operations

Swaging and Radial Forging: Swaging and radial forging are forging processes used to reduce the diameter of a tube or solid rod. Swaging is often performed on the end of a workpiece to create a tapered section. The swaging process shown is accomplished by means of rotating dies that hammer a workpiece radially inward to taper it as the workpiece is fed into the dies.



Swaging process to reduce solid rod stock; the dies rotate as they hammer the work. In the radial forging, the workpiece rotates while the dies remain in a fixed orientation as they hammer the work.

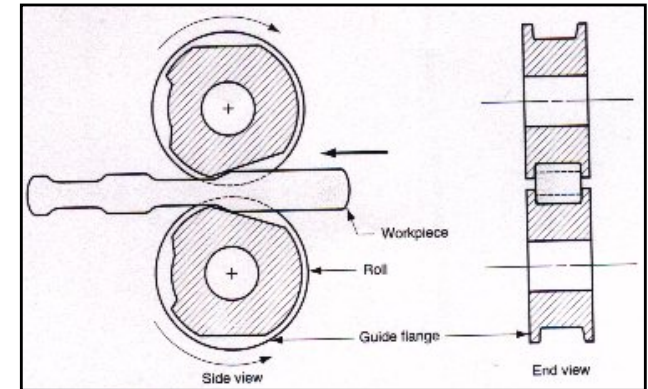


Examples of parts made by swaging: (a) reduction of the solid stock (b) tapering a tube (c) swaging to form a groove on a tube (d) pointing of a tube and (e) swaging of neck on a gas cylinder

The above Figure shows some examples of the **shapes and products** that are made by **swaging**. A mandrel is sometimes required to control the shape and size of the internal diameter of tubular parts that are swaged. Radial forging is similar to swaging in its action against the work and is used to create similar shapes. The difference is that in radial forging the dies do not rotate around the workpiece; instead, the work is rotated as it feeds into the hammering dies.

Other Forging & Related Operations

Roll Forging: Roll forging is a deformation process used to reduce the cross section of a cylindrical (or rectangular) workpiece by passing it through a set of opposing rolls that have grooves matching the desired shape of the part. The typical operation is shown in the following Figure.



Roll forging

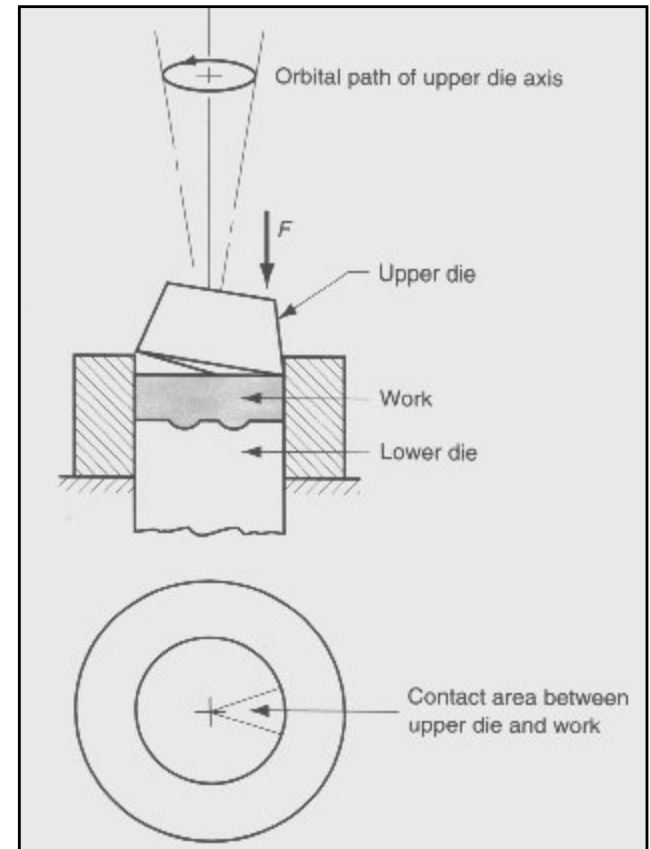
Roll forging is generally classified as a forging process, even though it utilizes rolls. The rolls do not turn continuously in roll forging, but rotate through only a portion of one revolution corresponding to the desired deformation to be accomplished on the part. Roll-forged parts are generally stronger and possess favorable grain structure compared to competing processes, such as machining, that might be used to produce the same part geometry.

Isothermal and Hot-die Forging: *Isothermal forging* is a term applied to a hot forging operation in which the workpart is maintained at or near its starting elevated temperature during deformation, usually by heating the forging dies to the same elevated temperature. By avoiding chill of the workpiece on contact with the cold die surfaces as in conventional forging, the metal flows more readily and the force required to perform the process is reduced.

Other Forging & Related Operations

Isothermal forging is more expensive than conventional forging and is usually reserved for difficult-to-forge metals, such as titanium and superalloys, and for complex part shapes. The process is sometimes carried out in a vacuum to avoid rapid oxidation of the die material. Similar to isothermal forging is hot-die forging, in which the dies are heated to a temperature that is somewhat below that of the work metal.

Orbital Forging: In this process, deformation occurs by means of a cone shaped upper die that is simultaneously rolled and pressed into the workpart. As shown in the next slide, the work is supported on a lower die, which has a cavity into which the work is compressed. Because the axis of the cone is inclined, only a small area of the work surface is compressed at any moment. As the upper die revolves, the area under compression also revolves. These operating characteristics of orbital forging result in a substantial reduction in the press load required to accomplish deformation of the work.

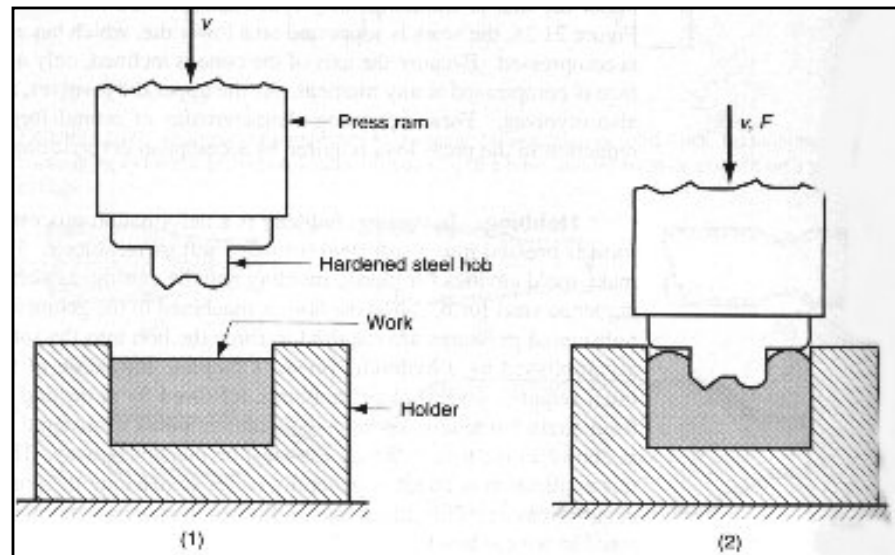


Orbital forging

Other Forging & Related Operations

Hobbing: In forging, hobbing is a deformation process in which a hardened steel form is pressed into a soft steel (or other soft metal) block. The process is often used to make mold cavities for plastic molding and die casting, as shown on the next slide. The hardened steel form called the *hob*, is machined to the geometry of the part to be molded. Substantial pressures are required to force the hob into the soft block, and this is usually accomplished by a hydraulic press. Complete deformation of the die cavity in the block often requires several steps: hobbing, followed by annealing to recover the work metal from strain hardening. When significant amounts of material are deformed in the block, as previously shown, the excess must be machined away. The advantage of hobbing in this application is that it is generally easier to machine the positive form than the mating negative cavity. This advantage multiplies in cases where more than one cavity are to be made in the die block.

Hobbing: (1) before deformation (2) as the process is completed

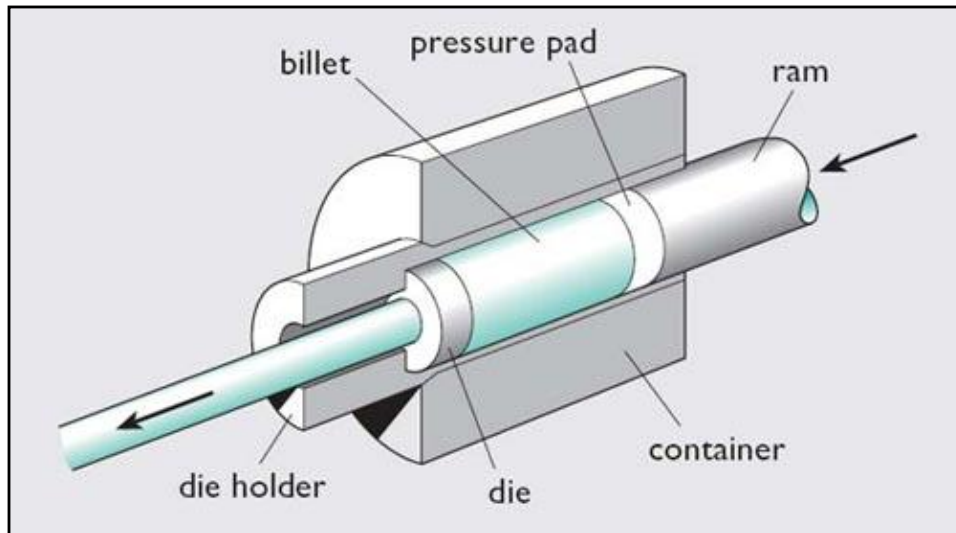


Extrusion of Metals

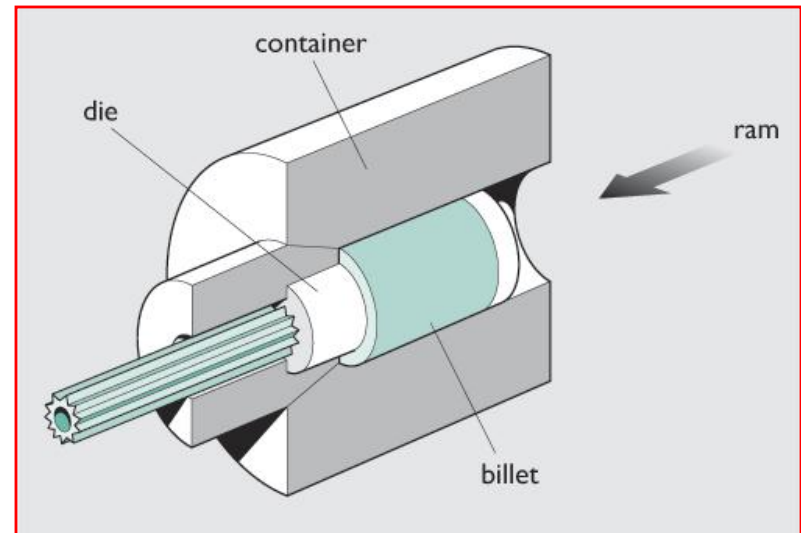
Extrusion

Extrusion is the process of forcing a material through a **DIE** to produce a very long **WORKPIECE** of constant shape and cross section. Extrusion can be done “cold” (at room temperature) or “hot” so that the material is softened slightly. The metal is subjected to plastic deformation and it undergoes reduction and elongation during extrusion. The section of the product will depend upon the shape of the die opening.

Extrusion process could well be considered as **adaptation of closed die forging**, the difference being that in a forging, the main body of the metal is the product and flash is cut away and discarded; in extrusion, the flash (metal flowing out of the die) is the product and the slug remaining in the die is not used.



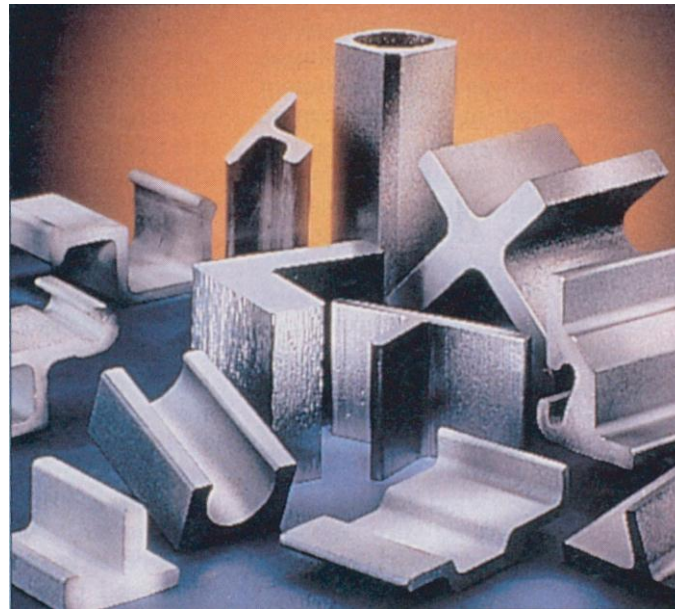
Metal extrusion



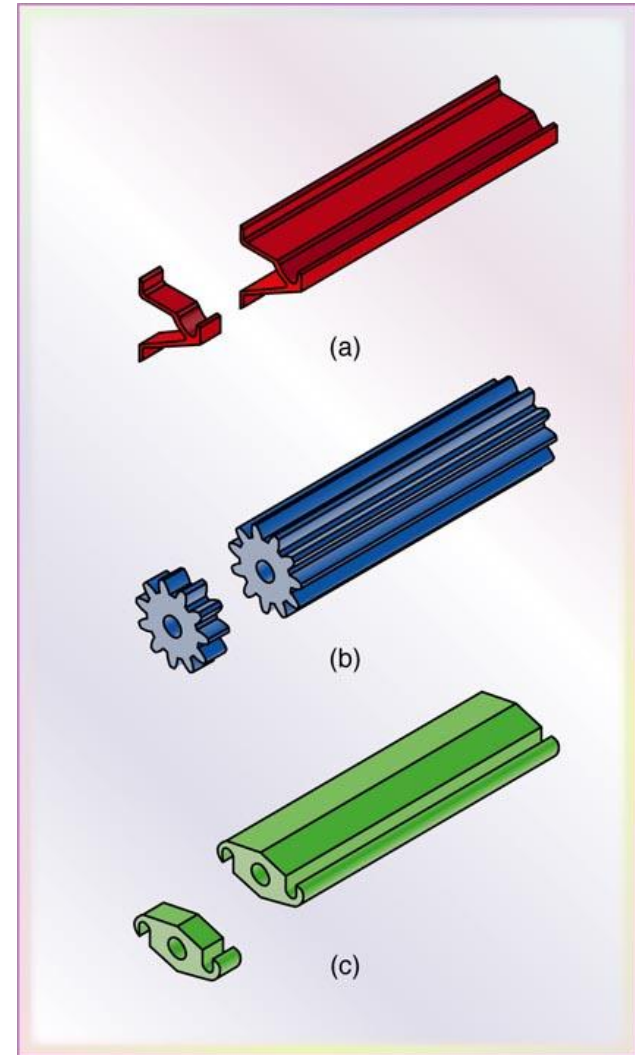
Extruding a gearwheel

Extrusions Products

Typical products made by extrusion are railings for sliding doors, tubing having various cross sections, structural and architectural shapes, and door and window frames. Extruded products can be cut into desired lengths, which then become discrete parts such as brackets, gears and coat hangers. Commonly extruded materials are aluminum, copper, steel, magnesium and lead.



Extrusions and examples of products made by sectioning off extrusions.



Extrusion Processes

Depending on the ductility of the material used extrusions can be carried out various ways:

- ▶ **Hot Extrusion** – Extrusion carried out at elevated temperatures
 - ▶ forward or direct extrusion and
 - ▶ backward or indirect extrusion
- ▶ **Cold Extrusion** – Extrusion carried out at ambient temperature. Often combined with forging operations
- ▶ **Hydrostatic extrusion** – pressure is applied by a piston through incompressible fluid medium surrounding the billet

Hot Extrusion:

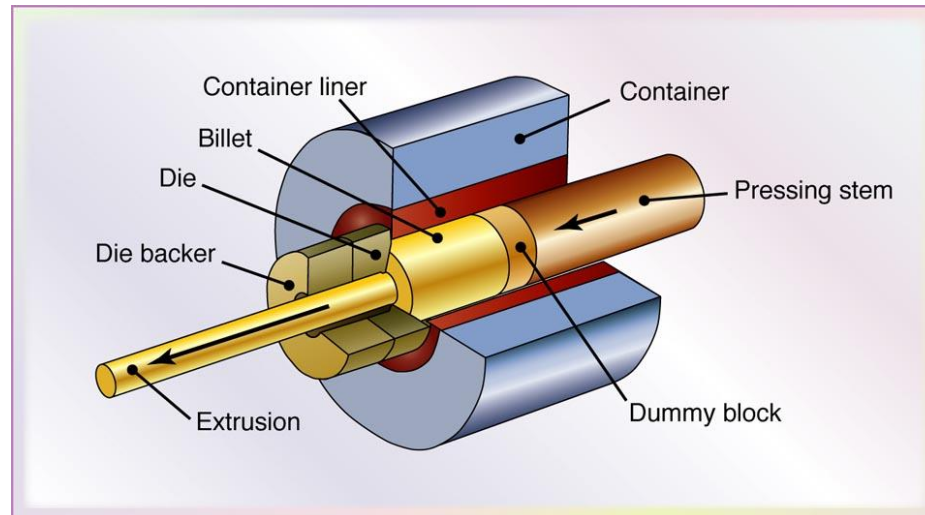
Extrusion is carried out at elevated temperatures-for metals and alloys that do not have sufficient ductility at room temperature, or in order to reduce the forces required. In this extrusion, die wear can be excessive and cooling of the hot billet in the chamber can be a problem, which results in highly non-uniform deformation. To reduce cooling of the billet and to prolong die life, extrusion dies may be preheated, as is done in hot forging operations. Hot billet causes the following problems:

- Because the billet is hot, it develops an oxide film unless heated in an inert-atmosphere furnace. This film can be abrasive and it can affect the flow pattern of the material.
- It also results in an extruded product that may be unacceptable in cases in which good surface finish is important.

Extrusion Processes

In order to avoid the formation of oxide films on the hot extruded product, the dummy block placed ahead of the ram is made a little smaller in diameter than the container. As a result, a thin cylindrical shell (**skull**), consisting mainly of the oxidized layer, is left in the container. The extruded product is thus free of oxides; the skull is later removed from the chamber. The following figures illustrate the hot extrusion process for producing solid products by (a) **forward or direct extrusion** and (b) **backward or indirect extrusion** process.

(a) Direct Extrusion: In this extrusion process, the heated billet is placed in the container. A ram towards the die pushes it. The metal is subjected to plastic deformation, slides along the walls of the container and is forced to flow through the die opening. At the end of the extruding operation, a small piece of metal, called butt-end scrap, remains in the container and cannot be extruded. Direct extrusion process is shown in the following Figure

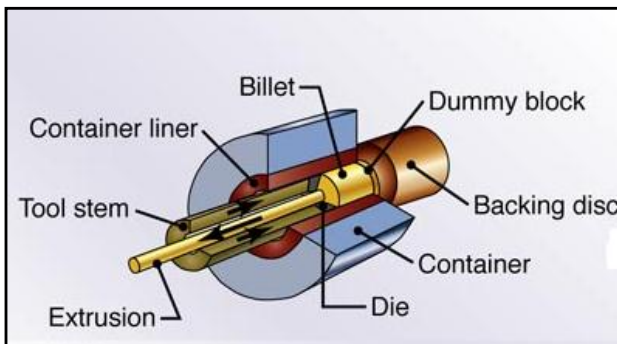


Extrusion Processes

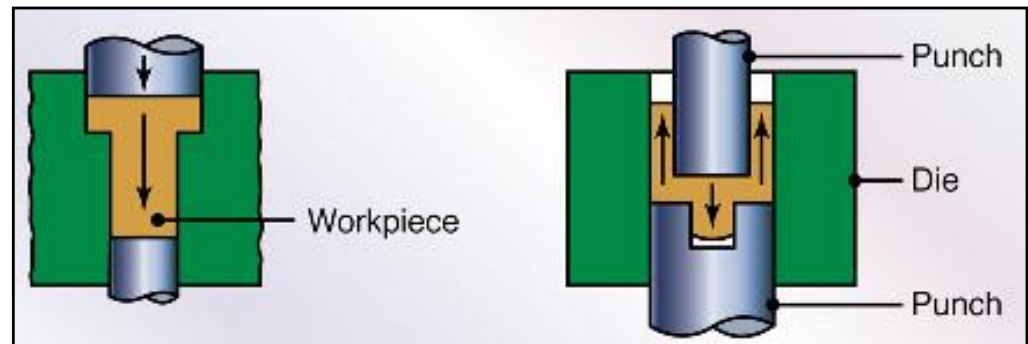
b) Indirect Extrusion: For the production of solid part, the die is mounted on the end of a hollow ram and enters the container as shown in the following Figure, the outer end of container being closed by a closure plate. As the ram travels, the die applies pressure on the billet and the deformed metal flows through the die opening in the direction opposite to the ram motions and the product is extruded through the hollow ram. In indirect extrusion, there is practically no slip of billet with respect to the container walls.

Cold Extrusion:

This process is similar to hot extrusion except that the metals worked possess the plasticity necessary for successful forming without heating them. Usually, These metals have a high degree of ductility. Cold extrusion is also done to improve the physical properties of a metal and to produce a finished part. Cold extrusion is done mostly on vertical mechanical presses because they are fast and simple. The method is fast, wastes no or little materials and gives higher accuracy and tolerance.



Indirect Extrusion



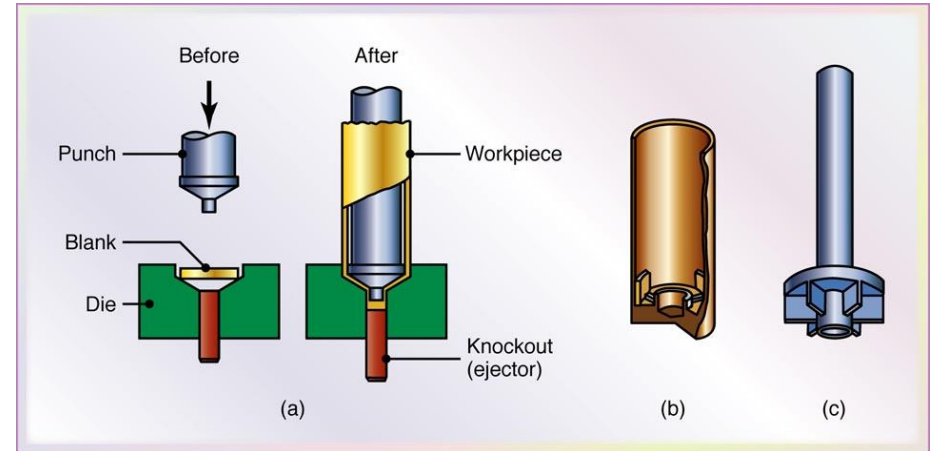
Cold Extrusion

Extrusion Processes

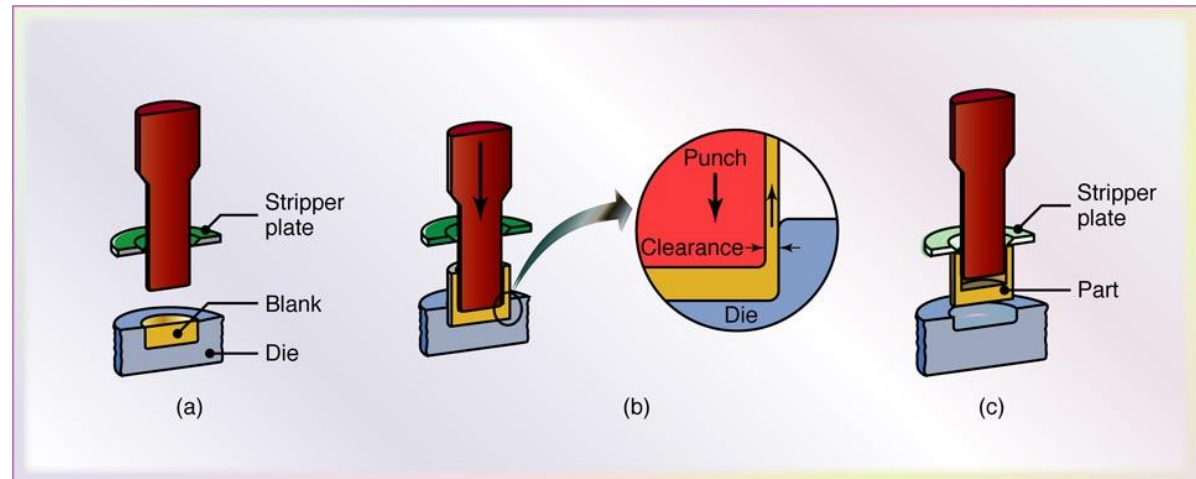
The widely employed cold extrusion methods are:

- The Hooker method or extrusion down,
- Cold impact extrusion or extrusion up method

(a) Impact extrusion of a collapsible tube by the *Hooker process*. (b) and (c) two examples of products made by impact extrusion. These parts also may be made by casting, forging, or machining. The choice of process depends on the materials involved, part dimensions, and wall thickness, and the product properties desired. Economic considerations also are important in final process selection.



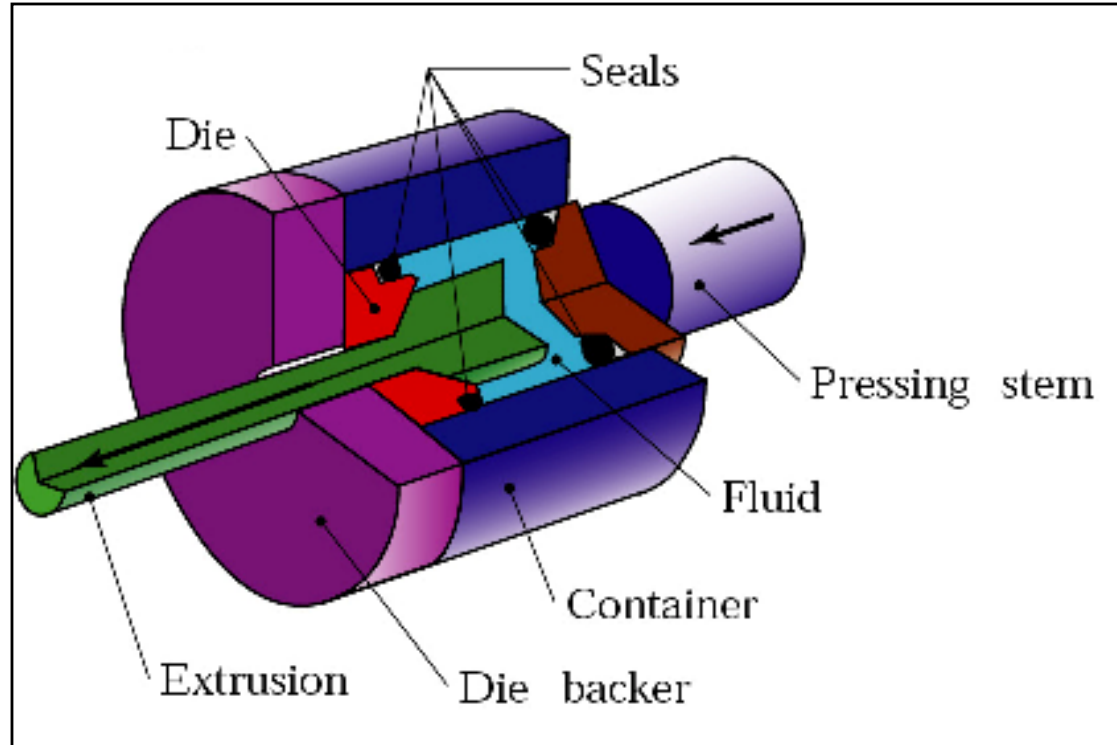
Impact-extrusion process. The extruded parts are stripped by use of a stripper plate, because they tend to stick to the punch.



Extrusion Processes

Hydrostatic Extrusion:

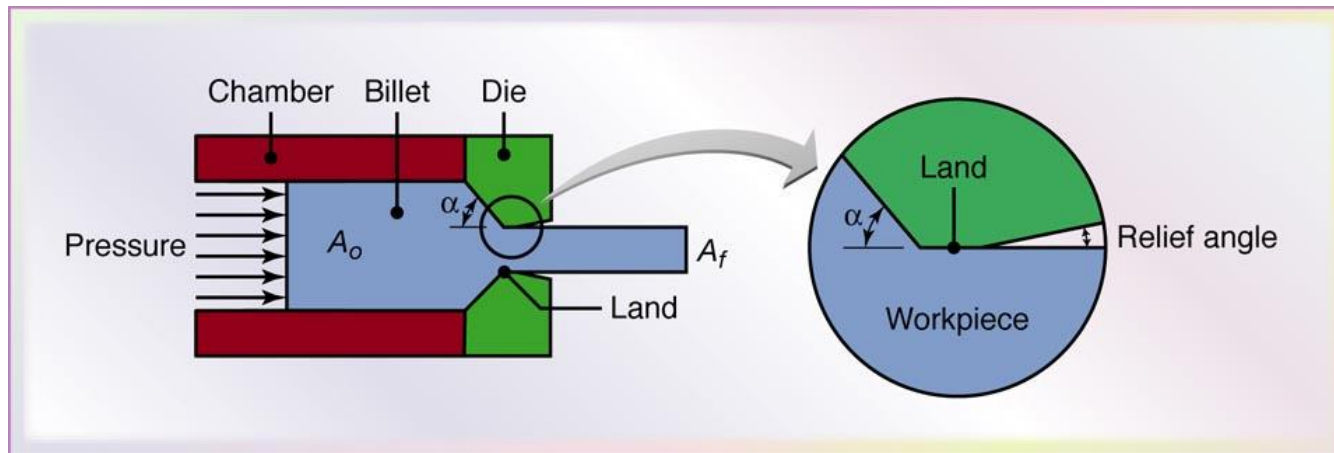
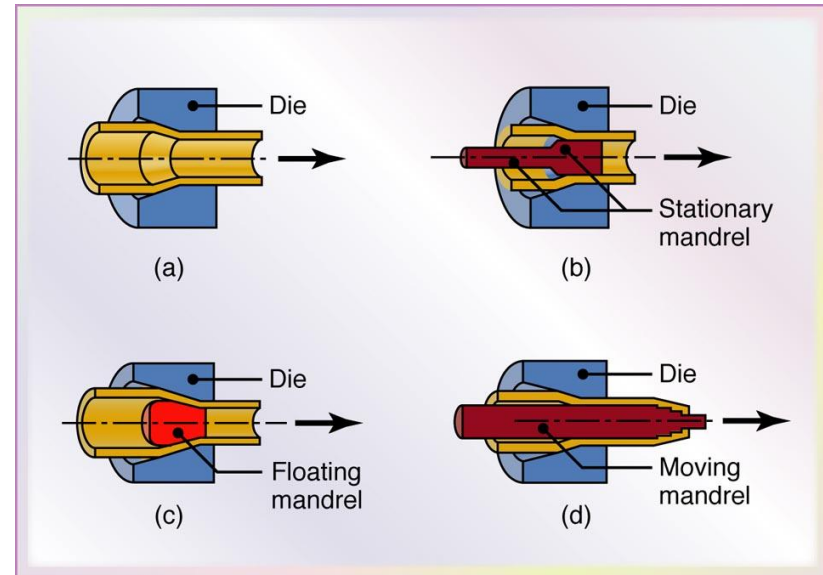
- A Billet that is smaller than the chamber is used.
- The Chamber is filled with a fluid. Pressure is then applied to the pressing stem
- There is no friction to overcome



Hydrostatic extrusion

Tube-Drawing & Process Variables

Tube-drawing operations, with and without an internal mandrel. Note that a variety of diameters and wall thicknesses can be produced from the same initial tube stock.



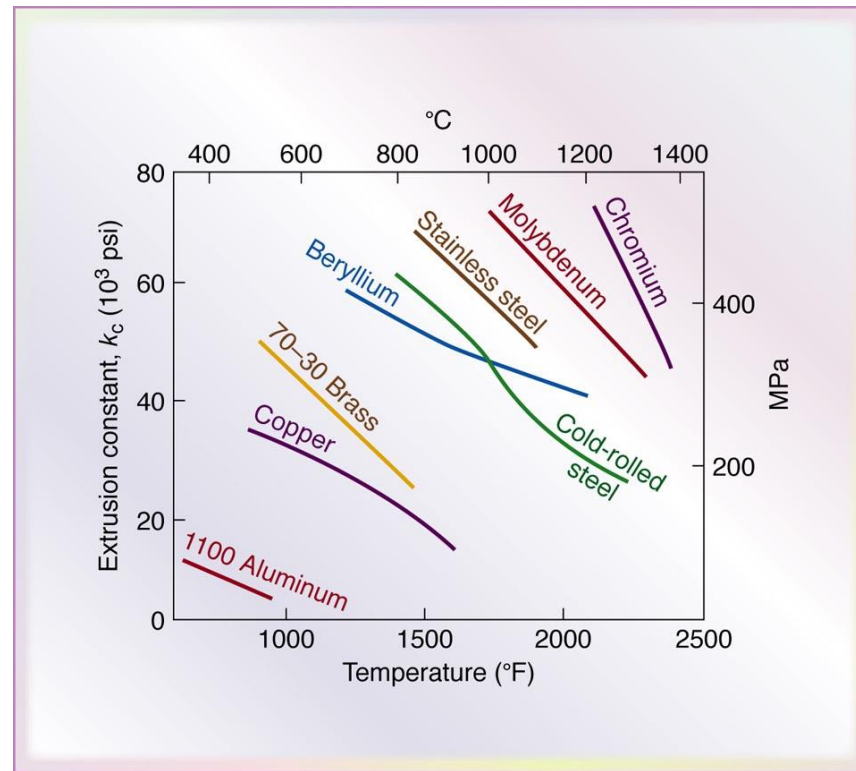
Process variables in direct extrusion. The die angle, reduction in cross-section, extrusion speed, billet temperature, and lubrication all affect the extrusion pressure.

Extrusion Force

$$\text{Extrusion force, } F = A_o k \ln \left(\frac{A_o}{A_f} \right)$$

k -extrusion constant

A_o , A_f billet and extruded product areas



Extrusion constant k for various metals at different temperatures.

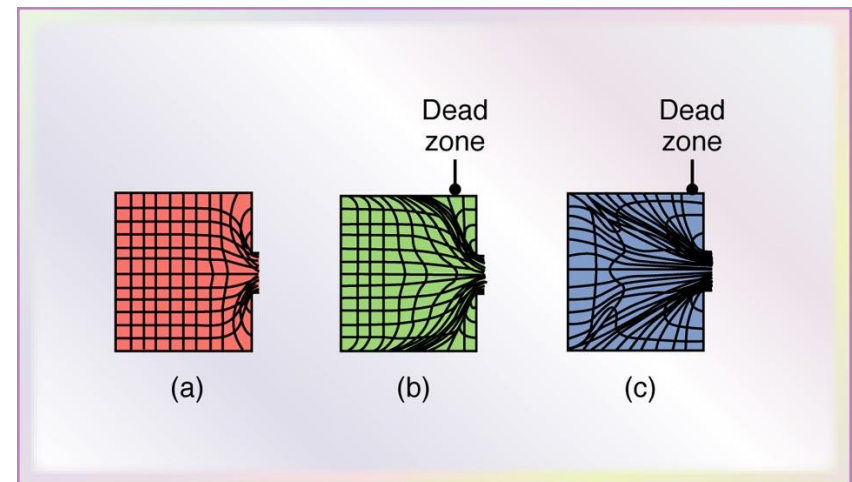
Metal Flow in Extrusion

The metal flow pattern in extrusion, as in other forming processes, is important because of its influence on the quality and the mechanical properties of the final product. The material flows longitudinally, much like incompressible fluid flow in a channel; thus, extruded products have an elongated grain structure (preferred orientation).

A common technique for investigating the flow pattern is to section the round billet in half lengthwise and then mark one face with square grid pattern. The two halves are placed in the chamber together and extruded. The products are then apart and studied. Following Figure shows typical flow patterns obtained by this technique in direct extrusion with square dies.

The conditions under which these different flow patterns occur are described in figure caption. Note that **dead-metal zones** in Fig. (b) and Fig.4 (c), where the metal at the corners is essentially stationary. This situation is similar to stagnation of fluid flow in channels that have sharp turns.

Types of metal flow in extruding with square dies. (a) Flow pattern obtained at low friction or in indirect extrusion. (b) Pattern obtained with high friction at the billet-chamber interfaces. (c) Pattern obtained at high friction or with coiling of the outer regions of the billet in the chamber. This type of pattern, observed in metals whose strength increases rapidly with decreasing temperature, leads to a defect known as pipe (or extrusion) defect.



Extrusion Defects

- **Surface Cracking:** Cracking on billet materials occurs due to temperature, friction, punch speed.
 - ▶ High Temperatures
 - Crack from along the grain boundaries. Typically occur in aluminum, magnesium, zinc alloys
 - ▶ Cold Temperatures
 - Caused by sticking of billet material at the die land
 - Known has the “Bamboo Defect” because of its similar appearance to bamboo
- **Pipe:** The metal-flow pattern tends to draw oxides and impurities toward the center of the billet
- **Internal Cracking:** Center of extruded product develops cracks.
 - ▶ Attributed to a state of hydrostatic tensile stress
 - ▶ Cracks increase with increasing die angle, impurities, and decreasing extrusion ratio and friction

Advantages

Advantages:

- The range of extruded items is very wide. Cross-sectional shapes not possible by rolling can be extruded, such as those with re-entrant sections.
- No time is lost when changing shapes since the dies may be readily removed and replaced.
- Dimensional accuracy of extruded parts is generally superior to that of rolled ones.
- In extrusion, the ductility of the metals is higher as the metal in the container is in composite compression, this advantage being of particular importance in working poorly plastic metals and alloys.
- Very large reductions are possible as compared to rolling, for which the reduction per pass is generally ≤ 2 .
- Automation in extrusion is simpler as items are produced in a single passing.
- Small parts in large quantities can be made. For example, to produce a simple pump gear, a long gear is extruded and then sliced into a number of individual gears.
- It does not need draft or flash to trim and needless machining as it is more accurate than forging.

Disadvantages & Applications

Disadvantages:

- Process waste in extrusion is higher than in rolling, where it is only 1 to 3%
- In-homogeneity in structure and properties of an extruded product is greater due to different flows of the axial and the outer layers of blanks.
- Service life of extrusion tooling is shorter because of high contact stresses and slip rates.
- Relatively high tooling costs, being made from costly alloy steel.
- In productivity, extrusion is much inferior to rolling, particularly to its continuous varieties.
- Cost of extrusion are generally greater as compared to other techniques

Applications:

- Extrusion is more widely used in the manufacture of solid and hollow sections from poorly plastic non-ferrous metals and their alloys (aluminum, copper, brass and bronze etc.)
- Steel and other ferrous alloys can also be successfully processed with the development of molten-glass lubricants.
- Manufacture of sections and pipes of complex configuration.
- Medium and small batch production
- Manufacture of parts of high dimensional accuracy
- The range of extruded items is very wide: rods from 3 to 250 mm in diameter, pipes of 20 to 400 mm in diameter and wall thickness of 1 mm and above and more complicated shapes which can not be obtained by other mechanical methods.

THE END