Extrusion and Drawing

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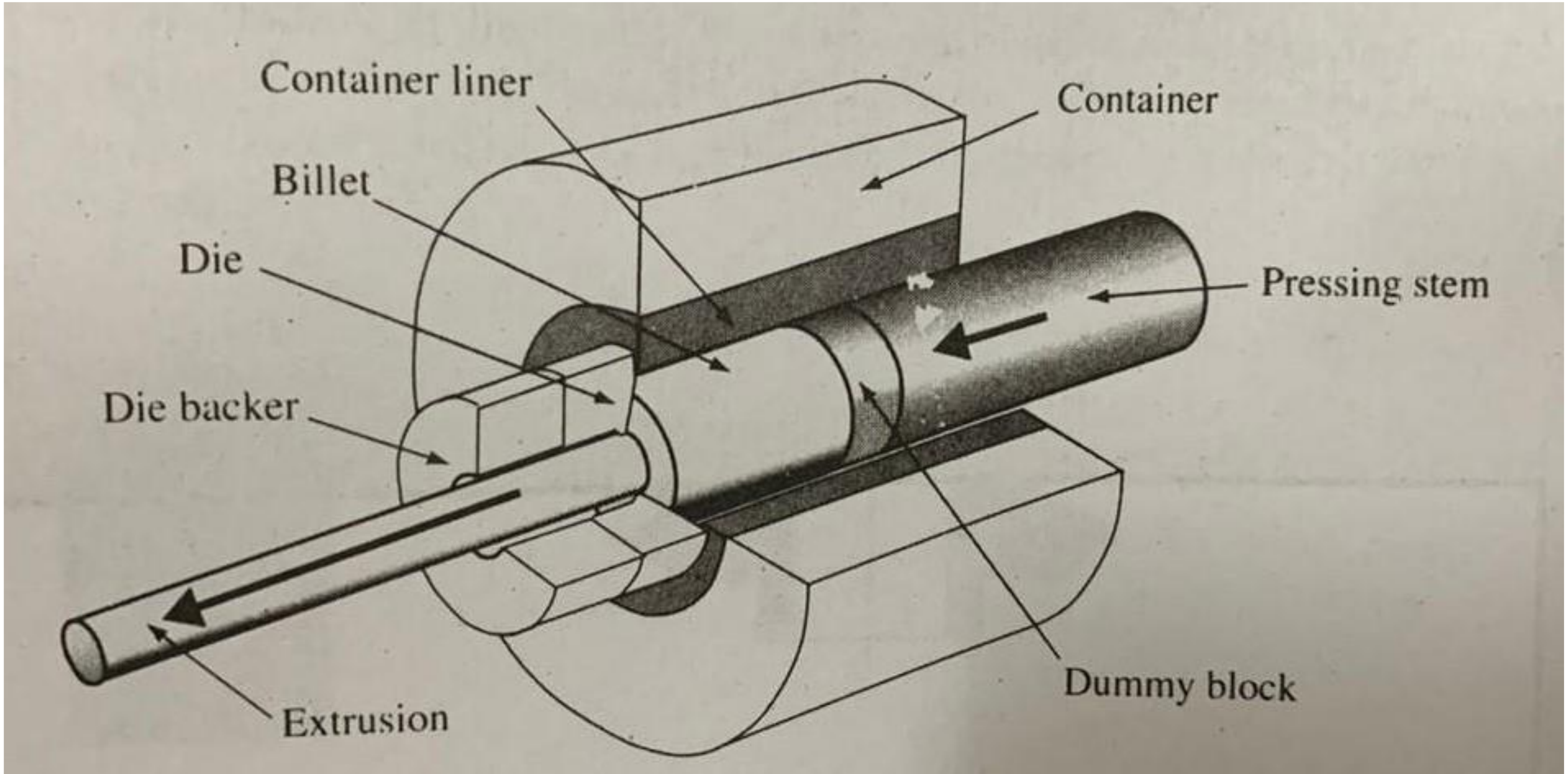
Extrusion

- Extrusion is a **metal forming process** in which metal or work piece is forced to flow through a die to reduce its cross section or convert it into desire shape. This process is extensively used in pipes and steel rods manufacturing. The force used to extrude the work piece is compressive in nature.

EXTRUSION

Extrusion is the process that forces metal to flow through a shape-forming die. The metal is plastically deformed under compression in the die cavity. Extrusion produces only compressive and shear forces in the stock without any tensile force, which makes high deformation possible without tearing the metal. It is a hot-working process which, like forging, rolling, etc., uses the good deformability of heated metallic materials for shaping them. A metal billet heated to the appropriate temperature is fed into the cylindrical container of the extrusion press and is forced by the action of a ram through a steel die whose orifice has the desired shape to produce the solid or hollow section



Working Principle:

Extrusion is a simple compressive metal forming process. In this process, piston or plunger is used to apply compressive force at work piece. These process can be summarized as follow.

- First billet or ingot (metal work piece of standard size) is produced.
- This billet is heated in hot extrusion or remains at room temperature and placed into a extrusion press (Extrusion press is like a piston cylinder device in which metal is placed in cylinder and pushed by a piston. The upper portion of cylinder is fitted with die).
- Now a compressive force is applied to this part by a plunger fitted into the press which pushes the billet towards die.
- The die is small opening of required cross section. This high compressive force allow the work metal to flow through die and convert into desire shape.
- Now the extruded part remove from press and is heat treated for better mechanical properties.

The metal emerges from the die as a continuous bar, which is cut to the required lengths. Extrusion products are therefore essentially linear in character, in the sense that shaping is confined to the cross-section only. The process is therefore eminently suitable for the production of bar-like and tubular objects. The cross-section that can be produced vary from solid round, rectangular, to L shapes, T shapes, tubes and many other different types. Extrusions, often minimize the need for secondary machining, but are not of the same dimensional accuracy or surface finish as machined parts. However, this process can produce a wide variety of cross-sections that are hard to produce cost-effectively using other methods.

Extrusion differs from drawing in that the metal is pushed, rather than pulled under tension. Extrusion processes can be carried on hot or cold.

Cold extrusion: Cold extrusion is the process done at room temperature or slightly elevated temperatures. This process can be used for most materials subject to designing robust enough tooling that can withstand the stresses created by extrusion. Cold extrusion can be used with any material that possesses adequate cold work ability–e.g., lead, tin, aluminum alloys, copper, titanium, molybdenum, vanadium, steel. Typical parts which are cold extruded are collapsible tubes, aluminium cans, cylinders, gear blanks.

The advantages of cold extrusion are:

1. No oxidation takes place.
2. Good mechanical properties due to severe cold working as long as the temperature created are below the recrystallization temperature.
3. Good surface finish with the use of proper lubricants.

Disadvantages:
High force required.
Product is accomplished with strain hardening.

Hot extrusion: Hot extrusion is basically a hot working process. It is done at fairly high temperatures, approximately 50 to 75% of the melting point of the metal. The pressures can range from 35-700 MPa. Due to the high temperatures and pressures and its detrimental effect on the die life as well as other components, good lubrication is necessary. The principal variables, which influence the force required to cause extrusion, are:

(1) The type of extrusion
(2) The extrusion ratio
(3) The working temperature
(4) The speed of deformation, and
(5) The frictional conditions at the die and container wall.

Typical parts produced by hot extrusion are trim parts used in automotive and construction applications, window frame members, railings, aircraft structural parts.

Advantages:

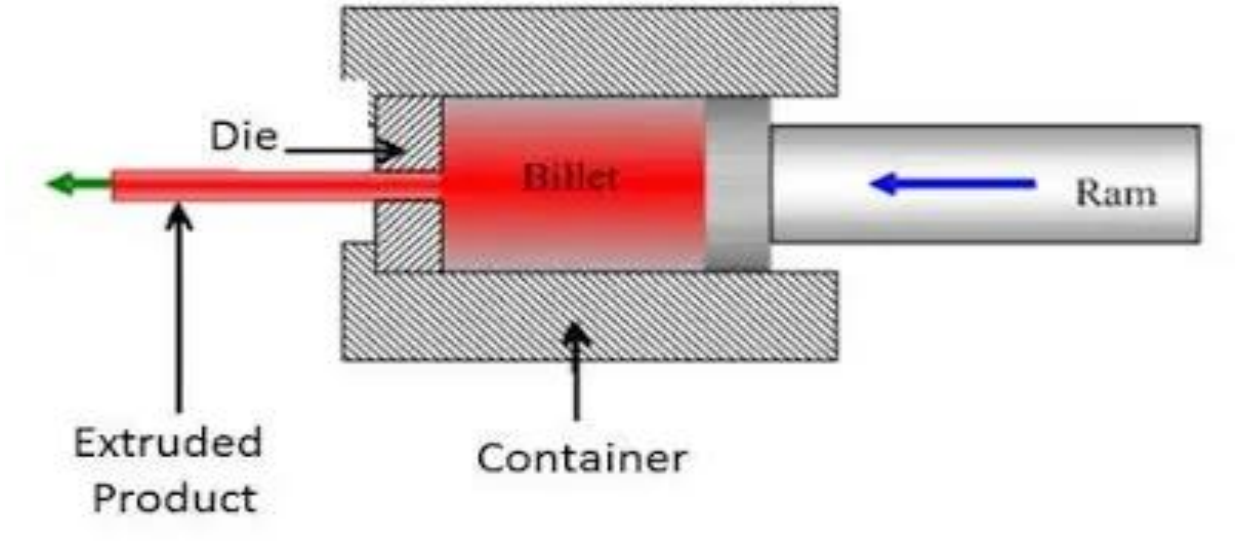
- Low force required compare to cold working.
- Easy to work in hot form.
- The product is free from stain hardening.

Disadvantages:

- Low surface finish due to scale formation on extruded part.
- Increase die wear.
- High maintenance required.

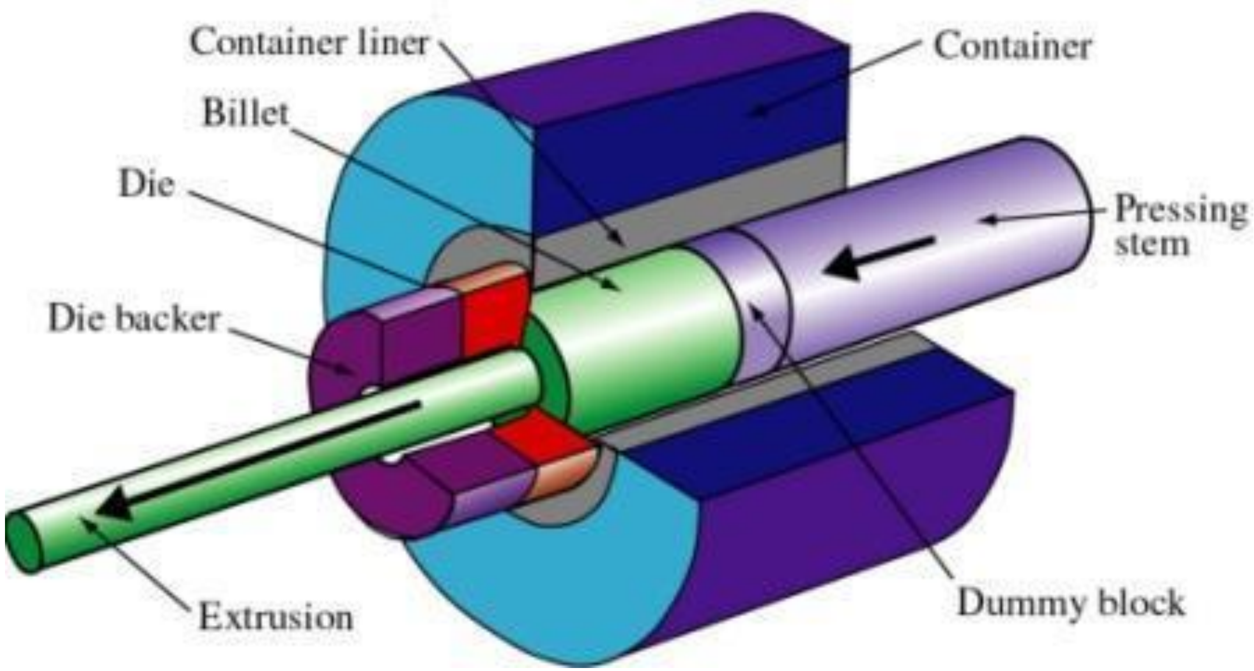
Types of Extrusion

1. Direct (forward) extrusion: Forward or direct extrusion is sometimes known as the Hooker process. In this process a ram forces the preheated billet through the die. The billet slides relative to the container wall; the wall friction increases the ram force considerably. A dummy block or pressure plate is placed at the end of the ram in contact with the billet. The process can be compared like squeezing toothpaste out of a tube.



Direct Extrusion

The process is generally used to produce profiled sections, thin-walled tubular parts with heavy flanges, straight tubular shapes, and hollow bar products. Typical products produced are bolts, screws or stepped shafts.



Under direct extrusion, the high friction caused by steels at higher temperatures is reduced using molten glass as a lubricant while oils with graphite powder are used for lubrication for low temperatures. The dummy block protects the tip of the pressing stem (punch or ram) in hot extrusion. When the punch reaches the end of its stroke, a small portion of the billet called the “butt end” cannot be pushed through the die opening.

Direct metal extrusion advantages

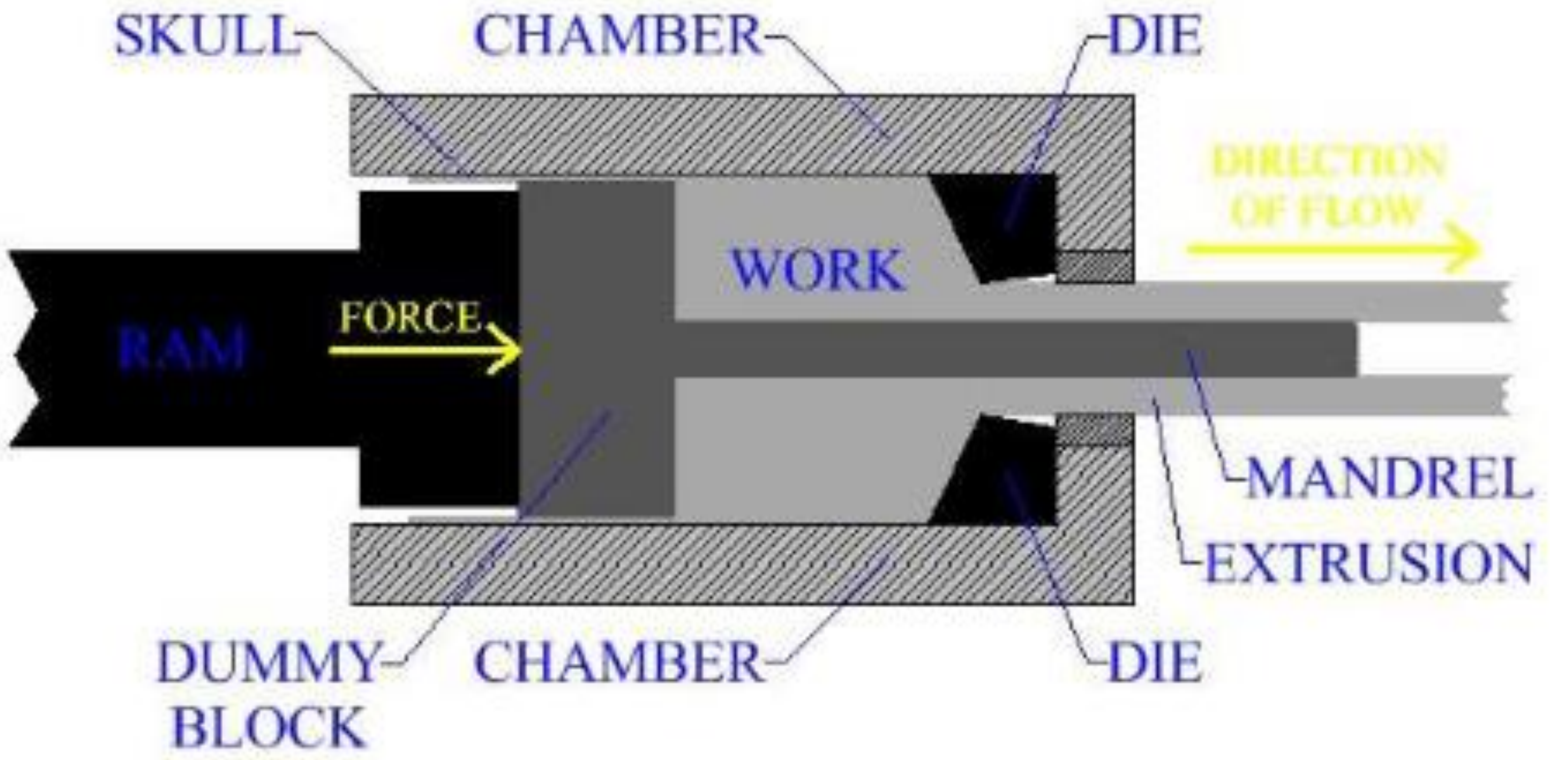
- No billet modification required
- It can be used for both hot and cold extrusion.
- Simple tooling compared to other extrusion processes

Direct metal extrusion disadvantages

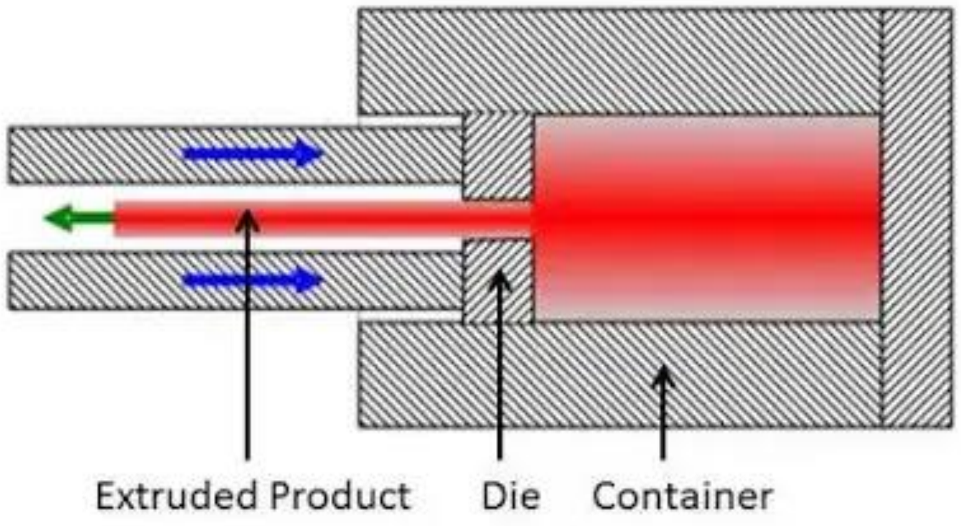
- High force requirement due to friction
- The butt end left inside the cavity
- The force required to push the ram changes as the punch moves

Direct extrusion of hollow part

Hollow, or semi hollow, parts can be directly extruded with the use of a mandrel attached to the dummy block. A hole is created through the work, parallel to the axis over which the ram applies the force to form the extrusion. The mandrel is fitted within this hole. Once the operation begins, the ram is forced forward. The extruded metal flows between the mandrel and the die surfaces, forming the part. The interior profile of the metal extrusion is formed by the mandrel, while the exterior profile is formed by the extruding die.

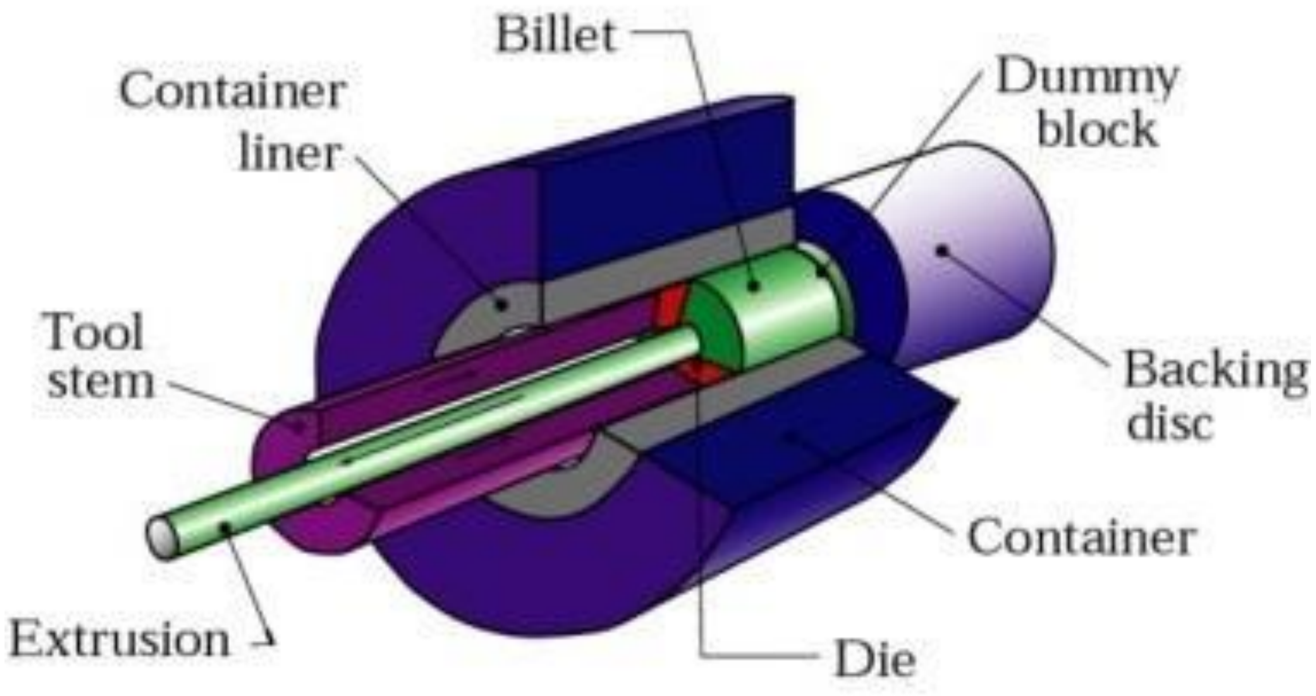


2. Indirect (reverse, inverted or backward) extrusion: Indirect extrusion is a process that forces the metal confined in the cavity to flow in a direction opposite to that of the ram travel.



Indirect Extrusion

Here, the die moves toward the billet; thus, except at the die, there is no relative motion at the billet-container interface. As a consequence, the frictional forces are lower and the power required for extrusion is less than for direct extrusion. In practice, a hollow ram carries a die, while the other end of the container is closed with a plate. Frequently, for indirect extrusion, the ram containing the die is kept stationary, and the container with the billet is made to move. Backward extrusion is useful in forming a variety of cylindrical shapes such as nuts, sleeves and tubular rivets.

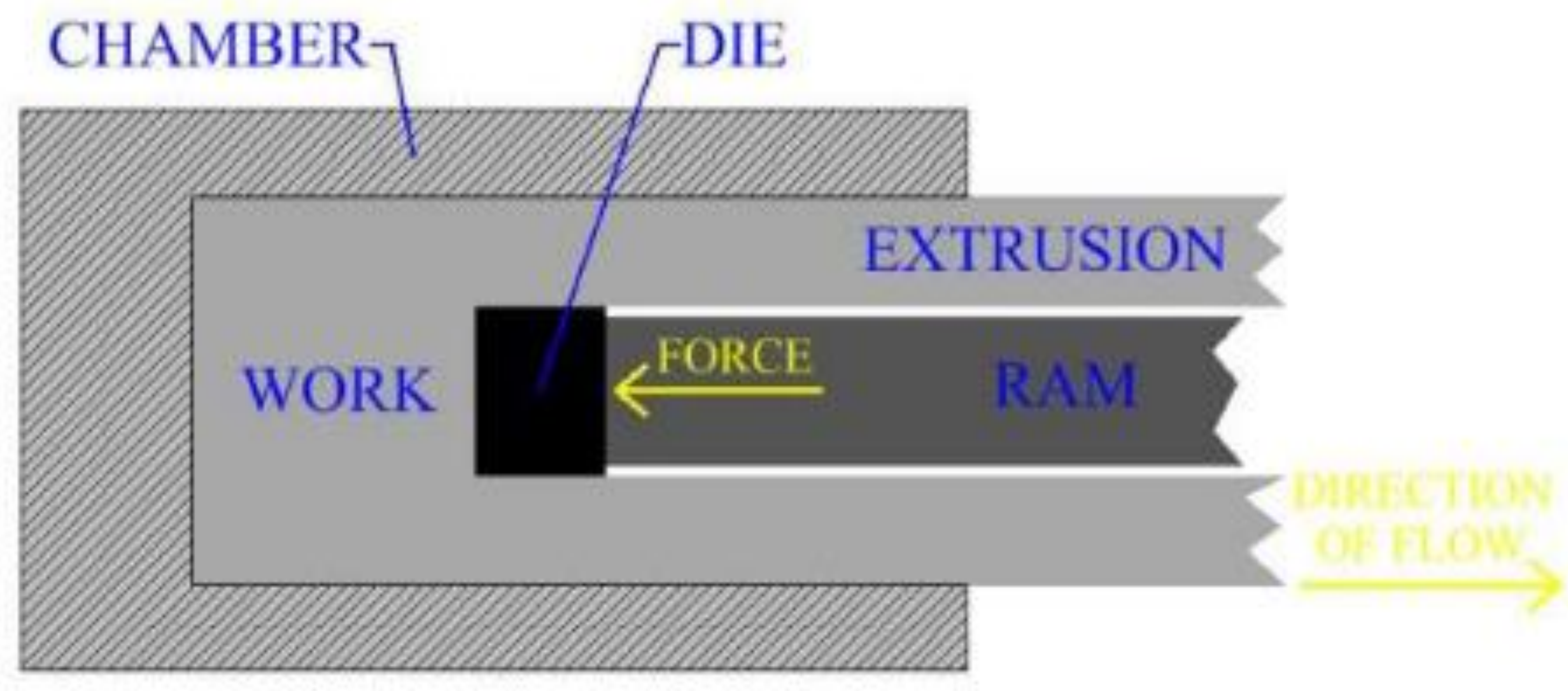


In-direct metal extrusion advantages
•Less friction and less power used
•It can be used for both hot and cold extrusion
•Simple tooling compared to other extrusion processes

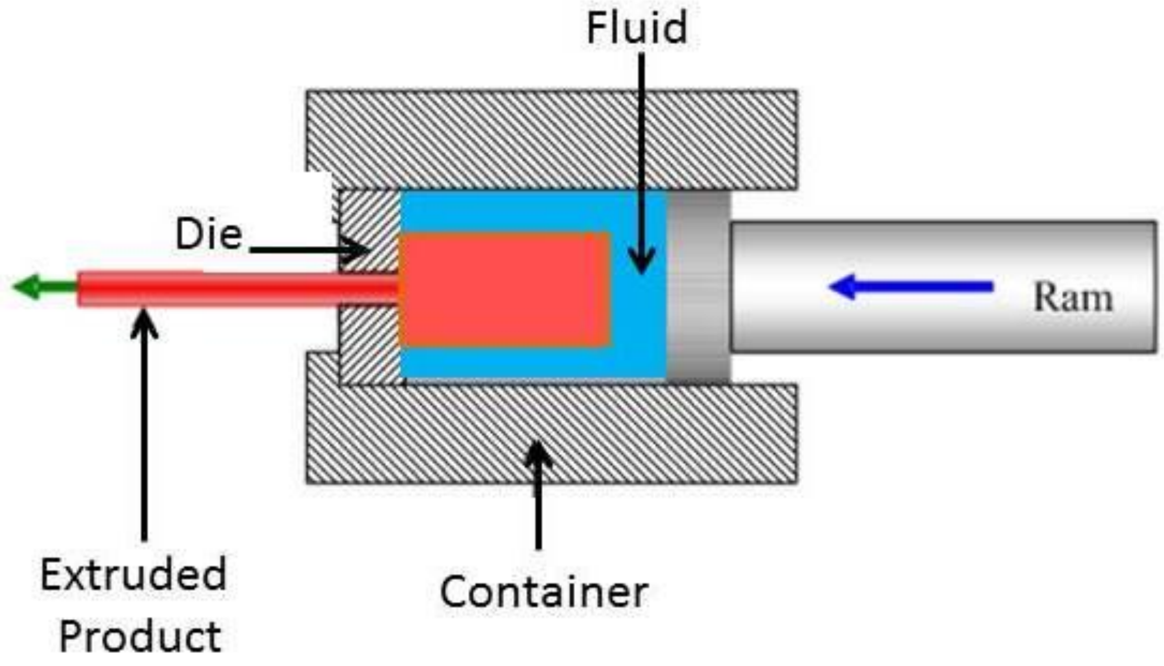
In-direct metal extrusion disadvantages
•Difficult to support the extruded part
•The hollow ram limits the load applied

Indirect extrusion of hollow part

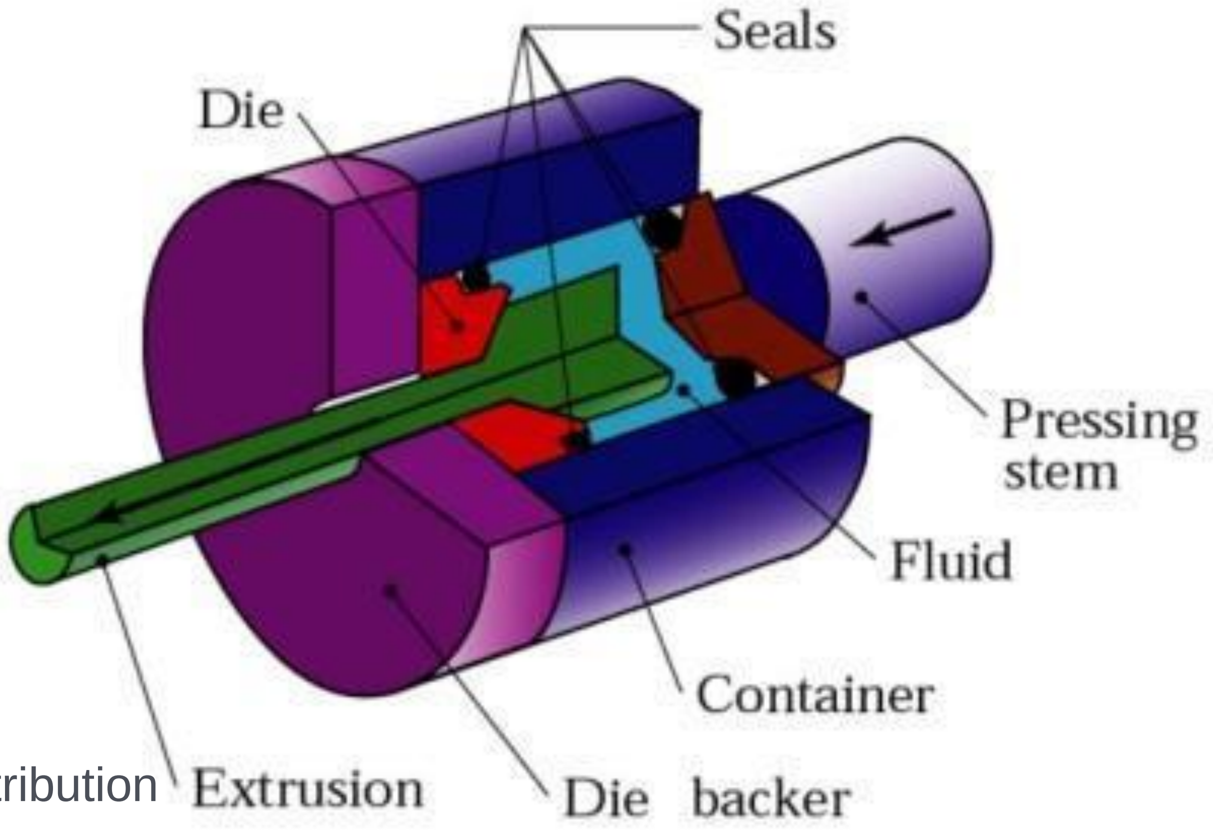
Indirect extrusion can also be used to produce hollow parts. In this process, a ram is forced into the work material. The ram gives the internal geometry to the tubular part, while the material is formed around it. Difficulties in supporting the ram limit this process and the length of tubular metal extrusions that may be manufactured.



3. Hydrostatic extrusion: In this process, the chamber is filled with a fluid that transmits the pressure to the billet, which is then extruded through the die. There is no friction along the walls of the container. Because the billet is subjected to uniform hydrostatic pressure, it does not upset to fill the bore of the container as it would in conventional extrusion. This means that the billet may have a large length to diameter ratio (even coils of wires can be extruded) or it may have an irregular cross section. Because of the pressurized fluid, lubrication is very effective, and the extruded product has good surface finish and dimensional accuracy.



Hydrostatic Extrusion



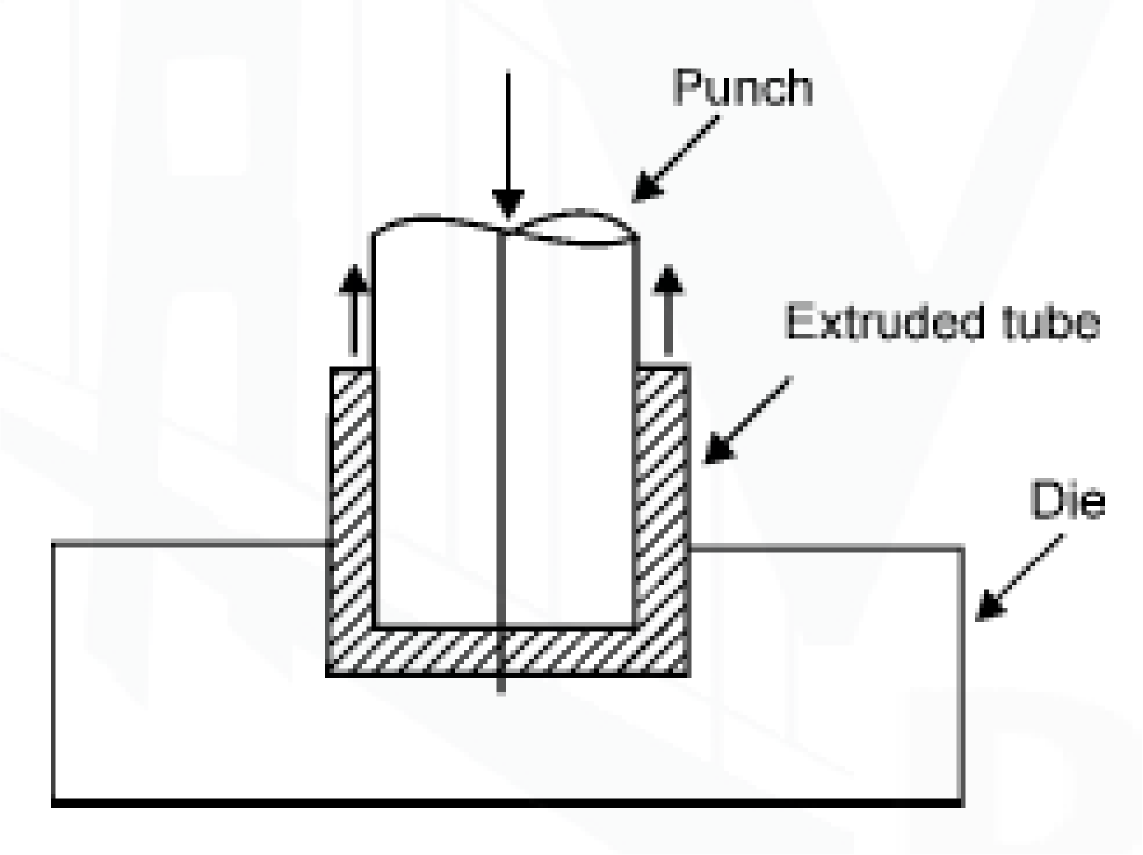
Hydrostatic metal extrusion advantages

- Low power/force requirement due to no friction
- Fast production rates & high reduction ratios
- Lower billet temperature
- Even the flow of material due to the balanced force distribution
- Large billets and large cross-sections can be extruded
- No billet residue is left in the container

Hydrostatic metal extrusion disadvantages

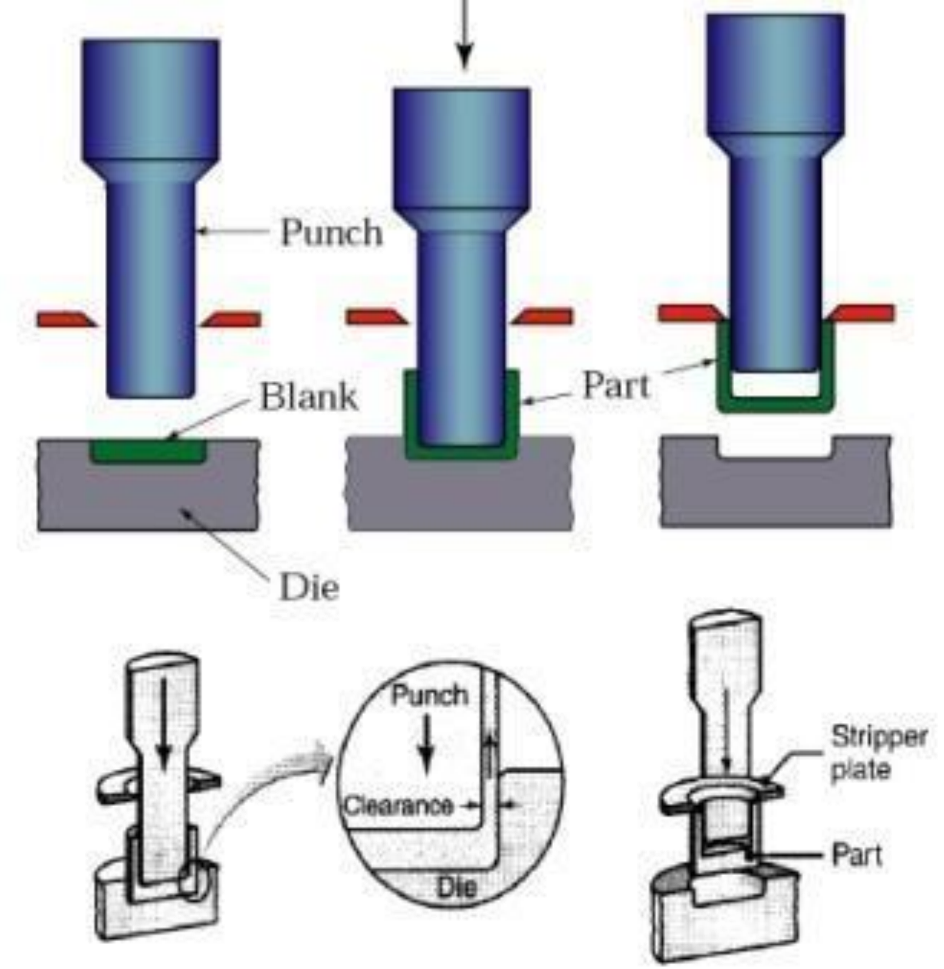
- Billets need to be prepared by tapering one end to match the die entry angle.
- Only cold extrusion is possible
- Difficult to contain the high-pressure fluid

5. Impact extrusion: It is a form of indirect extrusion and is particularly suitable for hollow shapes. It is usually performed on a high-speed mechanical press. The punch descends at a high speed and strikes the blank, extruding it upwards. The thickness of the extruded tubular section is a function of the clearance between the punch and the die cavity. Although the process is performed cold, considerable heating results from the high-speed deformation. Impact extrusion is restricted to softer metals such as lead, tin, aluminum and copper.



Impact metal extrusion advantages

•Raw material savings of up to 90%
•Reduced machining times by up to 75%
•Elimination of secondary machining operations
•Reduction in multi-part assemblies
•Improved mechanical properties for material strength and machining due to the cold working of the material
•Significantly reduced total part costs by up to 50%
•Hollow thin-walled tubes, closed on one end, are often produced in the manufacturing industry by backward impact extrusion.



Impact metal extrusion disadvantages

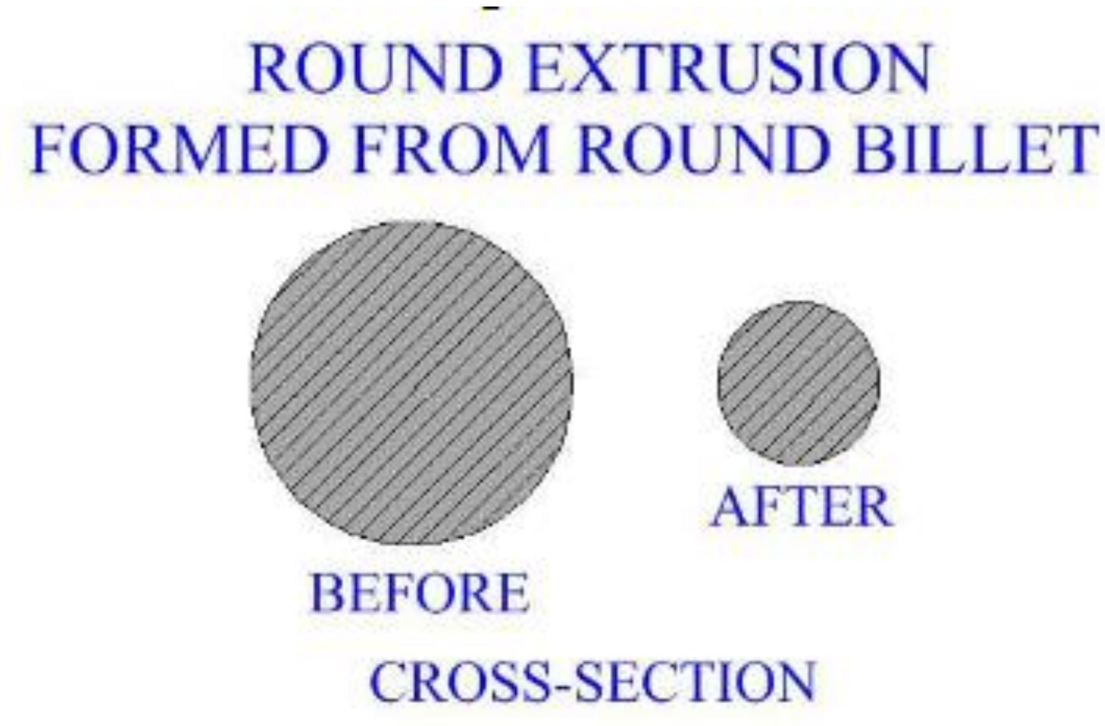
•Produced as long as the part is symmetrical over the axis by which it is formed
•Many of the parts formed by impacting in industry, will require further manufacturing processes, such as metal forging, ironing or machining, before completion.

Metal Extrusion practice

- Metal extrusion practice, in manufacturing industry, must take into consideration a variety of factors, many of which will be specific to each particular operation.
- The type of material, size of work piece, geometric cross section of extruded part, ram speed, temperature of work and type of metal extrusion process, are all important elements in the design and analysis of an extrusion operation.
- The main goal is to enact the right metal flow through the correct application of force.
- The force is applied through a ram, powered by some sort of press.
- Most extrusions are performed horizontally, by hydraulic presses.
- Hydraulic presses can deliver a constant force, at a constant speed, over a long stroke, making them ideal for extruding metal parts; however, in some instances mechanical presses may be used.
- The ram's speed affects the forces involved during the operation.
- Ram speeds can be as low as a few feet every minute, or may be as high as 15 feet per second, though most are under 2 feet per second.
- The length of extruded metal product in common manufacturing practice is generally up to 25 feet, but much longer lengths, as high as 90 feet, have been created.
- Many of the extruded sections produced in industry require bending or straightening after the completion of the extrusion process.
- When performed correctly, metal extrusion can be very economical for both small and large batch production.

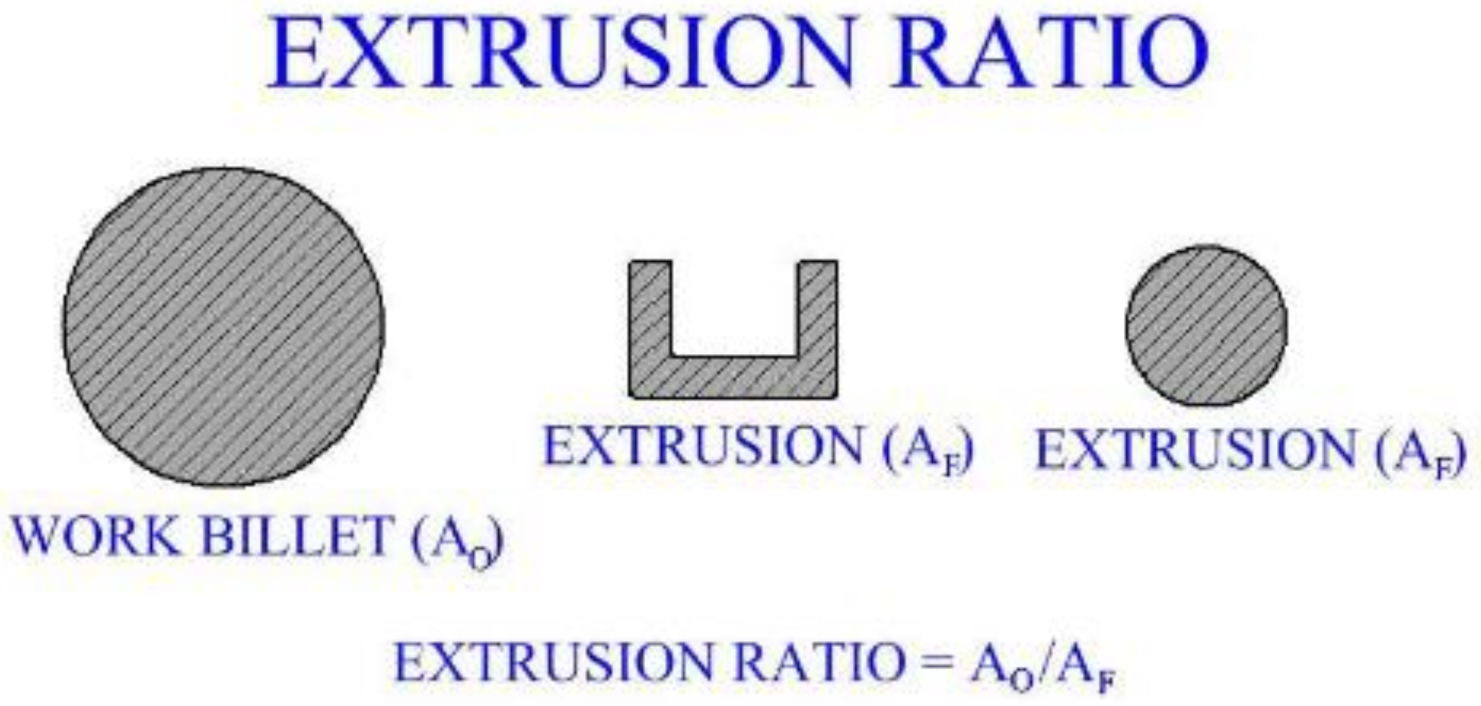
Extrusion Ratio

The extrusion process is capable of creating a tremendous amount of metal deformation of the work. The size of the cross section of the work billet may be much larger than the size of the cross section of the extruded part. For example, in figure 214 the starting work billet has a certain diameter, say 10 inches. It is formed into a round extrusion with a diameter of 5 inches. We can relate the size of the work's cross section with that of the extruded part by comparing their diameters. It can be said that the extrusion has a diameter of 1/2 the original work, thus measuring the cross sectional reduction that occurred during the metal manufacturing process.



To relate the cross section of the work piece to that of the extruded product, the extrusion ratio was established. The extrusion ratio is the ratio of the area of the work's cross section (A_o) to that of the extrusion's cross section (A_f). The extrusion ratio, or reduction ratio, can be expressed as (A_o/A_f).

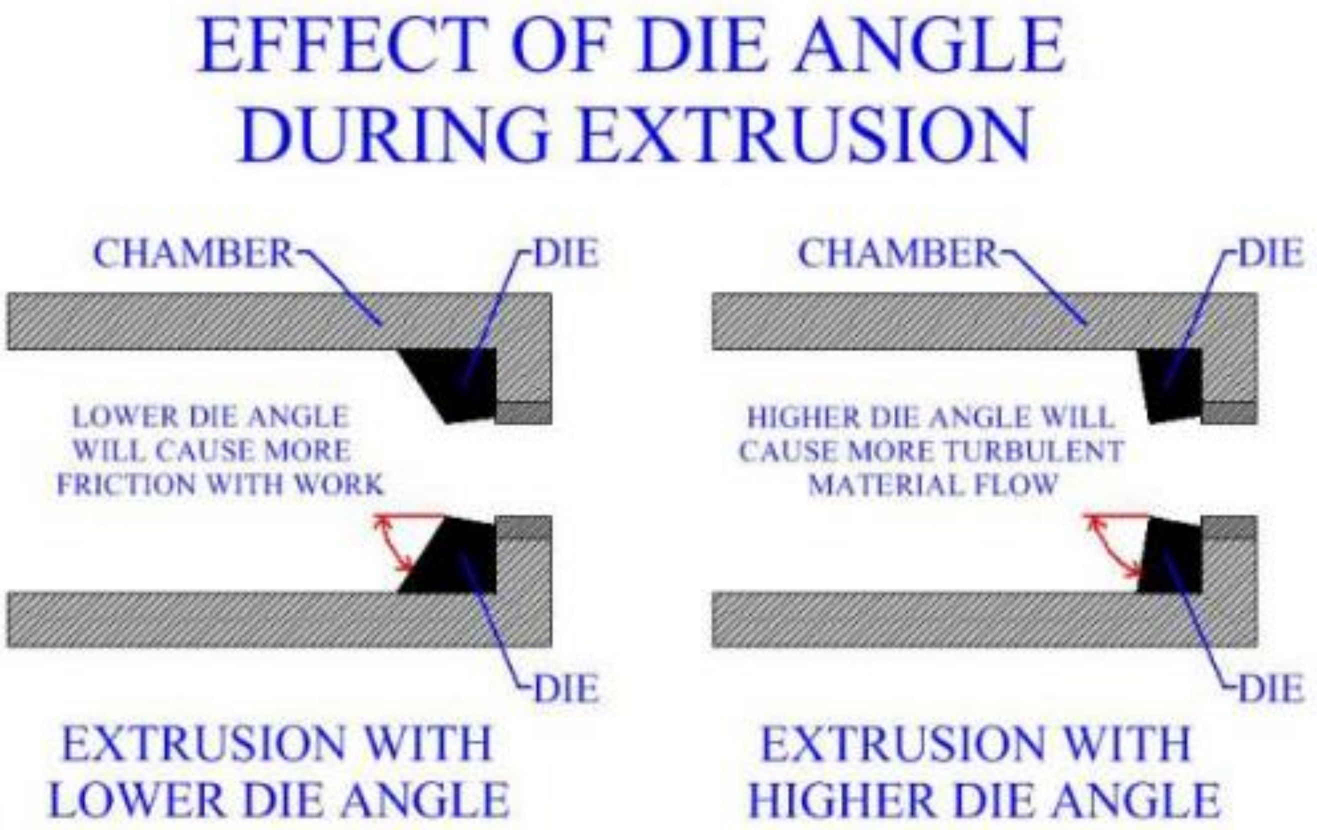
Obviously, since the starting work's cross section will be greater than that of the metal extrusion, the extrusion ratio will always be more than 1. In manufacturing industry, extrusion ratios typically range from about 4 to 100, although they can be even higher in certain special cases.



Metal Extrusion Die

- Metal extrusion die, used in manufacturing extruded sections, must have certain mechanical characteristics.
- Extrusion die must be strong and hard, capable of holding their dimensional accuracy throughout the high stresses created during the manufacturing process.
- They must also be resistant to wear, which is always an issue when extruding metal in large quantities.
- Dies for hot extrusion must have high thermal resistance and be able to maintain strength and hardness at elevated temperatures.
- Tool steels are a common type of material for metal extrusion molds. Extruding dies may be coated to increase wear resistance.
- Carbides are sometimes used for a mold material, carbides do not wear easy and can provide accurate part dimensions.

- Extrusion die angle is an important factor in the manufacturing process, as it is a large determinant in the flow of material.
- The amount of force necessary to form a certain cross section will vary with different die angles.
- A lower angle will create more friction at the work-die interface.
- Friction is a factor that increases the force necessary to extrude a part. High die angles create more material movement, particularly in the outer regions away from the center.
- The greater metal displacement gives a greater turbulence in the metal flow.
- Increased turbulence in the flow also increases the amount of force necessary for the operation. All factors must be calculated in the design of a metal extrusion process.



Application:

1. Extrusion is widely used in production of tubes and hollow pipes.
2. Aluminum extrusion is used in structure work in many industries.
3. This process is used to produce frames, doors, window etc. in automotive industries.
4. Extrusion is widely used to produce plastic objects.

Advantages of Extrusion

1. The tooling cost is low, as well as the cost due to material
2. Intricate cross sectional shapes, hollow shapes and shapes with undercuts can be produced.
3. The hardness and the yield strength of the material are increased.
4. In most applications, no further machining is necessary.

Limitations of Extrusion

1. High tolerances are difficult to achieve.
2. The process is limited to ductile materials.
3. Extruded products might suffer from surface cracking. It might occur when the surface temperature rise significantly due to high extrusion temperature, friction, or extrusion speed.
4. Internal cracking might also occur. These cracks are attributed to a state of secondary tensile stresses at the centre line of the deformation zone in the die.
5. For a small extusion ratio and large die angle, the centre of the extrusion is not directly deformed, but dragged along by the stretching outer surface material. This generates tensile stresses in the core which can lead to 'arrow-head' failure or centre-burst detects.

Drawing

- Drawing of wire from steel rod is a metal working process used for the reduction of the cross-section of the rod.
- Similarly rods are drawn from steel rounds of larger diameters.
- During drawing the volume remains the same and hence there is increased in the length of the drawn wire or rod.
- It is carried out by pulling the wire/rod through a single or a series of the drawing dies.
- In the case of series of drawing dies, the subsequent drawing die is to have smaller bore diameter than the previous drawing die.
- Drawing is usually performed in round sections at room temperature, thus it is classified as a cold working process.
- However, it can be performed at higher temperatures for large wires to reduce forces.

- Drawing process normally is most frequently used to produce round cross sections, but squares and other shapes can also be drawn.
- Wire/rod drawing is an important industrial process, providing commercial products.
- Rod and wire products cover a very wide range of applications which include shafts for power transmission, machine and structural components, blanks for bolts and rivets, electrical wiring, cables, wire stock for fences, rod stock to produce nails, screws, rivets, springs and many others.
- Drawing of rods from steel rounds is used to produce rods for machining, forging, and other processes etc.

- Advantages of drawing in the above applications include

(i) close dimensional control,

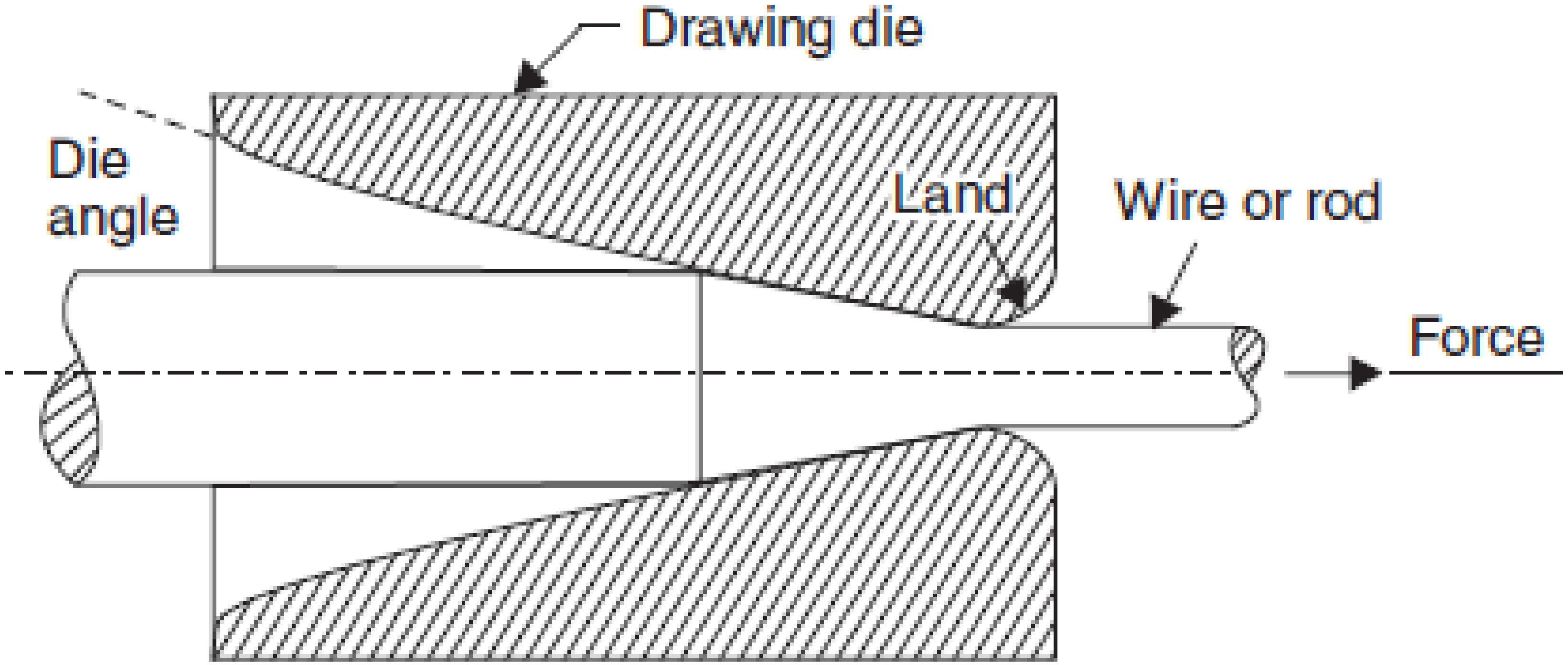
(ii) good surface finish,

(iii) improved mechanical properties such as strength and hardness,

(iv) adaptability to economical batch or mass production.

WIRE DRAWING

Wire drawing is a simple process. In this process, rods made of steel or non ferrous metals and alloys are pulled through conical dies having a hole in the centre. The included angle of the cone is kept between 8 to 24°. As the material is pulled through the cone, it undergoes plastic deformation and it gradually undergoes a reduction in its diameter. At the same time, the length is increased proportionately. The process is illustrated in Figure



- The dies tend to wear out fast due to continuous rubbing of metal being pulled through it.
- Hence they are made of very hard material like alloy steel, tungsten carbide or even diamond. In one pass, the reduction in cross-sectional area achieved is about 25–30%.
- Hence in a wire drawing plant, the wire has to pass through a number of dies of progressively reducing diameter to achieve the required reduction in diameter.
- However as the wire passes through dies and undergoes plastic deformation, it gets strain hardened. Its strength increases and capacity to further undergo plastic deformation decreases.
- Therefore during the entire run of the wire, from time to time, it has to be heated (and cooled) to remove the effect of work-hardening.
- This process is called “in process annealing”. The aim is to make the material soft and ductile again so that the process of drawing may be smoothly carried out.

- Thus, the difference between drawing and extrusion is that in extrusion the material is pushed through a die, whereas in drawing it is pulled through it.
- Although the presence of tensile stresses is obvious in drawing, compression also plays a significant role since the steel material is squeezed down as it passes through the die opening.
- For this reason, the deformation which occurs in drawing is sometimes stated to as indirect compression.

- The process characteristics of wire/rod drawing consists of

(i) pulling of the wire rod/round through the die to reduce its diameter,

(ii) drawing increases the length of the wire/rod as its diameter decreases,

(iii) several dies are used in succession (tandem) for small diameter wire,

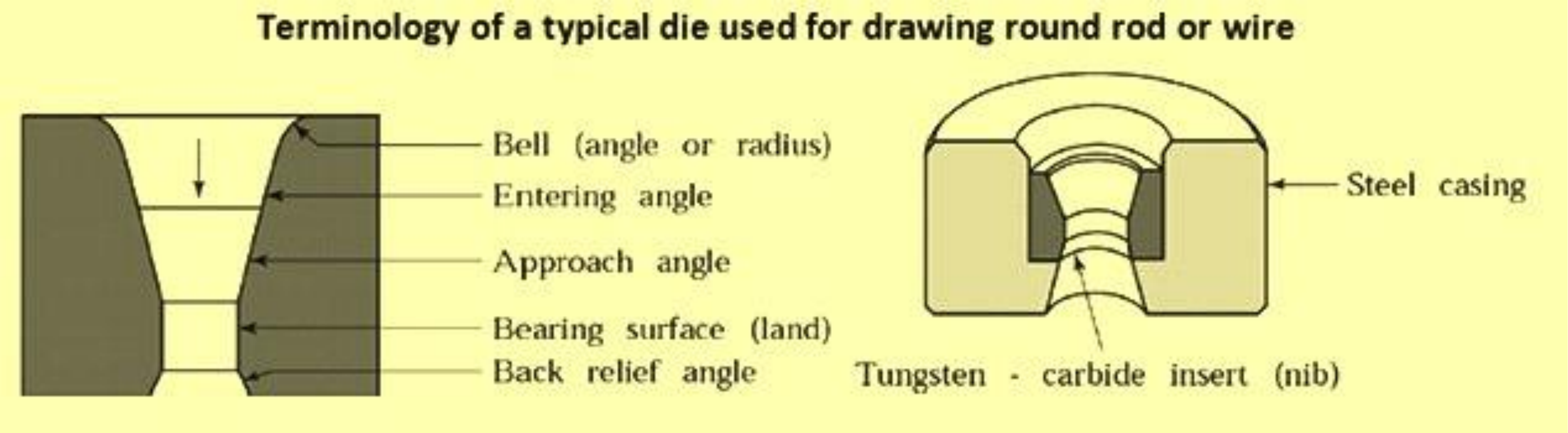
(iv) drawn wire/rod properties gets improved due to cold working, and

(v) wire temper can be controlled by swaging, drawing, and annealing treatments.

Drawing Process

- Before the actual drawing, the material to be drawn is properly prepared. This involves three steps namely (i) annealing, (ii) cleaning, and (iii) pointing.
- The purpose of annealing is to increase the ductility of the starting material to accept deformation during drawing. Annealing is also sometimes needed between steps in continuous drawing.
- Cleaning of the wire rods/rounds is required to prevent damage of the work surface and draw die. It involves removal of surface contaminants (e.g., scale and rust) by means of chemical pickling or shot blasting. In some cases, pre-lubrication of the work surface is accomplished subsequent to cleaning.
- Pointing involves the reduction in diameter of the starting end of the wire rods/rounds so that they can be inserted through the draw die to start the process. This is usually accomplished by swaging, rolling, or turning. The pointed end of the wire rods/rounds is then gripped by the carriage jaws or other device to initiate the drawing process.

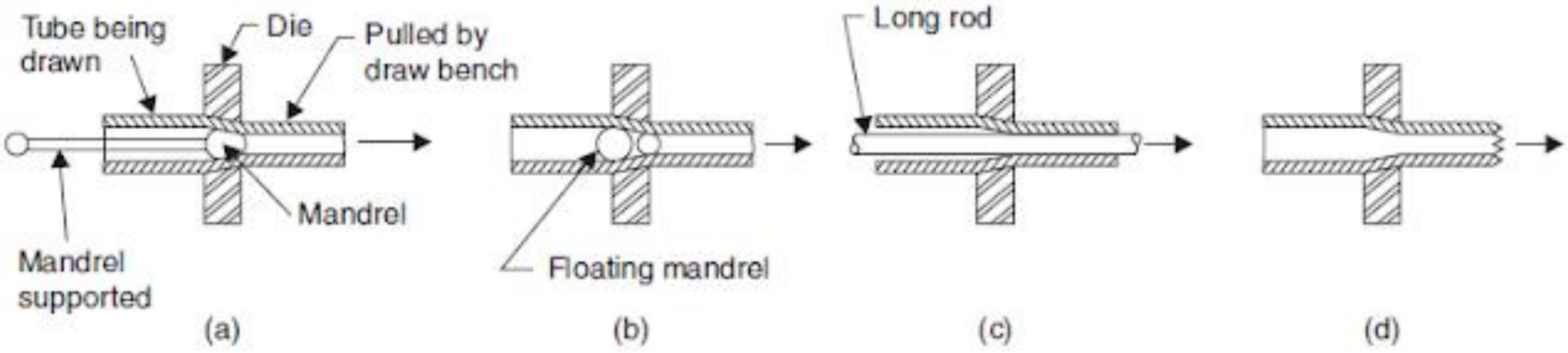
Terminology of a typical die



- A typical draw die has four distinguishing regions. These regions are (i) entry, (ii) approach angle, (iii) bearing surface (land), and (iv) back relief.
- The entry region is usually a bell-shaped mouth that does not contact the work. Shape of the bell causes hydrostatic pressure to increase and promotes the flow of lubricant into the die and prevents scoring of wire rod/round being drawn and die surfaces.
- The approach is where the drawing process occurs. It is cone-shaped with an angle (half angle) normally ranging from around 6 degrees to 20 degrees. The proper angle varies according to wire rod/round material.
- The bearing surface, or land, determines the size of the final drawn wire/rod. It produces a frictional drag on the wire/rod and also removes surface damage due to die wear, without changing dimensions.
- Finally, the back relief is the exit zone. It is provided with a back relief angle (half-angle) of around 30 degrees. The back relief allows the steel material to expand slightly as the wire leaves the die and also minimizes abrasion if the drawing stops or the die is out of alignment.

TUBE DRAWING

The ‘drawing’ process can also be used for tube drawing. Tube drawing does not mean manufacturing a tube from solid raw material. It means lengthening a tube reducing its diameter. Various arrangements used for tube drawing are shown in Figure.



Tube drawing is also similar to other two processes except it uses a mandrel to reduce wall thickness and cross section diameter of a tube. This mandrel placed with die and the work piece is pulled by a carriage system as describe in rod drawing. The tube is either circular or rectangular. It also required more than one pass to complete drawing operation.

Drawing defects

- Defects in the drawn wire/rod can be either due to the defects in the starting material (seams, slivers and pipe) or can be introduced by the deformation process.
- Typical defects in a drawn wire/rod are centre cracking.
- The defect centre burst or cracking (cupping) occurs for low die angles at low reductions. Centre cracks can occur in drawn products due to larger die angle, lower reduction per pass, and friction etc.
- Another major type of defect in drawing is seams, which are longitudinal scratches or folds in the material. Seams can open up during subsequent forming operations (such as upsetting, heading, thread rolling, or bending of the rod or wire), and they can cause serious quality-control problems.
- Various other surface defects (such as scratches and die marks) also can result from improper selection of the process parameters, poor lubrication, or poor die condition.