LECTURE NOTES

Module-IV

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SYLLABUS (BPUT)

5th Semester

PC 11: Basic Manufacturing Processes

MODULE - I (10 LECTURES)

Foundry: Types of patterns, pattern materials and pattern allowances. Moulding Materials - sand moulding, metal moulding, investment moulding, shell moulding. Composition of molding sand, Silica sand, Zircon sand, binders, additives, Binders - clay, binders for CO2, sand, binder for shell moulding, binders for core sand. Properties of moulding sand and sand testing, Melting furnaces - cupola, resistance furnace, induction and arc furnace, Solidification of castings, design of risers and runners, feeding distance, centre line freezing resistance chills and chaplets. Degasification and inoculation of metals. Casting methods like continuous casting, centrifugal casting, disc casting. Casting defects.

MODULE – II (8 LECTURES)

Welding and cutting: Introduction to gas welding, cutting, Arc welding and equipment's. TIG (GTAW) and MIG (GMAW) welding, resistance welding and thermit welding. Weldablity Modern Welding methods like plasma Arc, Laser Beam, Electron Beam, Ultrasonic, Explosive and friction welding, edge preparation in butt welding. Brazing and soldering, welding defects. Destructive and non-destructive testing of castings and welding.

MODULE – III (08 LECTURES)

Brief introduction to powder metallurgy processes. Plastic deformation of metals: Variables in metal forming and their optimization. Dependence of stress strain diagram on Strain rate and temperature. Hot and cold working of metals, classification of metal forming processes.

Rolling: Pressure and Forces in rolling, types of rolling mills, Rolling defects. Forging: Smith Forging, Drop and Press forging, M/c forging, Forging defects.

MODULE – IV (08 LECTURES)

Extrusions: Direct, Indirect, Impact and Hydrostatic extrusion and their applications, Extrusion of tubes. Wire drawing methods and variables in wire-drawing, Optimum dies shape for extrusion and drawing. Brief introduction to sheet metal working: Bending, Forming and Deep drawing, shearing. Brief introduction to explosive forming, coating and deposition methods.

BOOKS

[1] Manufacturing technology by P.N.Rao, Tata McGraw Hill publication.
[2] Welding Technology by R.A. Little, TMH
[3] Manufacturing Science by A.Ghosh and A K Malick, EWP
[4] Fundamentals of metal casting technology by P.C. Mukherjee, Oxford PIBI.
[5] Mechanical Metallurgy by Dieter, Mc-Graw Hill
[6] Processes and Materials of Manufacture by R.A Lindberg, Prentice hall (India)
[7] A Text Book of Production Engineering by P.C.Sharma, S.Chand.

Digital Learning Resources:

NPTEL MOOCs:

Course Name: Fundamentals of Manufacturing Processes

Course Link: https://nptel.ac.in/courses/108/102/108102047/

Module – IV

Extrusion and sheet metal works

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Module IV Extrusion and sheet metal works

Extrusion is a method of forming in which metals or plastics are forced through a die or series of dies, resulting in a specific shape of constant cross section. With the proper tooling, extrusions may be tapered or stepped. Extrusions can be either very thick in cross section or very thin and be either solid or hollow. The extruded stock, which can be 100 feet in length or longer, is then cut to a convenient stock size and used as specific products, assembly components, or as raw stock material for further processing. Extrusion size is expressed as a circle size which relates to the smallest circle diameter which can enclose an extrusion's cross section.

Metal Extrusion

Metal extrusion processes may be performed hot, warm, or cold. Each method has its own unique operating parameters.

Hot Extrusion uses heated feedstock, called a billet, that ranges in temperature from 200° to 2,300° Fahrenheit, or 90° to 1,260° Celsius depending on the material. Aluminum is the most common hot extruded material, with billet temperatures ranging from 575° to 1,100° Fahrenheit, or300° to 600° Celsius.

Hot extrusion is always performed at temperatures much higher than the recrystallization temperature of the material to be extruded. The heated billet is confined in a container, force is applied and the billet is extruded through a die or dies. Hot extrusion is used to produce close tolerance dimensions as well as smooth, fine surfaces. Additionally, and depending on the metal used, improved microstructures are obtained. The process is also very economical in that most of the metal extruded is usable.

The primary type of hot extrusion is direct, or forward, extrusion. Direct extrusion is commonly performed in horizontal hydraulic presses. The heated billet is loaded into a thick-walled container from which it is pushed through the extrusion die by a ram. Between the ram and the billet is an intermediate dummy block. Lubrication is used to reduce friction along the billet length and its container. In operation, force increases rapidly as the billet is upset to fill the container, then increases further as breakthrough force before extrusion begins. Upon breakthrough, the force declines as billet length decreases until a minimum force is reached. as the billet thins, the force rapidly rises again to continue metal flow radially toward the die opening.

Hot extrusion presses are rated in force capacity which relates to available ram pressure on the billet. Ram pressure requirements are based upon:

- Billet material and temper
- Cross section dimensions
- Complexity of the extrusion
- Extrusion length and temperature
- Another factor in determining ram force requirements is the extrusion ratio. This is determined by dividing the cross sectional area of the container liner by the cross sectional area of the die openings.

Warm and Cold Extrusion Processes

Warm extrusion refers to the extruding of feedstock or billet while it is above room temperature, but well below the recrystallization temperatures used in hot extrusion. Cold extrusion refers to extrusion at room temperatures. Because the feedstock is at lower temperatures, no micro- structural changes occur during processing. Warm and cold extrusion processes increase the strength and hardness of the finished extrusion. Reduced heat also lowers pollution concerns and eliminates costly high temperature tooling. While virtually all metals may be warm and cold extruded, those having the highest ductility are more suited for processing. Warm and cold extrusion processes are commonly integrated into continuous and semi-continuous manufacturing operations, with the three primary methods including:

- Indirect extrusion
- Combination extrusion
- Impact extrusion

Indirect extrusion, which is also called backward extrusion, is used to produce hollow shapes with the inside diameter defined by the male punch and the outside diameter controlled by the female die. Combination extrusion combines various types of extruding including direct and indirect methods to produce more complex shapes. Impact extrusion is similar to the other extrusion methods described, but is a much faster process. Using shorter strokes and shallower dies, punch impact moves the feedstock slug either up, down, or in both directions at once, without being completely confined by either the punch or die walls. Ductile and low melting point metals such as tin, aluminum, zinc, and copper are well suited for impact extruding.

Types of extrusion:

Extrusion ratio: It is the ratio of area of cross-section of the billet to the areaof cross-section of the extrude. R = Ao/Af

Another parameter used in extrusion is shape factor, ratio of perimeter tothe cross-section of the part. An extruded rod has the lowest shape factor. Extrusion is classified in general into four types. They are:

- Direct extrusion,
- indirect extrusion,
- impact extrusion and
- hydrostatic extrusion.

In extrusion process, the billet is placed in a container, pushed through thedie opening using a ram and dummy block. Both ram and billet move.

Direct extrusion:

Direct extrusion, also called forward extrusion, is a process in which is the billet moves along the same direction as the ram and punch do. Sliding of billet is against stationary container wall.Friction between the container and billet is high. As a result, greater forces are required. A dummy block of slightly lower diameter than the billet diameter is used in order to prevent oxidation of the billet in hot extrusion. Hollow sections like tubes can be extruded by direct method, by using hollow billet and a mandrel attached to the dummy block.

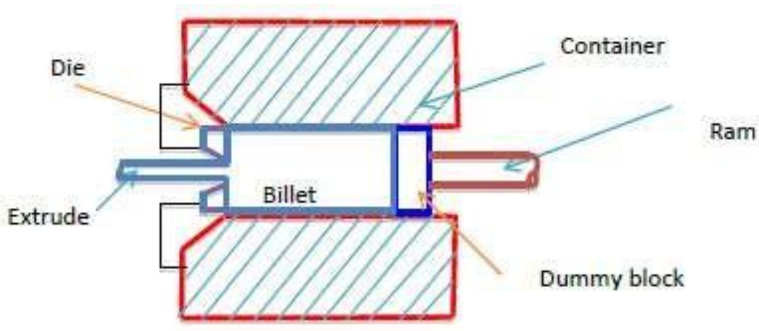


Fig: Direct Extrusion

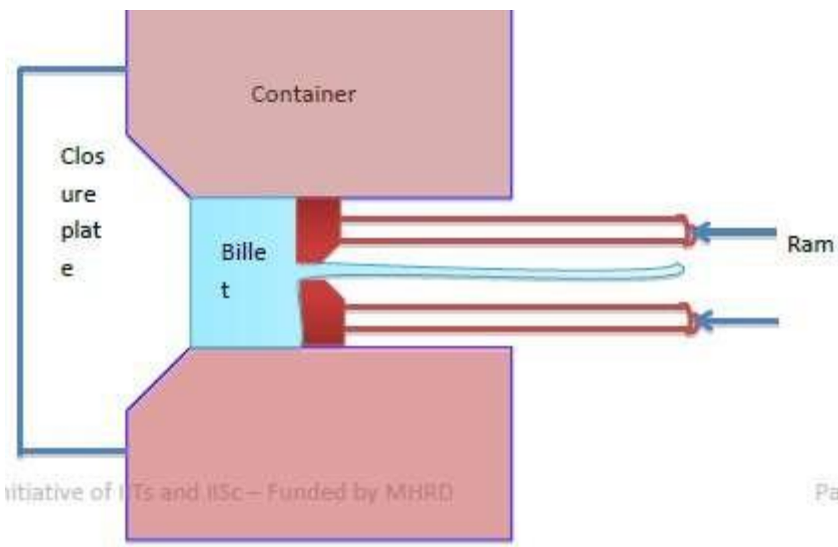


Fig: Indirect Extrusion

Indirect extrusion (backward extrusion) is a process in which punch moves opposite to that of the billet. Here there is no relative motion between container and billet. Hence, there is less friction and hence reduced forces are required for indirect extrusion. For extruding solid pieces, hollow punch is required. In hollow extrusion, the material gets forced through the annular space between the solid punch and the container. The variation of extrusion pressure in indirect extrusion is shown above. As seen, extrusion pressure for indirect extrusion is lower than that for direct extrusion. Many components are manufactured by combining direct and indirect extrusions. Indirect extrusion can not be used for extruding long extrudes.

Hydrostatic extrusion:

In hydrostatic extrusion the container is filled with a fluid. Extrusion pressure is transmitted through the fluid to the billet. Friction is eliminated inthis process because of there is no contact between billet and container wall. Brittle materials can be extruded by this process. Highly brittle materials can be extruded into a pressure chamber. Greater reductions are possible by this method. Pressure involved in the process may be as high as 1700 MPa. Pressure is limited by the strength of the container, punch and die materials. Vegetable oils such as castor oil are used. Normally this process is carried out at room temperature. A couple of disadvantages of the process are: leakage of pressurized oil and uncontrolled speed of extrusion at exit, due to release of stored energy by the oil. This may result in shock in the machinery.

This problem is overcome by making the punch come into contact with the billet and reducing the quantity of oil through less clearance between billet and container. Hydrostatic extrusion is employed for making aluminium or copper wires-especially for reducing their diameters. Ceramics can be extruded by this process. Cladding is another application of the process. Extrusion ratios from 20 (for steels) to as high as 200 (for aluminium) can be achieved in this process.

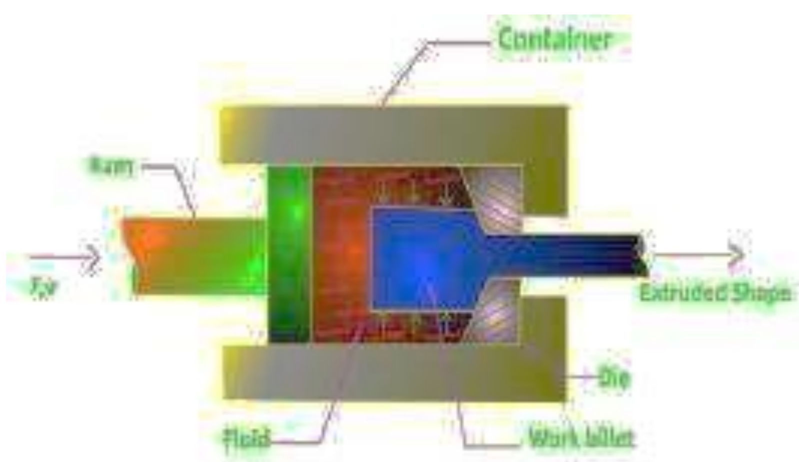


Fig: Hydrostatic Extrusion

Impact extrusion: Hollow sections such as cups, toothpaste containers are made by impact extrusion. It is a variation of indirect extrusion. The punch is made to strike the slug at high speed by impact load. Tubes of small wall thickness can be produced. Usually metals like copper, aluminium, lead are impact extruded.

Tube extrusion:

Employing hollow billet and a mandrel at the end of the ram, hollow sections such as tubes can be extruded to closer tolerences. The mandrel extends upto the entrance of the die. Clearance between the mandrel and die wall decides the wall thickness of the tube. The mandrel is made to travel alongwith the ram in order to make concentric tubes by extrusion.

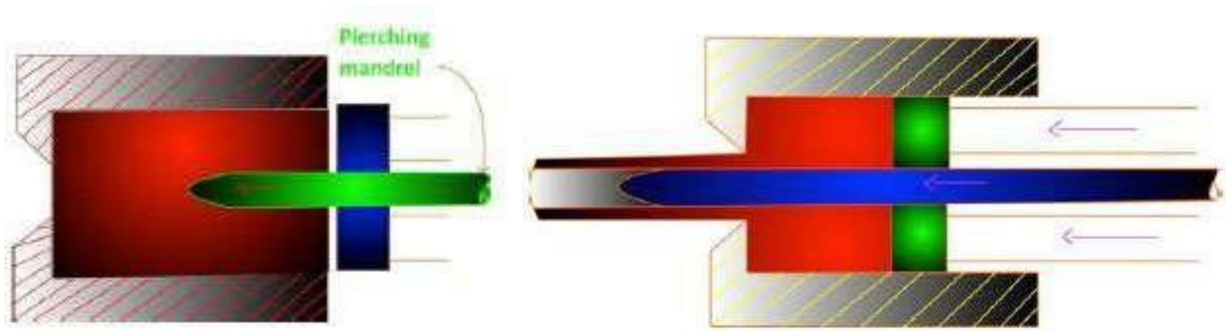
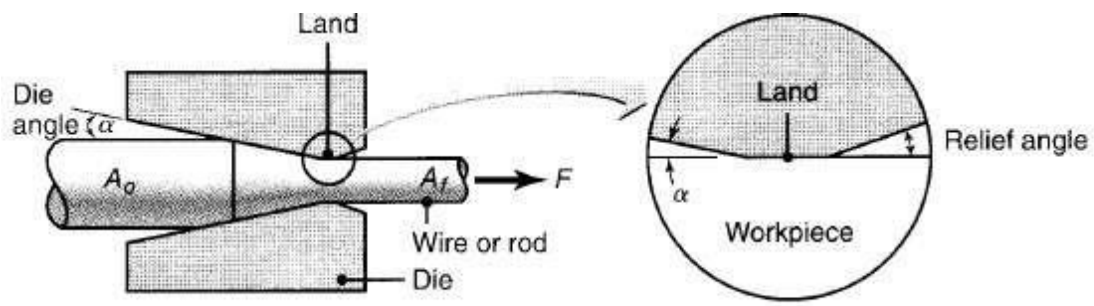


Fig. Tube extrusion

Tubes can also be made using solid billet and using a piercing mandrel to produce the hollow. The piercing mandrel is made to move independently with the help of hydraulic press. It moves along with the ram coaxially. First the ram upsets the billet, keeping the mandrel withdrawn. Next the mandrel pierces the billet and ejects a plug of material from central. Then the ram and mandrel together are moved in and extrude the billet.

Wire Drawing

In drawing, the cross section of a long rod or wire is reduced or changed by pulling (hence the term drawing) it through a die called a draw die (Fig. 7.1). 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 because the metal is squeezed down as it passes through the die opening. For this reason, the deformation that occurs in drawing is sometimes referred to as indirect compression. Drawing is a term also used in sheet metalworking. The term wire and bar drawing is used to distinguish the drawing process discussed here from the sheet metal process of the same name. Rod and wire products cover a very wide range of applications, including shafts for power transmission, machine and structural components, blanks for bolts andrivets, electrical wiring, cables,..Etc.



Process variables in wire drawing. The die angle, the reduction in cross sectional area per pass, the speed of drawing, the temperature and the lubrication all affect the drawing force, F.

The major processing variables in drawing are similar to those in extrusion that is, reduction in cross-sectional area, die angle, friction along the die- workpiece interface, and drawing speed.

The die angle influences the drawing force and the quality of the drawn product. The basic difference between bar drawing and wire drawing is the stock size that is processed. Bar drawing is the term used for large diameter bar and rod stock, while wire drawing applies to small diameter stock. Wire sizes down to 0.03 mm (0.001 in) are possible in wire drawing. Bar drawing is generally accomplished as a single-draft operation—the stock is pulled through one die opening. Because the beginning stock has alarge diameter, it is in the form of a straight cylindrical piece rather than coiled.

This limits the length of the work that can be drawn. By contrast, wire is drawn from coils consisting of several hundred (or even several thousand) feet of wire and is passed through a series of draw dies. The number ofdies varies typically between 4 and 12. In a drawing operation, the change in size of the work is usually given by the area reduction, defined asfollows:

$$r = \frac{A_o - A_f}{A_o}$$

Where r=area reduction in drawing; Ao=original area of work, mm2 (in2); and Af=final area, mm2 (in2). Area reduction is often expressed as a percentage.

In bar drawing, rod drawing, and in drawing of large diameter wire for upsetting and heading operations, the term draft is used to denote the before and after difference in size of the processed work. The draft is simply the difference between original and final stock diameters:

$$d = D_o - D_f$$

Where d = draft, mm (in); Do = original diameter of work, mm (in); and Df = final work diameter, mm (in).

Tube Drawing:

Drawing can be used to reduce the diameter or wall thickness of seamless tubes and pipes, after the initial tubing has been produced by some other process such as extrusion. Tube drawing can be carried out either with or without a mandrel. The simplest method uses no mandrel and is used for diameter reduction, as in Figure given below. The term tube sinking is sometimes applied to this operation.

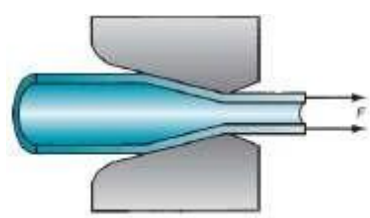
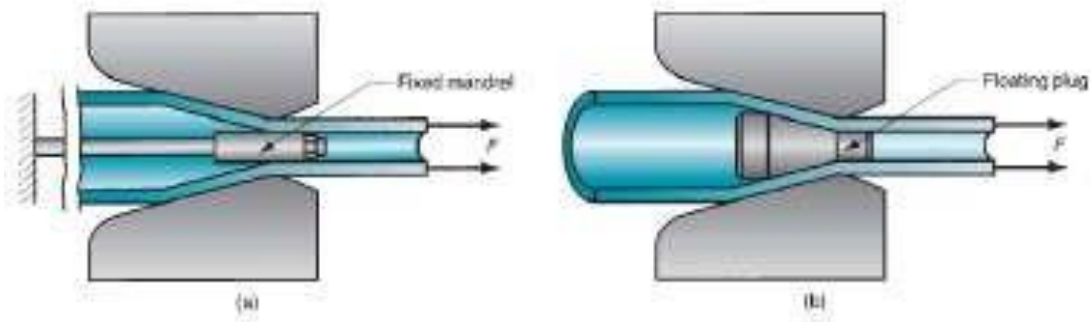


Fig. Tube drawing with no mandrel

The problem with tube drawing in which no mandrel is used, as in Figure above, is that it lacks control over the inside diameter and wall thickness of the tube. This is why mandrels of various types are used, two of which are illustrated in Figure below. The first, Figure (a) uses a fixed mandrel attached to a long support bar to establish inside diameter and wall thickness during the operation. Practical limitations on the length of the support bar in this method restrict the length of the tube that can be drawn. The second type, shown in (b), uses a floating plug whose shape is designed so that it finds a ‘‘natural’’ position in the reduction zone of the die. This method removes the limitations on work length present with the fixed mandrel.



Fixed mandrel **Floating plug**

Drawing Equipment:

Bar drawing is accomplished on a machine called a draw bench, consisting of an entry table, die stand (which contains the draw die), carriage, and exit rack.

The arrangement is shown in Figure below.The carriage is used to pull the stock through the draw die. It is powered by hydraulic cylinders or motor- driven chains. The die stand is often designed to hold more than one die, so that several bars can be pulled simultaneously through their respective dies.

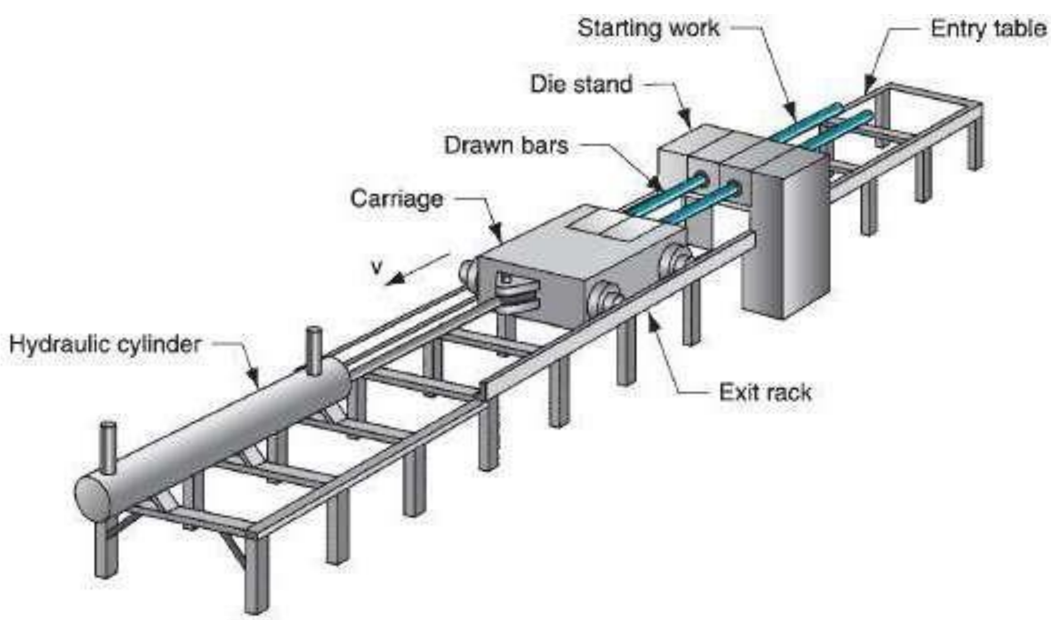
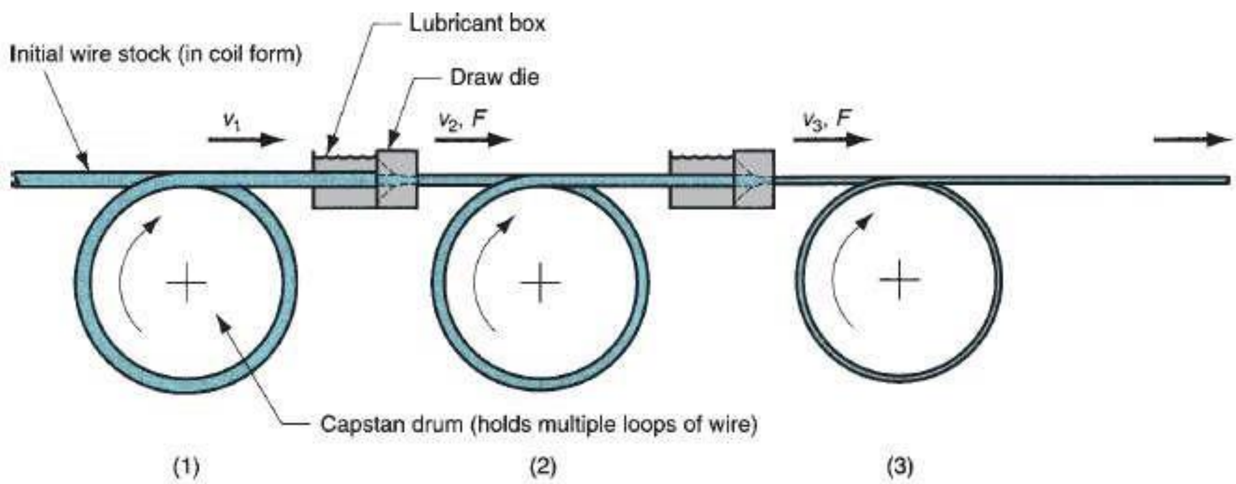


Fig. Hydraulically operated draw bench for drawing metal bars

Wire drawing is done on continuous drawing machines that consist ofmultiple draw dies, separated by accumulating drums between the dies, as in Figure 7.5. Each drum, called a capstan, is motor driven to provide the proper pull force to draw the wire stock through the upstream die. It also maintains a modest tension on the wire as it proceeds to the next draw die in the series. Each die provides a certain amount of reduction in the wire, so that the desired total reduction is achieved by the series. Depending on the metal to be processed and the total reduction, annealing of the wire is sometimes required between groups of dies in the series.



Draw Dies:

Figure given below identifies the features of a typical draw die. Four regions of the die can be distinguished: (1) entry, (2) approach angle, (3) bearing surface (land), and (4) back relief. The entry region is usually a bell-shaped mouth that does not contact the work. Its purpose is to funnel the lubricant into the die and prevent scoring of work and die surfaces.

The approach is where the drawing process occurs. It is cone-shaped with an angle (half angle) normally ranging from about 6◦ to 20◦. The proper angle varies according to work material. The bearing surface, or land, determines the size of the final drawn stock. Finally, the back relief is the exit zone. It is provided with a back relief angle (half-angle) of about 30◦. Draw dies are made of tool steels or cemented carbides. Dies for high-speed wire drawing operations frequently use inserts made of diamond (both synthetic and natural) for the wear surfaces.

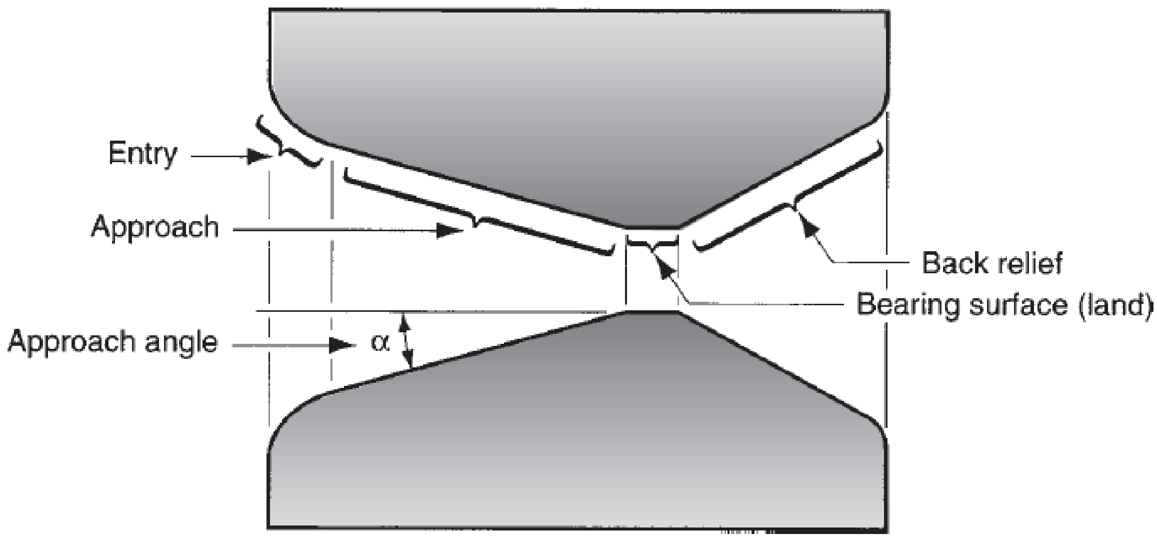
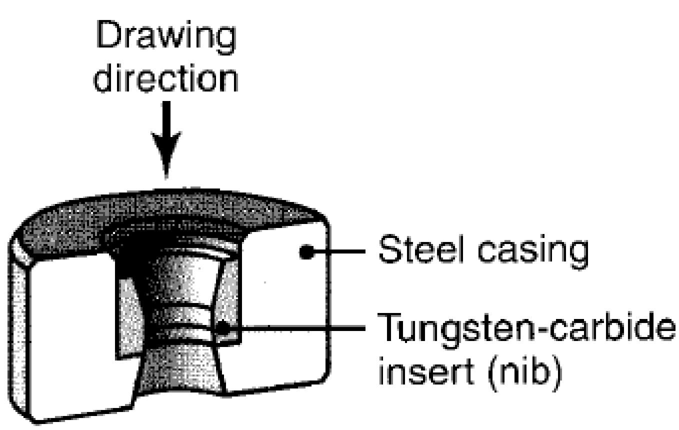


Fig. Draw die for drawing of round rod or wire.

Die Material:

Die materials for drawing typically are tool Steels and carbides. For hot drawing, cast-steel dies are used because of their high resistance to wear at elevated temperatures. Diamond dies are used for drawing fine wire with diameters ranging from 2 μm to 1.5 mm. They may be made from a single- crystal diamond or in polycrystalline form with diamond particles in a metal matrix (compacts). Because of their very low tensile strength and toughness, carbide and diamond dies typically are used as inserts or nibs, which are supported in a steel casing.



Drawing Defects and Residual Stresses

Typical defects in a drawn rod or wire are **similar to those observed in extrusion** especially center cracking another major type of defect in drawing is **seams**, which are longitudinal scratches or folds in the material. Seams may 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 selectionof the process parameters, poor lubrication, or poor die condition.

Because they undergo nonuniform deformation during drawing, cold-drawn products usually have residual stresses. For light reductions, such as only a few percent, the longitudinal-surface residual stresses are compressive (while the bulk is in tension) and fatigue life is thus improved. Conversely, heavier reductions induce tensile surface stresses (while the bulk is in compression). Residual stresses can be significant in causing stress- corrosion cracking of the part over time. Moreover, they cause the component to warp if a layer of material subsequently is removed such as by slitting, machining, or grinding.

Rods and tubes that are not sufficiently straight (or are supplied as coil) can be straightened by passing them through an arrangement of rolls placed at different axe.

SHEET METAL WORKING

Sheet metal is simply metal formed into thin and flat pieces. It is one of the fundamental forms used in metalworking, and can be cut and bent into a variety of different shapes. Countless everyday objects are constructed of the material. Thicknesses can vary significantly, although extremely thin thicknesses are considered foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate.

Sheet metal processing

The raw material for sheet metal manufacturing processes is the output of the rolling process. Typically, sheets of metal are sold as flat, rectangular sheets of standard size. If the sheets are thin and very long, they may be in the form of rolls. Therefore the first step in any sheet metal process is to cut the correct shape and sized 'blank' from larger sheet.

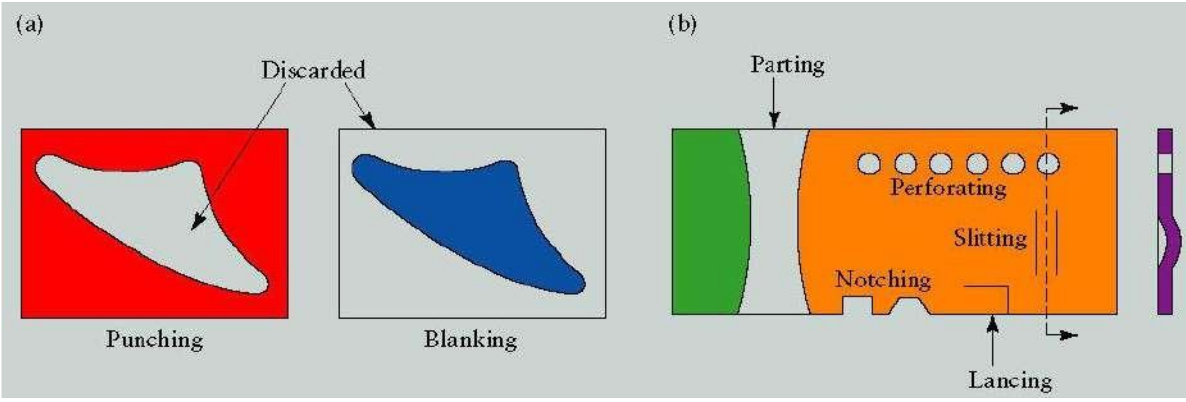
Sheet metal forming processes

Sheet metal processes can be broken down into two major classifications and one minor classification

- **Shearing processes** -- processes which apply shearing forces to cut, fracture, or separate the material.
- **Forming processes** -- processes which cause the metal to undergo desired shape changes without failure, excessive thinning, or cracking. This includes bending and stretching.
- **Finishing processes** -- processes which are used to improve the final surface characteristics.

Shearing Process

1. **Punching:** shearing process using a die and punch where the **interior** portion of the sheared sheet is to be **discarded.**
2. **Blanking:** shearing process using a die and punch where the **exterior** portion of the shearing operation is to be **discarded**.
3. **Perforating**: punching a number of holes in a sheet
4. **Parting:** shearing the sheet into two or more pieces
5. **Notching:** removing pieces from the edges
6. **Lancing:** leaving a tab without removing any material



Shearing Operations: Punching, Blanking and Perforating

Forming Processes

- **Bending:** forming process causes the sheet metal to undergo the desired shape change by bending without failure. Ref fig.2 & 2a
- **Stretching:** forming process causes the sheet metal to undergo the desired shape change by stretching without failure. Ref fig.3
- **Drawing:** forming process causes the sheet metal to undergo the desired shape change by drawing without failure.
- **Roll forming:** Roll forming is a process by which a metal strip is progressively bent as it passes through a series of forming rolls.

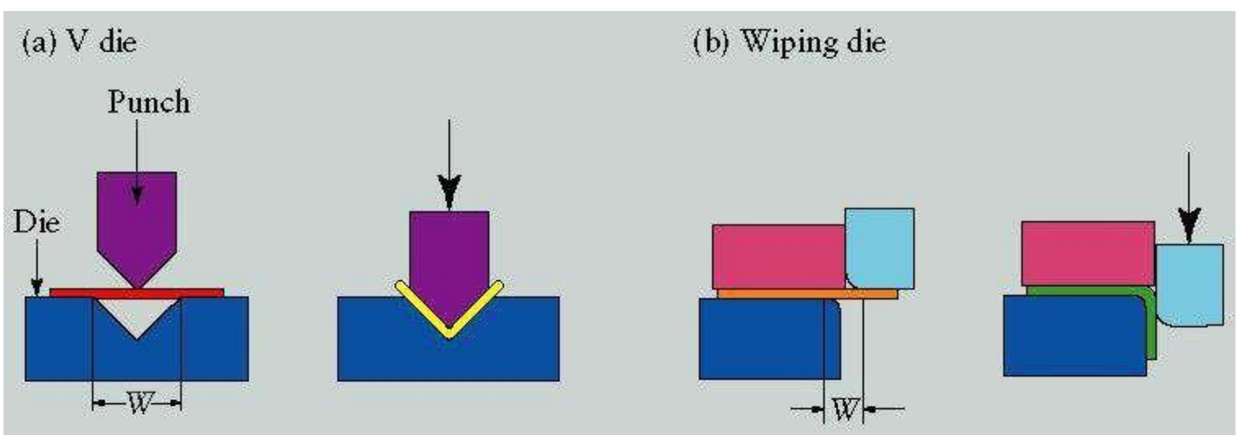


Fig. Common Die-Bending Operations

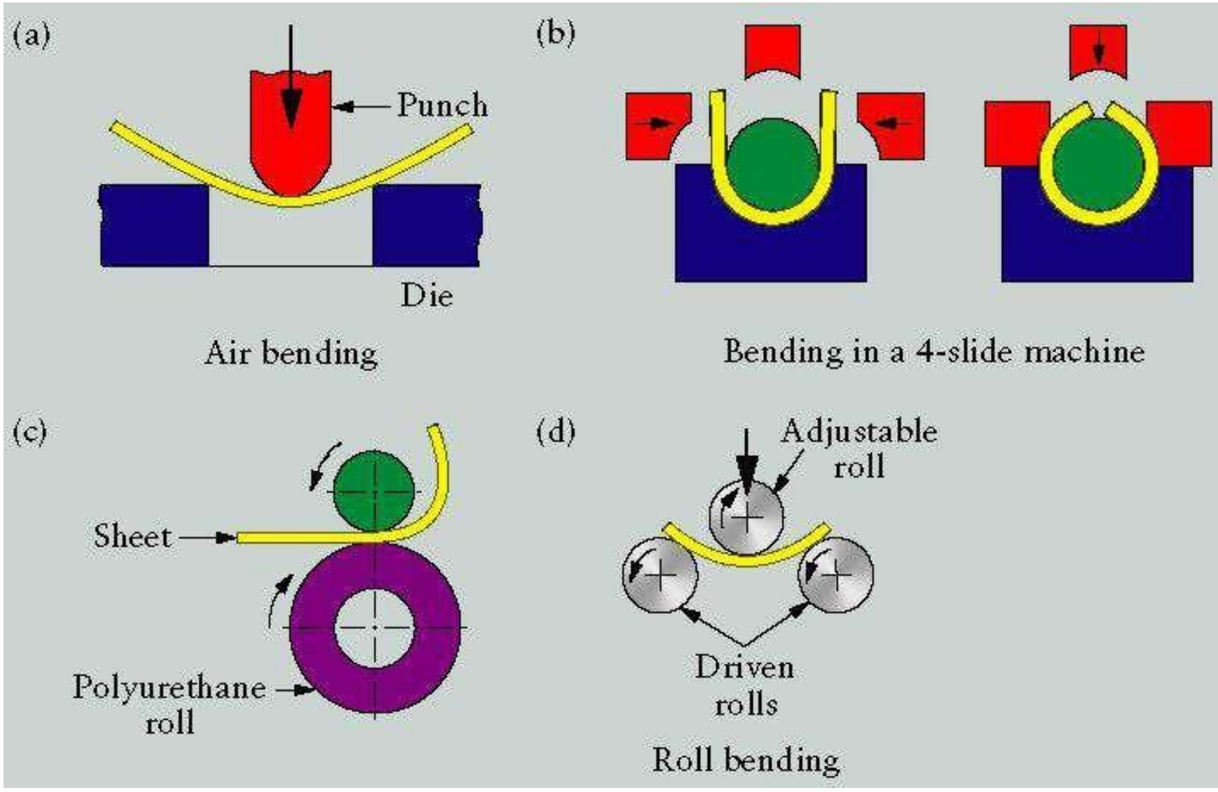


Fig. Common Die-Bending Operations (Various Bending Operations)

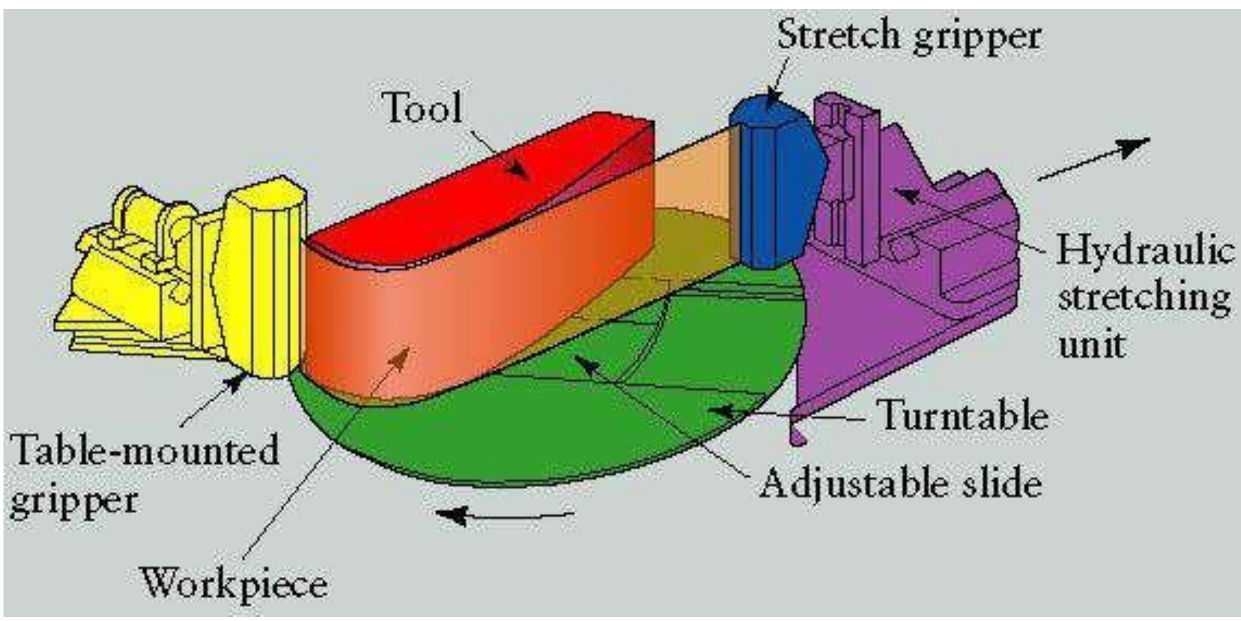


Fig. Schematic illustration of a stretch-forming process.

Merits

- High strength
- Good dimensional accuracy and surface finish
- Relatively low cost

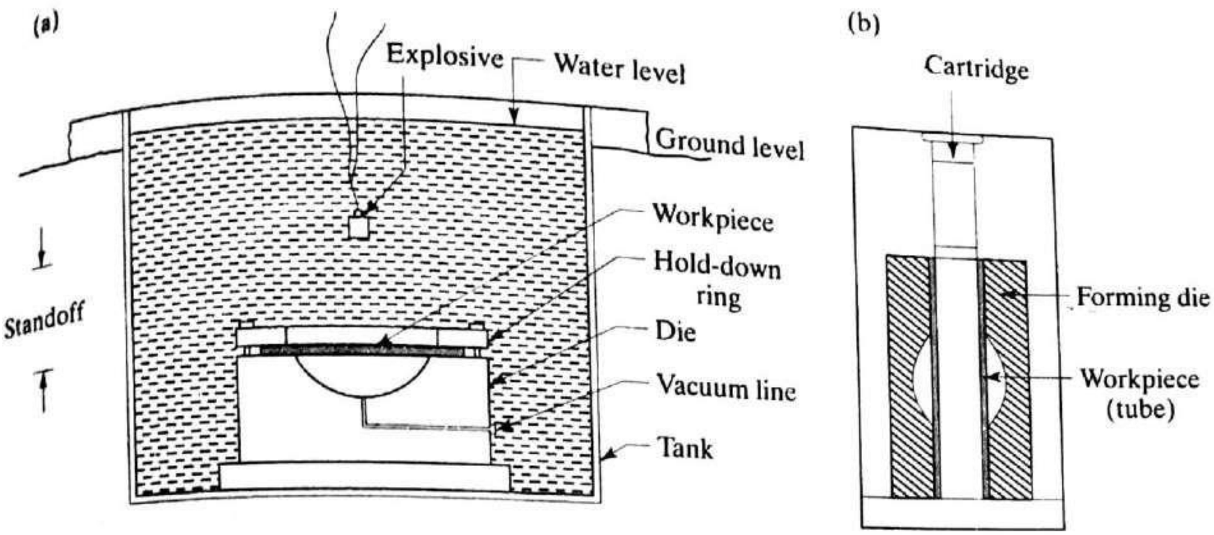
Demerits

- Wrinkling and tearing are typical limits to drawing operations
- Different techniques can be used to overcome these limitations
- Draw beads
- Vertical projections and matching grooves in the die andblank holder
- Trimming may be used to reach final dimensions

Applications

- Roofings
- Ductings
- Vehicles body buildings like 3 wheelers, 4 wheelers, ships,aircrafts etc.
- Furnitures, House hold articles and Railway equipment

Explosive forming is a metalworking technique in which an explosive charge is used instead of a punch or press. It can be used on materials for which a press setup would be prohibitively large or require an unreasonably high pressure, and is generally much cheaper than building a large enough and sufficiently high-pressure press; on the other hand, it is unavoidably an individual job production process, producing one product at a time and with a long setup time. The schematic diagram of explosive forming is shown below:



(a) Schematic illustration of the explosive forming process

(b) Illustration of the confined method of explosive bulging of tubes.

The energy was first utilized to form metals in early 1900s. Typically, in explosive forming the sheet metal blank is clamped over a die and the entire assembly is lowered into a tank filled with water. The air in the die cavity is evacuated, an explosive charge is placed at a certain height and the charge is detonated. The rapid conversion of the explosive charge into gas generates a shock wave. The pressure of this wave is sufficient to form sheet metals. The peak pressure P due to the explosion, generated in water is given by the expression

$$p = k\left(\frac{\sqrt[3]{W}}{R}\right)^{a}$$

Where, P is in psi, k is a constant which depends on the type of explosive, W is the weight of the explosive in pound, R is the distance of the explosive from the work piece surface(standoff) in feet and a is a constant, generally taken to be 1.15.

A veriety of shapes can be formed by the use of this process, provided thatthe material is ductile at the high rates of deformation characteristics of the explosive nature of the process. Explosive forming is versatile — there is virtually no limit to the size of the work-piece and it is particularly suitable for low quantity production runs of large parts, such as occur in aerospace applications.

Steel plates 25mm thick and 3.6m in diameter have been formed by this method. Tubes having walls as thick as 25mm have been bulged by explosive forming techniques.

The mechanical properties of the parts made by this process are basically the same as those of parts made by conventional forming methods.

Depending on the number of parts to be produced, dies may be made of alluminium alloy, reinforced concrete, wood, plastics or composite materials.

Applications

Some of the applications of explosive forming include:

- Sheet metal panels
- Tubing
- Housings
- Jet engine parts
- Missile nose cones
- Ducts

Materials for explosive forming

- Both ferrous and nonferrous metals including steel, aluminum, magnesium, and their alloys.
- Some metal matrix composites like aluminum matrix, copper matrix and lead matrix composites.

Process Variations

- Explosives can be placed at a fixed distance from the workpiece. After detonation the explosive forces travel through the intervening medium to reach the work piece. This method is called the standoff method.
- Alternatively, the explosive can be placed directly on the work piece. Upon detonation, explosive forces hit the work piece directly. This is called the contact method.

Design Considerations

- Section thickness at any point should be in the range of 1 mm to10mm.
- Tolerance of 0.25mm to 1mm should be provided.
- Surface roughness of 1.575mm to 12.3mm can be achieved.

Economic Considerations

- Slow production rate of 0.5 to 6 pieces per hour.
- High labor skills required.
- Low equipment costs, moderate tooling costs.
- Economical for batch production.

Quality Considerations

- Explosives contaminate the transfer media, which need to be cleaned each time for better quality and process control.
- It is difficult to control the mechanical properties and dimensions of the part.

Advantages

- Complex shapes can be produced.
- Smoothness of the contour can be controlled.
- Cheap alternative to Superplastic Forming.

Disadvantages

- Only viable for low production volumes.
- Handling explosives requires great care and safety precautions.

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