1.1.HOT EXTRUSION

It is the process of enclosing the heated billet or slug of metal in a closed cavity and then pushing it to flow from only one die opening so that the metal will take the shape of the opening. The pressure is applied either hydraulically or mechanically.

Tubes, rods, hose, casing, brass cartridge, moulding-trims, structural shapes, aircraft parts, gear profiles, cable sheathing etc. are some typical products of extrusion.

The intricacy in parts that can be obtained by extrusion is more than that of rolling, because the die required being very simple and easier to make. Also, extrusion is a single pass process unlike rolling. The amount of reduction that is possible in extrusion is large.

The extrusion setup consists of a cylinder container into which the heated billet or slug of metal is loaded. On one end of the container, the die plate with the necessary opening is fixed. From the other end, a plunger or ram compresses the metal billet against the container walls and the die plate, thus forcing it to flow through the die opening, acquiring the shape of the opening. The extruded metal is then carried by the metal handling system as it comes out of the die.

*The **extrusion ratio** is defined as the ratio of cross- sectional area of the billet to that of the extruded section*. The typical values of the extrusion ratio are 20 to 50.

Hot extrusion process is classified as:

1. **Direct or Forward Hot Extrusion:** The heated metal billet is placed into the die chamber and the pressure is applied through ram. The metal is extruded through die opening in the forward direction, i.e., the same as that of the ram. In forward extrusion, the problem of friction is prevalent. To reduce such friction, lubricants are to be commonly used. Fig 4.3 (a)

2. **Indirect or Backward Hot Extrusion:** The billet remains stationary while the die moves into the billet by the hollow ram (or punch), through which the backward extrusion takes place. Since, there is no friction force between the billet and the container wall, therefore, less force is required by this method. However, this process is not widely used because of the difficulty occurred in providing support for the extruded part. Fig. 4.3 (b)

3. **Tube Extrusion:** This process is an extension of direct extrusion process where additional mandrel is needed to restrict flow of metal for production of seamless tubes. Aluminum based toothpaste and medicated tubes are produced using this process. Fig. 4.4 (c and d)

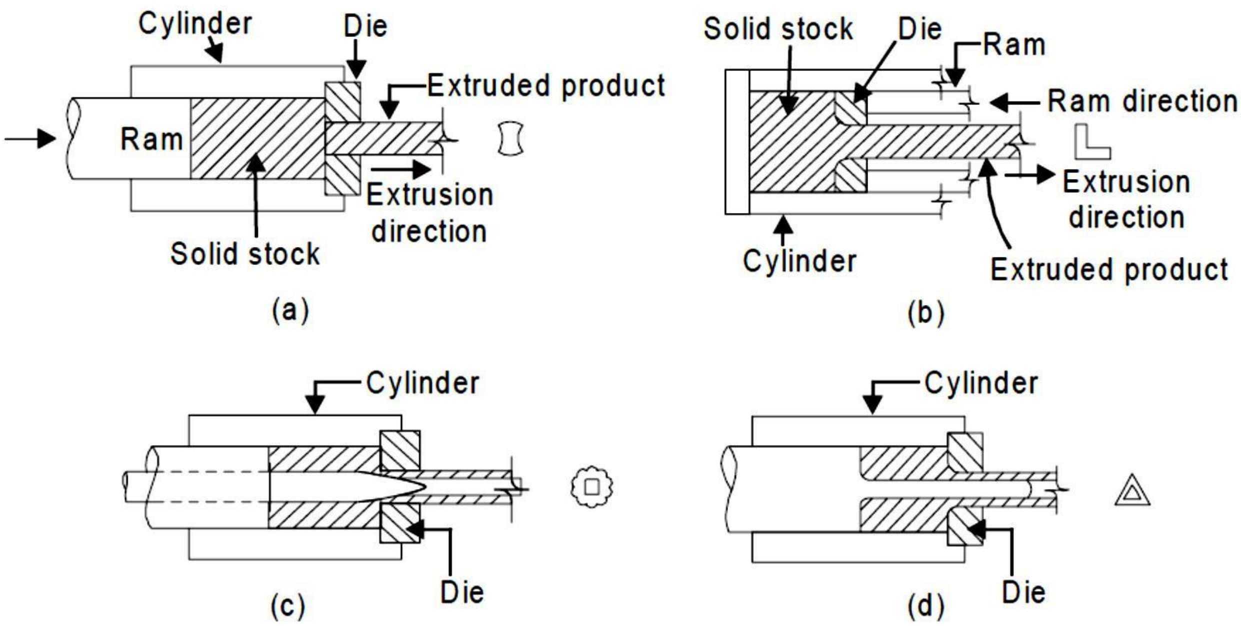


Fig. 1 Method of hot extrusion

4. **Impact Extrusion:** It is an extrusion process used to create metal products and objects via a press. It can be performed either with a mechanical press or a hydraulic press. Regardless, the press is responsible for forcing a metal slug through a die. The press will move the punch down onto the metal slug, thereby forcing the metal slug through the die. The metal slug will then take the physical properties of the die. After the metal slug has been forced through the die, it's removed via an ejector.

   Although there are other extrusion processes available, impact extrusion has become a popular choice among manufacturing companies. It's considered a cold-working process, meaning manufacturing companies don't need to heat the metal slug beforehand. The metal slug can be deformed at or near room temperature. Unlike many other extrusion processes, impact extrusion only requires a single impact.

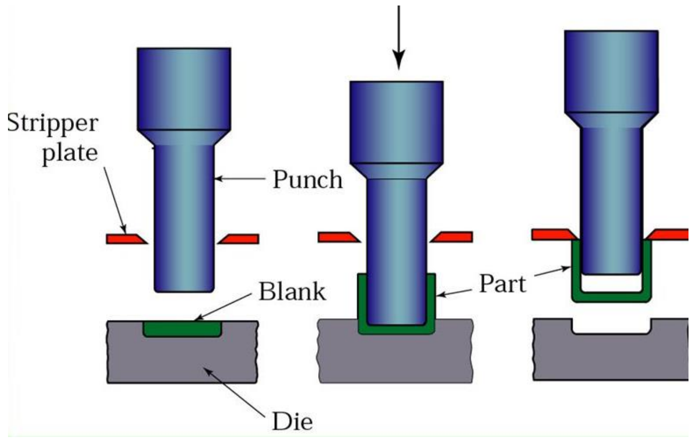
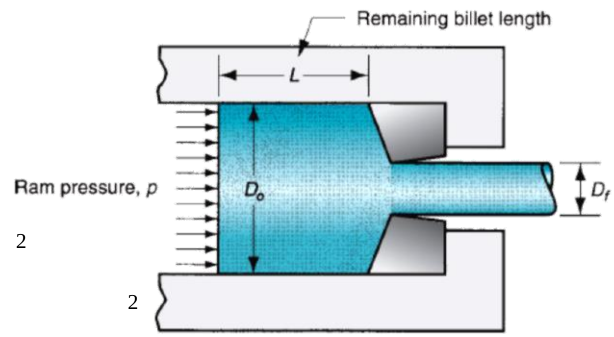


Fig. 2 Impact Extrusion

Analysis of Extrusion:



Extrusion ratio, also called the reduction ratio

$$r_x = \frac{A_\circ}{A_f}$$

A_o= cross-sectional area of the starting billet, mm^2

A_f = final cross-sectional area of the extruded section, mm^2

True Strain in extrusion

$$\epsilon = \ln r_x = \ln \frac{A_\circ}{A_f}$$

True Strain in extrusion -Johnson formula-

$$\epsilon_x = a + b \ln r_x$$

Where εx = extrusion strain; and
a and b are empirical constants for a given die angle (a = 0.8 and b = 1.2 to 1.5)

Pressure applied by the ram (without friction) (Indirect Extrusion)

$$p = \bar{Y}_f \epsilon_x$$

Where Yf = average flow stress during deformation, MPa

In direct extrusion: *the effect of friction between the container walls and the billet causes the ram pressure to be greater than for indirect extrusion.*

Pressure applied by the ram (with friction) (Direct Extrusion)

$$p = \bar{Y}_f \left(\epsilon_x + \frac{2L}{D_\circ} \right)$$

Where:

2L/Do accounts for the additional pressure due to friction L is the portion of the billet length remaining to be extruded and Do is the original diameter of the billet.

Ram force in indirect or direct extrusion

$$F = pA_\circ$$

Where Ao billet area

Example: A billet 75mm long and 25mmin diameter is to be extruded in a direct extrusion operation with extrusion ratio r_x = 4.0. The extrudate has a round cross section. The die angle (half angle) = 90°. The work metal has a strength coefficient = 415 MPa, and strain-hardening exponent = 0.18. Use the Johnson formula with a = 0.8 and b = 1.5 to estimate extrusion strain. Determine the pressure applied to the end of the billet as the ram moves forward.

Sol.:

Compute the ideal true extrusion strain using Johnson's formula.

$$\epsilon = \ln r_x = \ln 4.0 = 1.3863$$

$$\epsilon_x = 0.8 + 1.5(1.3863) = 2.8795$$

Calculate average flow stress (Y_f):

$$\bar{Y}_f = \frac{415(1.3863)^{0.18}}{1.18} = 373 \text{ MPa}$$

Let us examine the ram pressure at billet lengths of

L= 75mm (starting value),
L= 50 mm,
L=25 mm,
L= 0.

$$p = \bar{Y}_f \left(\epsilon_x + \frac{2L}{D_\circ}\right)$$

L=75mm, $$p = 373\left(2.8795 + 2\frac{75}{25}\right) = 3312\ \text{MPa}$$

L=50mm, $$p = 373\left(2.8795 + 2\frac{50}{25}\right) = 2566\ \text{MPa}$$

L=25mm, $$p = 373\left(2.8795 + 2\frac{25}{25}\right) = 1820\ \text{MPa}$$

L=0 mm, $$p = 373\left(2.8795 + 2\frac{0}{25}\right) = 1074\ \text{MPa}$$

Q1: A cylindrical billet is 200 mm long and 100 mm in diameter. It is reduced by indirect extrusion to a 30 mm diameter. Die angle = 90°. In the Johnson equation, a = 0.8 and b = 1.5. In the flow curve for the work metal, strength coefficient = 250 MPa and strain hardening exponent = 0.15. Determine (a) extrusion ratio, (b) true strain (homogeneous deformation), (c) extrusion strain, (d) ram pressure, and (e) ram force.

Q2: Solve the previous problem except direct extrusion is used instead of indirect extrusion. Determine (a) extrusion ratio, (b) true strain (homogeneous deformation), (c) extrusion strain, (d) ram pressure, and (e) ram force. Solve parts (d) and (e) at the following two billet lengths during the process: L = 175 mm and L = 25 mm.

Q3: A 5.0-in-long cylindrical billet whose diameter = 2.0 in is reduced by indirect extrusion to a diameter = 0.50 in. Die angle = 90°. In the Johnson equation, a = 0.8 and b = 1.5. The work metal is low-carbon steel with a strength coefficient = 75,000 lb/in^2 and strain hardening exponent = 0.25. Determine (a) extrusion ratio, (b) true strain (homogeneous deformation), (c) extrusion strain, (d) ram pressure, (e) ram force, and (f) power if the ram speed = 20 in/min.

Q4: An indirect extrusion operation is performed on an aluminum billet with diameter = 2.0 in and length = 8.0 in. Final shape after extrusion is a rectangular cross section that is 1.0 in by 0.25 in. Die angle = 90°. The aluminum has a strength coefficient = 26,000 lb/in^2 and strain-hardening exponent = 0.20. In the Johnson extrusion strain equation, a = 0.8 and b = 1.2. (a) Compute the extrusion ratio, true strain, and extrusion strain. (b) What is the shape factor of the extrudate? (c) If the butt left in the container at the end of the stroke is 0.5 in long, what is the length of the extruded section? (d) Determine the

YouTube: https://youtu.be/c_XphFhbHeE