Extrusion

Extrusion is a compression process in which the work metal is forced to flow through a die opening to produce a desired cross-sectional shape.

Advantages of process

① a variety of shapes are possible, especially with hot extrusion.

② grain structure and strength properties are enhanced in cold and warm extrusion.

③ fairly close tolerances are possible, especially in cold extrusion

④ in some extrusion operations, little or no wasted material is created.

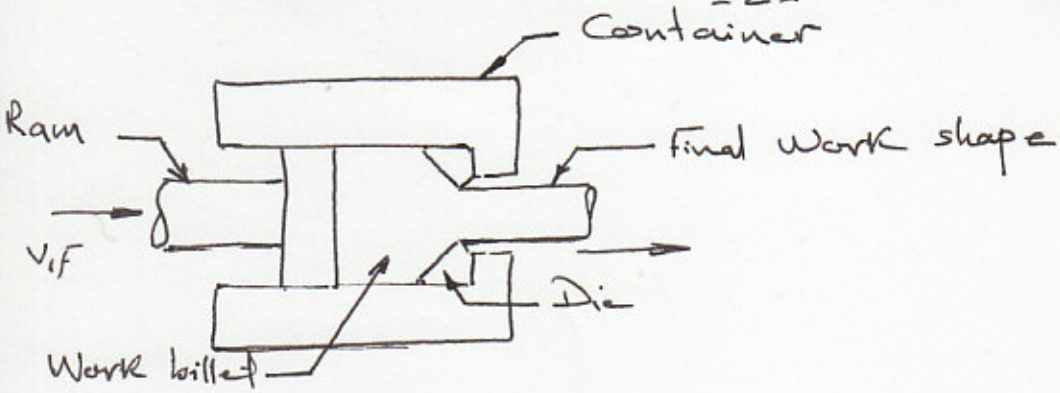
Direct Extrusion (forward)

A metal billet is loaded into a container, and a ram compresses the material, forcing it to flow through one or more openings in a die at the opposite end of the container.

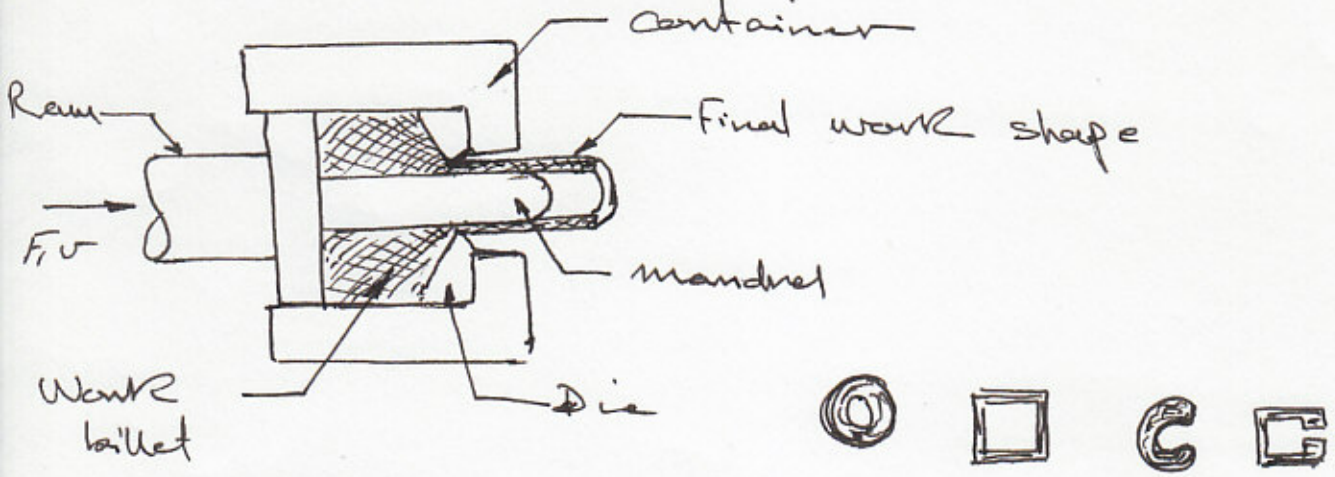
As the ram approaches the die, a small portion of the billet remains, which cannot be forced through the die opening. This extra portion, called the butt, is seperated from the product by cutting it just beyond the exit of the die

Significant friction that exists between the work surface and the walls of the container as the billet is forced to slide toward the die opening.

This friction causes a substantial increase in the ram force required in the direct extrusion.



Direct extrusion to produce solid cross-section

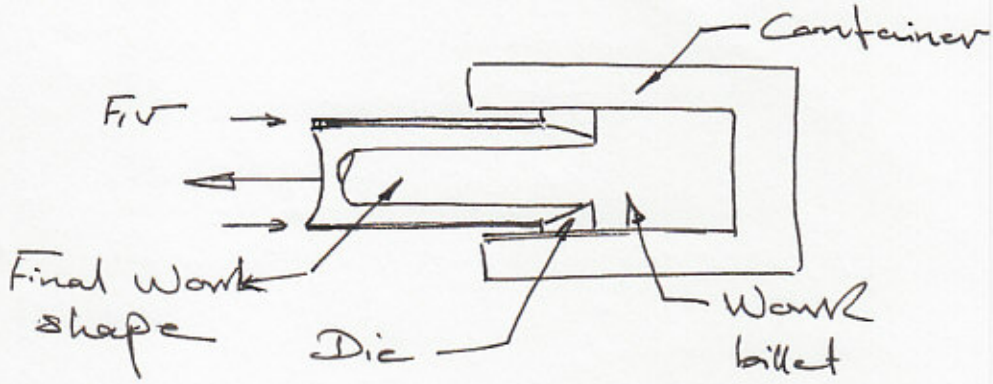


Direct extrusion to produce a hollow or semihollow cross-section

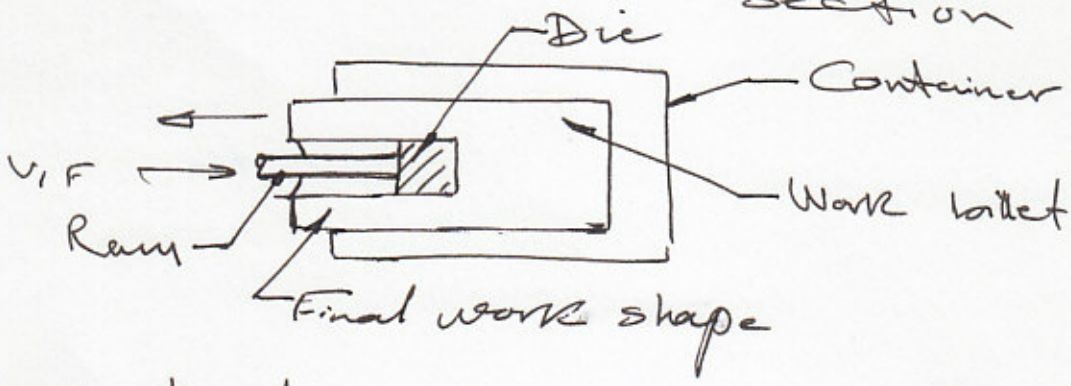
The starting billet in direct extrusion is usually round in cross-section, but the final shape is determined by the shape of the die opening.

In indirect Extrusion (backward) or (reverse) the die is mounted to the ram rather than at opposite end of the container. As the ram penetrates into the work, the metal is forced to flow through the clearance in a direction opposite to the motion of the ram. Since the billet is not forced to move relative to the container, there is no friction at the container walls, and the ram force is therefore lower than in direct extrusion.

Limitations (lower rigidity of the hollow ram and the difficulty in the supporting the extruded product as it exits the die.



Indirect extrusion to produce a solid cross-section



Indirect extrusion to produce a hollow cross-section.

Analysis of Extrusion

Extrusion ratio, $r_x = \frac{A_o}{A_f}$

True strain, $\epsilon = \ln r_x$

Ram pressure, $p = \bar{Y} \ln r_x$ (under ideal condition)

$\bar{Y}$ = average flow stress.

Extrusion is not a frictionless process. The friction effect to increased the strain in direct extrusion.

The following empirical eq produced by Johnson for estimating extrusion strain, ϵ_x

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

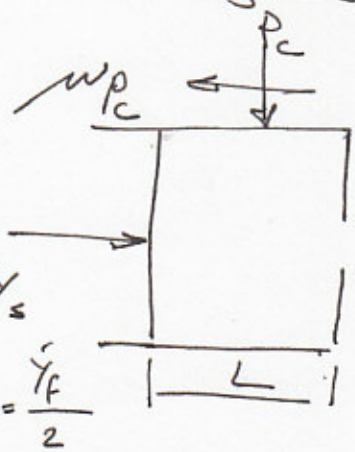
$a = 0.8$, $b = 1.2$ to 1.5

a & b are constant value

- The ram pressure to perform indirect extrusion, $p = \bar{Y}_f \epsilon_x$ ——— (*)

- 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

$$P_f \frac{\pi D_o^2}{4} = \mu P_c \pi D_o L$$



- Sticking occurs when friction stress = shear yield stress Y_s

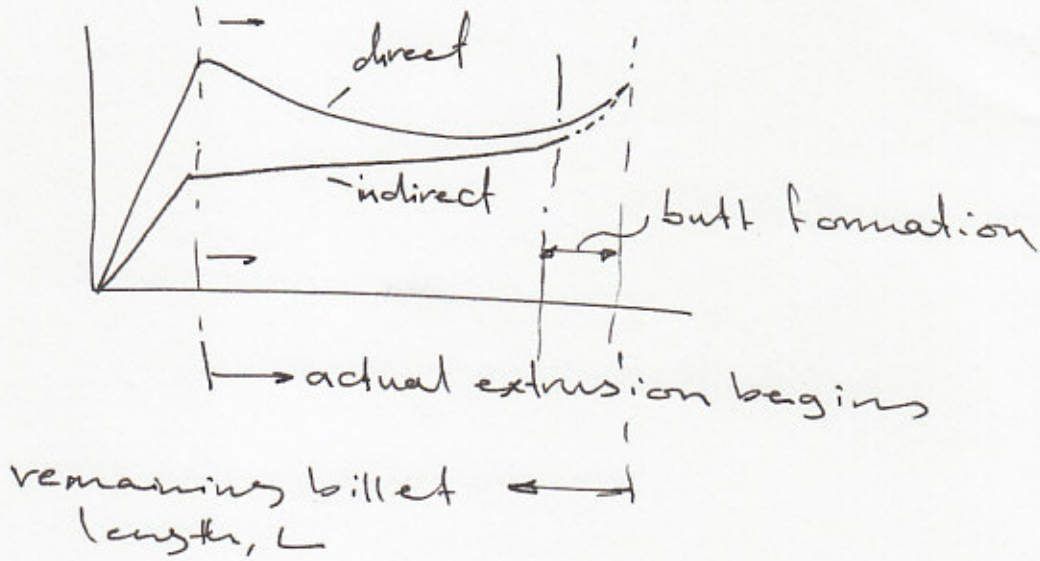
$$P_f \frac{\cancel{\pi} D_o^{\cancel{2}}}{4} = Y_s \cancel{\pi} \cancel{D_o} L$$

$$Y_s = \frac{\bar{Y}_f}{2}$$

$$P_f = \bar{Y}_f \frac{2L}{D_o}$$

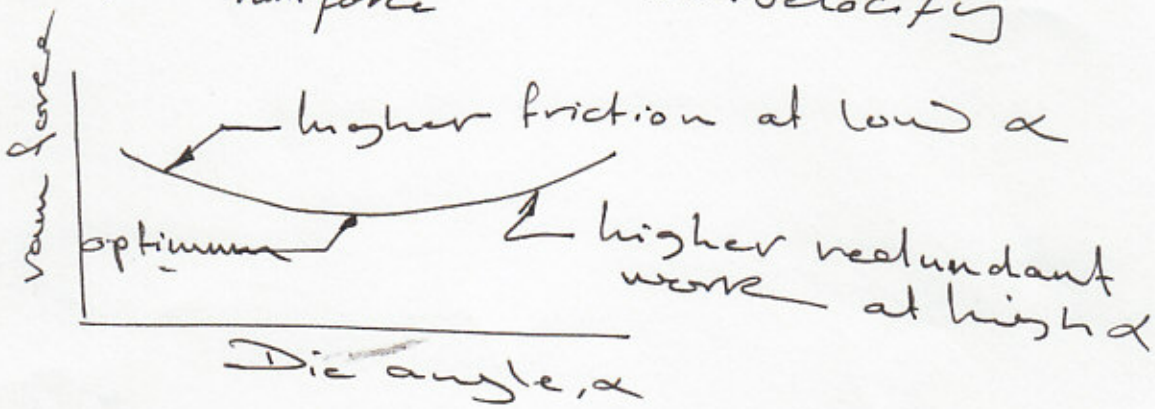
$$P_{direct} = P_{in} + P_f \Rightarrow P_{direct} = \bar{Y}_f \epsilon_x + \bar{Y}_f \frac{2L}{D_o} \Rightarrow \bar{Y}_f \left(\epsilon_x + \frac{2L}{D_o} \right).$$

Ram force, $F = PA_o$



Power required, $\underline{P} = F\,v$

ram force — ram velocity



- effect of die angle on ram force.

- effect of the die orifice shape

shape factor, $K_x = 0.98 + 0.02\left(\frac{C_x}{C_c}\right)^{2.25}$

(C_x/C_c) from 1.0 to about 6.0.

- Thin walled sections have higher shape factors and more difficult to extrude.

then $P = K_x\,\bar{Y}_f\,\epsilon_x$ — indirect

$P = K_x\,\bar{Y}_f\left(\epsilon_x + \frac{2L}{D_o}\right)$ — direct.