

Extrusion Dies and Presses

Important factors in an extrusion die are *die angle* and *orifice shape*. Die angle, more precisely die half-angle, is shown as in Figure 8 (a). For low angles, surface area of the die is large, leading to increased friction at the die–billet interface. Higher friction results in larger ram force. On the other hand, a large die angle causes more turbulence in the metal flow during reduction, increasing the ram force required. Thus, the effect of die angle on ram force is a U-shaped function, as in Figure 8 (b). An optimum die angle exists, as suggested by our hypothetical plot. The optimum angle depends on various factors (e.g., **work material, billet temperature, and lubrication**) and is therefore difficult to determine for a given extrusion job. Die designers rely on rules of thumb and judgment to decide the appropriate angle. Our previous equations for ram pressure, Eqs. (4-6), apply to a circular die orifice. The shape of the die orifice affects the ram pressure required to perform an extrusion operation. A complex cross section, such as the one shown in Figure 9, requires a higher pressure and greater force than a circular shape. The effect of the die orifice shape can be assessed by the die shape factor, defined as the ratio of the pressure required to extrude a cross section of a given shape relative to the extrusion pressure for a round cross section of the same area. We can express the shape factor as follows:

$$K_x = 0.98 + 0.02 \left(\frac{C_x}{C_c} \right)^{2.25} \quad 4-8$$

where K_x = die shape factor in extrusion; C_x = perimeter of the extruded cross section, mm (in); and C_c = perimeter of a circle of the same area as the extruded shape, mm (in). Eq. (4-8) is based on empirical data. over a range of C_x/C_c values from 1.0 to about 6.0. The equation may be invalid much beyond the upper limit of this range.

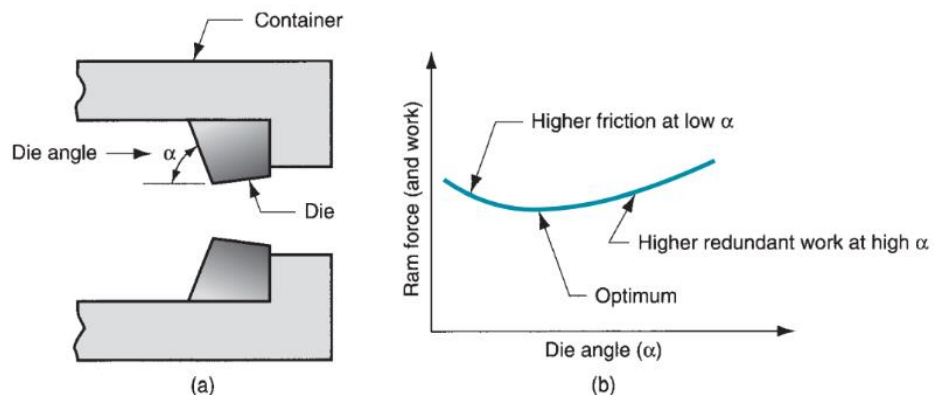


Figure 8
 (a) Definition of die angle
 in direct extrusion;
 (b) effect of die angle on
 ram force.

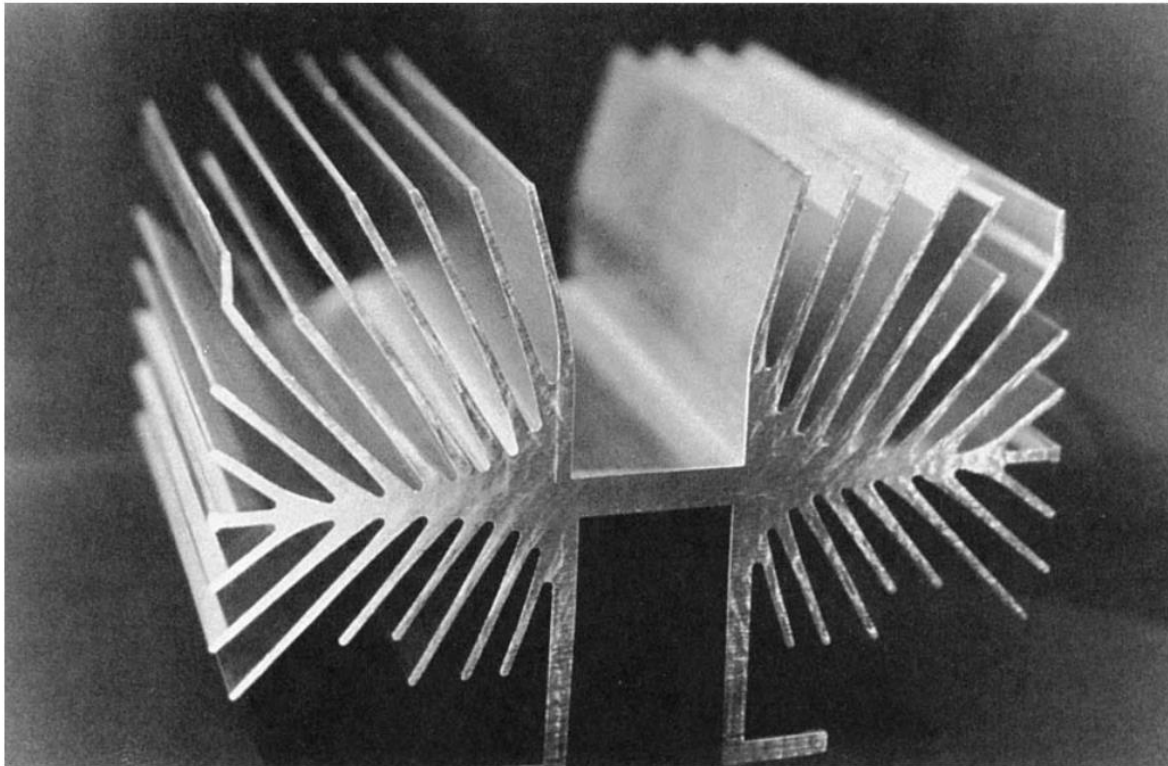


Figure 9 A complex extruded cross section for a heat sink. (Photo courtesy of Aluminum Company of America, Pittsburg, Pennsylvania.)

As indicated by Eq. (4-8), the shape factor is a function of the perimeter of the extruded cross section divided by the perimeter of a circular cross section of equal area. A circular shape is the simplest shape, with a value of $K_x = 1.0$. Hollow, thin-walled sections have higher shape factors and are more difficult to extrude. The increase in pressure is not included in our previous pressure equations, Eqs. (4-5 and 4-6), which apply only to round cross sections. For shapes other than round, the corresponding expression for indirect extrusion is

$$p = K_x \bar{Y}_f \epsilon_x \quad 4-9$$

For direct extrusion

$$p = K_x \bar{Y}_f \left(\epsilon_x + \frac{2L}{D_o} \right) \quad 4-10$$

where p = extrusion pressure, MPa (lb/in²); K_x = shape factor; and the other terms have the same interpretation as before. Values of pressure given by these equations can be used in Eq. (4-7) to determine ram force. Die materials used for hot extrusion include tool and alloy steels. Important properties of these die materials include high wear resistance, high hot hardness, and high thermal conductivity to remove heat from the process. Die materials for cold extrusion include tool steels and cemented carbides. Wear resistance and ability to retain shape under high stress are desirable properties. Carbides are used when high production rates, long die life, and good dimensional control are required. Extrusion presses are either horizontal or vertical, depending on orientation of the work axis. Horizontal types are more common. Extrusion presses are usually hydraulically driven. This drive is especially suited to semi-continuous production of long sections, as in direct extrusion. Mechanical drives are often used for cold extrusion of individual parts, such as in impact extrusion.

high velocity extrusion (Impact extrusion)

In high velocity extrusion forces and pressures are generally higher than those obtaining at conventional speed, although in region of impact speeds between about 10 and 30 m/s, energy requirements may well be lower than at low speeds. there is therefore some advantage in using impact speeds in this range. The machine will in any case be smaller than its conventional equivalent.

High speed extrusion of metals, in both the backward and forward directions, is a feasible proposition. In this process reduction in area is not very large. Figure 10 shows some of the components made by high speed extrusion.

During high velocity extrusion the majority of energy expended during extrusion is converted to heat, causing a considerable temperature rise in the product, which can in some metals cause annealing and recrystallization of the product. Figure 11 shows comparison of extrusion pressure required for slow speed extrusion and high speed extrusion.

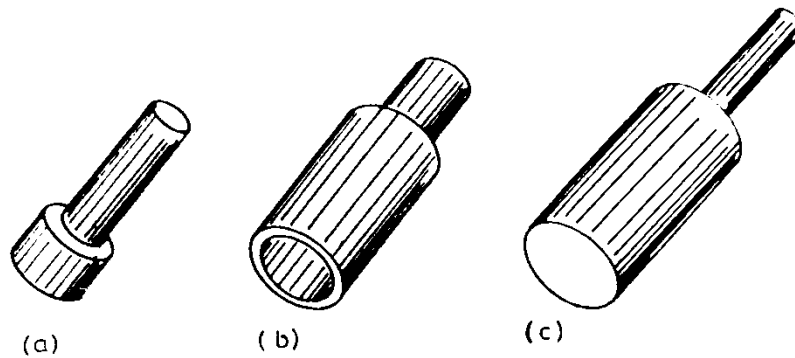


Figure 10

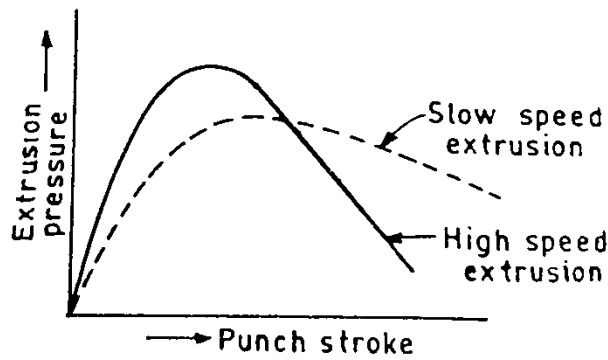


Figure 11

Advantages of impact extrusion

1. Surface finish of parts extruded at high speed is often superior to that obtained at conventional speed, and in the case of forward extrusion. there is a better chance of obtaining a straighter product.
2. At low speed extrusion there is lubricant break down which causes severe scoring of the extruded product, but chances of lubricant break down during high speed extrusion are very less.
3. The obtained parts in impact extrusion are more straight
4. This method can use cheaper lubricants without adverse effect on surface finish. the improvement in lubrication conditions is due to the reduction in friction forces between the extruding material and the die at high sliding speeds.

Tool materials

Material used for making tools for high speed extrusion should have high shock resistance and wear resistance. High speed cold extrusion tools must be tougher than is common in conventional practice, because of the severe shock conditions. This can only be obtained at the expense of some loss of hardness and therefore of wear resistance.

High carbon, high chromium steels are the most satisfactory punch and ejector materials. A very high carbon content should be avoided because such steels are prone to cracking under shock loads. The punch is usually the most highly stressed member of the tooling set up. Generous radii should be provided at all changes in section. Surface finish of the tools affects life as well as function. Small imperfections are potential stress raisers, and should be polished out, particularly on the punch.

Flow of metal

One of the most significant differences between extrusions produced at high and low speeds is probably the way in which the metal flows in the region of entry to the die. It is observed that there is improvement in flow at high speed in both ferrous and non-ferrous extrusions.

The improvement in flow at high speeds suggests a lowering of frictional forces, and indeed, the type of flow in the slow speed extrusions could well be associated with poor lubrication in comparison with the flow patterns of extrusions produced at higher speeds. During slow speed as in **figure 12** extrusion process the extruding metal forms a “virtual die” or dead metal zone across the face of the dies, bounded by a layer of intense shear which invariably results in internal cracking of the metal along this line. the lines in the deformation region have been compressed together, characterizing a very high resistance to flow .at high impact speed **figure 13**, the dead metal zone is still present, but is very much reduced in extent. And the lines are relatively widely spaced in the deformation zone.as impact speeds are increased further it has been observed that the dead metal zone becomes even smaller in size, the lines even more widely spaced. The improvement in flow at high speeds suggests a lowering of frictional forces.

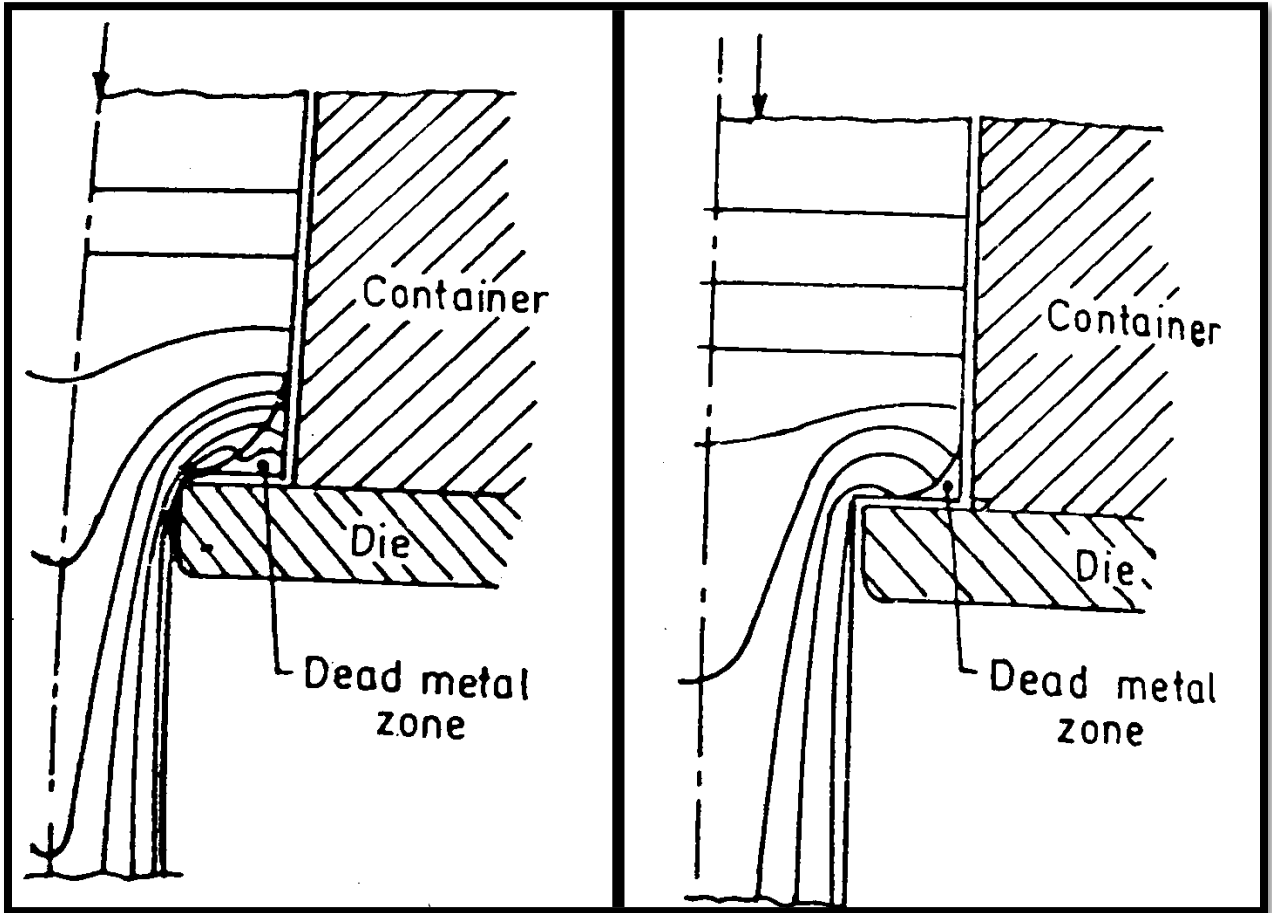


Figure 12

figure 13

Effect of temperature

Extremely high temperature can develop in zones of severe deformation in high speed extrusion, even when the billet is not preheated. In warm, or hot extrusion, the risk of high local temperature is obviously greater, although the temperature rise during the actual extrusion process may not be as great as in cold extrusion, because the resistance of deformation of a hot metal is less than that of a cold one. Upper limits of working temperature can therefore be exceeded locally, and damage can result.