

FUNDAMENTALS OF IMPACT EXTRUSION

Impact extrusion is a process in which metal is forced to flow under the influence of high compressive stresses. The mechanism depends on whether working occurs above or below the temperature of recrystallization. Wagner¹ has differentiated between these two types of activity by calling them the thermoplastic range and the crystoplastic range.

The thermoplastic range lies above the temperature of recrystallization and the structure of the crystals is not stable in this range. Thus, interatomic stresses, resulting from flow in this range, can be partially relieved by atomic rearrangement at in the operating temperature. This rearrangement however requires a finite time interval. Lead and tin are in the thermoplastic at room temperature, whereas aluminum, zinc and magnesium are in the range at slightly elevated temperatures. Disturbance of the slip planes causes work – hardening, but is relieved to some extent by recrystallization – the actual relief depending on time and temperature.

The crystoplastic range is below the temperature of recrystallization. In this range, plastic flow causes permanent deformation of the structure with areas of relatively high energy at the slip planes. According to Wagner, there are three distinct regions in the crystoplastic range.

- 1) A low region near the yield point which has no sharply defined stress – strain relationship.
- 2) A middle region in which the true stress - strain relationship is sharply defined i.e. the increase of stress with strain is fairly constant. This is the region in which major commercial forming operations are performed.
- 3) An upper region that is poorly defined. Transition into this region occurs with a sharp rise in stress with increasing strain. Templin² has defined the point of abrupt change in the stress – strain relationship as the point at which all favorably oriented slip planes have been exhausted. In the upper region, exceptional strength is developed during compression working operations, such as impact extrusion, and a rise in temperature resulting from internal friction appears to be essential.

Unlike the basic law underlying elastic deformations, which are rather well defined, the laws of plastic deformation appear to be complex and are only partially understood. It is doubtful whether some of the physical laws are valid for material being worked in the plastic range. Wager¹ points out that Hooke's Law seems to be inapplicable in the plastic range for a metal that hardens during working, whereas Pascal's appears to be only approximately correct. Poisson's ratio changes in value a change that is to be expected because the more nearly a material approaches the liquid state, the nearer the ratio approaches a value of 0.5.

Because of the difficulties in developing the underlying principles, much dependence has been placed on experimental work. As happens frequently, however, practical has far outstripped theory, and much additional experimental work will be required before the laws of plastic deformation as applied to impact extrusion are fully understood. It is necessary to rely on data, many of which are qualitative, in discussing the factors that affect impact extrusion. Among these factors are flows during extrusion, extrusion forces and speed of extrusion.

GENERAL NATURE OF THE PROCESS

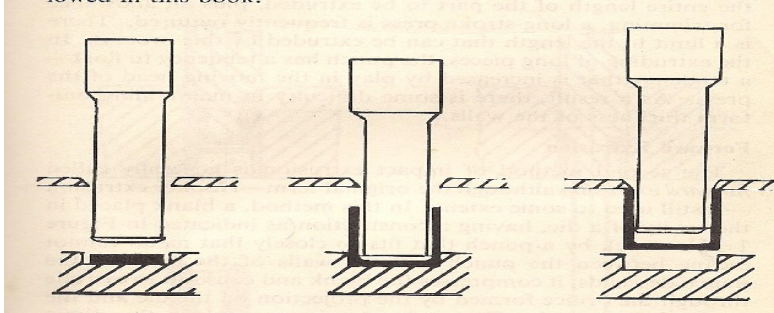
The methods used in impact extrusion are shown, schematically. The two processes were called, respectively, impact extrusion and Hooker extrusion for many years. Current practice in most plants seems to be to call them backward – and forward extrusion.

Backward Extrusion

The original method of impact extrusion is not known as backward extrusion. In this method, a blank of the material to be extruded is placed in the cavity of a die and struck by a punch. The metal of the blank is forced to flow upward through the annular opening between punch and die and it rises along the punch. The thickness of the base is determined by the stroke of the press and is independent of the thickness of the wall.

Backward extrusion can be used to produce a wide variety of shells with circular, oval, square, rectangular, and various other cross sections. In general, the side walls must be perpendicular to the base to permit flow during extrusion, but ribs can be formed on internal or external walls. In addition multi – wall shells can be formed.

Backward extrusion has the advantages of simplicity of tooling and ease in removing the shell after forming. There are also limitations. As the punch must be long enough to accommodate the entire length of the part to be extruded, plus an allowance for trimming, a long – stroke press is frequently required. There is a limit to the length that can be extruded by the process. In the extruding of long pieces, the punch has a tendency to float - a tendency that is increased by play in the moving head of the press. As a result, there is some difficulty in maintaining uniform thickness of the walls



Forward Extrusion

The second method of impact extrusion is generally called forward extrusion although the original term – Hooker extrusion - is still used to some extent. In this method, a blank placed in the cavity of a die, having a construction is struck by a punch that fits so closely that material cannot escape between the punch and the walls of the die. As the punch descends, it compresses the blank and causes it to extrude through the orifice formed by the projection on the die and the nose of the punch. Forward extrusion resembles the direct extrusion of hot billets in hydraulic presses but the length of the part that can be formed by forward extrusion is more restricted.

Although that blanks can be used, blanks are generally preformed to the contour necessary to obtain the desired configuration in the extruded part. Forward extrusion can be used to produce open – or closed – end tubes: the bottoms of closed – end tubes can be the same thickness as the side – walls or heavier. Side walls can be parallel or tapered. Parts can be produced with fillets.

Forward extrusion requires less power than backward extrusion, and smaller presses can be used to produce parts of equivalent size. As true alignment of punch and die is assured, tolerances can be held more closely than is possible in backward extrusion. Because the length of the part is practically independent of the length of the punch, a short stocky punch can be used.

There are disadvantages, also. Secondary tooling may be required to permit removal of the extruded part from the die and this requirement will increase the cost of tooling for forward extrusion over that required for a simple backward extrusion. In addition, the shapes that can be produced by forward extrusion are more limited than those that can be formed by backward extrusion. In particular, the base of the forward - extruded part must be plain because there is no forging action against the bottom of the die.

Combined Extrusion

From the preceding discussion, it may appear that each of the methods must be used separately. Such is not the case. Backward and forward extrusion can be used simultaneously to form parts and this procedure is followed frequently. Possibilities of combining the methods will be discussed in the chapter dealing with design.

COMPARISON OF IMPACT EXTRUSION WITH OTHER PROCESS

The role of impact extrusion as a production can be indicated by comparison with certain other processes which may be considered to compare with it. These include deep drawing, hydraulic extrusion, and forging..

Deep Drawing

Both impact extrusion and deep drawing use a combination of punch and die to form a hollow shell from a cold blank. They differ in the manner in which deformation occurs. In impact extrusion, the metal is forced through an orifice under compressive stresses. In deep drawing, the metal is pulled into the die by the punch and stressed in tension.

Hydraulic Extrusion

Both impact extrusion and hydraulic extrusion involve forcing a metal through a die under compressive stresses. Although the metal is generally cold – worked during impact extrusion and hot worked during hydraulic extrusion, this is not a distinguishing factor.

The major difference between the two processes lies in the type of product. That produced by impact extrusion is a single component which may or may not require additional operations to produce the finished part. The product of hydraulic extrusion is generally a rod, tube, structural shape, or other semi finished mill form.

Forging

There is no well – defined line of demarcation between backward extrusion and forging. The bottom of a backward extruded part is forged; in some press – formed parts, extensions, such as bosses, are extruded around the punch. Forgings are generally formed hot but can be formed cold in some metals, whereas impact extruded parts are usually cold – formed. Thus forging and impact extrusion overlap.

They differ in one characteristic. Forgings usually have non – fined recesses into which any extruded metal is forced. In impact extrusion, the extruded portion is not confined after passing through the orifice between punch and die.

Impact extrusion yields a more concentric product than forging does and the parts produced are more uniform in weight. The surface of the part is also superior, thus reducing the number of finishing operations required.

ADANTAGES AND LIMITATIONS OF IMPACT EXTRUSION

The economic significance of impact extrusion lies in the opportunities it affords for more effective use of materials, reduction of labor costs, elimination of intermediate operations, improvements in quality of product, and the attainment of high rates of production with relatively simple tools. There are also limitations. Some of the advantages and disadvantages are summarized in Table 1:1 4. Comparison with other production processes points up the advantages more specifically.

LIMITATION OF IMPACT EXTRUSION

Advantages

1) High – speed production with low unit cost.

2) Low scrap losses. 2) Shapes that can be produced are limited.

3) Tooling relatively cheap. 3) Ratio of length to diameter is restricted.

4) Bottom thickness independent of wall thickness 4) Maximum size of part is determined by capacity of press.

5) Combines operations by forming ribs, fins, holes, 5) Generally large production runs are required for during extrusion. economy.

Disadvantages

1) Relatively few alloys can be processed commercially at present

- 6) Parts can be made with Zero degree draft angels.
- 7) Surface finishes of 20 to 70 micro – inches obtainable.
- 8) High mechanical properties can be obtained.
- 9) One-piece parts can be used instead of assemblies

Deep Drawing:

Selection of impact extrusion of deep drawing as the method of production often depends on the configuration of the part. In the production of some parts, the methods are competitive. Choice of impact extrusion may be based on the following advantages mentioned by Jevons⁵ and Askew⁶.

- 1) Certain shapes such as deep thin – walled shells, which would be difficult to make by deep drawing, can be impact – extruded in one operation.
- 2) Certain metals such as lead, which cannot be deep drawn can be easily impact – extruded into thin – walled shells.
- 3) The base of an impact – extruded part can be thicker than the side walls and shaped to various profiles – an operation that cannot be performed by ordinary deep drawing.
- 4) Tool costs to produce a deep shell are often lower for impact extrusion than for deep drawing because only a single set is required.
- 5) Higher rates of production can generally be maintained by impact extrusion.
- 6) It is often possible to use a thinner – walled impact – extruded part than a similar deep – drawn part because of the increased strength resulting from the severe cold working.
- 7) There is generally less scrap from impact extrusion than from deep drawing.

The difference in losses in scrap can be very significant. In German practice , the deep drawing of cups from aluminum, brass. Or steel can result in 60 per cent of scrap; impact extrusion can reduce loss in scrap to 10 per cent?

As a specific example of the advantages of impact extrusion over deep drawing, Galber¹ cited the production of a hollow shell having a height six times the inside diameter. To produce this shell by deep drawing required blanking, three drawing stages, and leveling. The same part was produced in two steps by impact extrusion; cutting a blank from a rod, and backward extruding. The impact – extruded part required only 72 per cent as much material as the drawn part, and cost only 12 per cent as much.

Machining:

The advantages of impact extrusion over machining have been discussed by Galloways.⁸ Production of parts based on machining often results in losses of 50 to 60 per cent in scrap. With impact extrusion, these losses are reduced to about 10 per cent. Highly stresses parts that are produced by machining must be made from alloy steels that are subsequently heat – treated. Similar components can often be produced from low - carbon steels by impact extrusion because of the excellent mechanical properties developed by cold working.

Epner⁹ cites the production of a control arm busing for automotive use. This part formerly produced on a screw machine and heat – treated to obtain the required properties, is now produced by cold extrusion and requires no heat treatment. He mentioned also that impact – extruded parts have tolerances equal to those obtainable in conventional boring and turning operations, and that the excellent finish of the surface often avoids the need for grinding and polishing operations.

Other Processes

Impact extruded parts have displaced castings, forgings, and weldments in various applications. Generally, the substitution has required redesign of a specific part. Examples will be given in the chapter dealing with the various metals that are being extruded.