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AN OVERVIEW OF BASIC DIE OPERATIONS

The basic die operations divided into several categories such as *cutting, bending, forming, drawing* and *squeezing.* All of these operations require that portions of the workpiece undergo *plastic deformation*. To accomplish this, pressures in excess of the *yield point* of the material are used.

Understanding how these processes are appropriately applied, is a key designing and maintaining dies for successful pressworking. Knowledge of material and die interactions is also required for cost effective design, repair and troubleshooting.

In a sucessful stamping enterprise, the goal is to be the lowest cost producer with the best quality. The best processes are used. Appropriate tooling designs and efficient die maintenance are essential. The following are examples of some basic metal forming processes that are used alone or in combination. It is essential to remember that the goal of a metal fabricator is to add value to metal.

A Simple Cutting Die

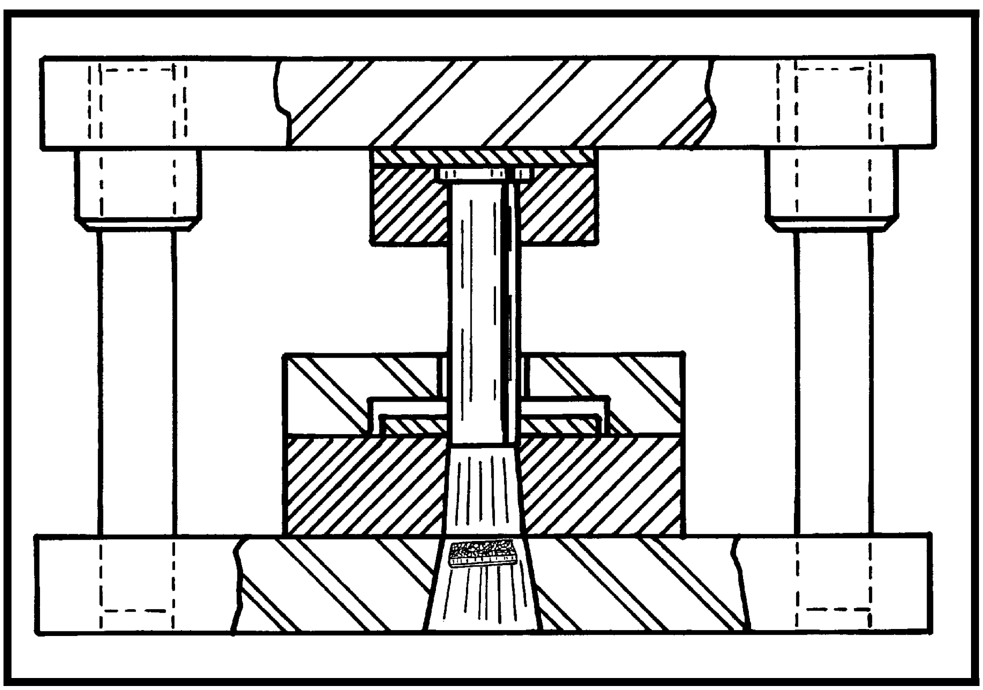

Figure 1. A sectional view of a cutting die for punching a round hole.
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Cutting, Punching and Perforating

Cutting operations are essentially a controlled process of plastic deformation or yielding of the material leading to fracture. Both tensile and compressive strains are involved. Bending or stretching of the scrap portion and occasionally the work may also occur. Figure 1 shows a sectional view of a simple cutting die for punching a round hole.

Bending and Forming

Simple *air bending* involves both tensile and compressive straining of the material in the bend zone. Upon release from the die, residual stresses result in a *springback* of the material. Springback is a result of the partial release of *residual stresses* in the material.

To lessen the effect of residual stresses, the metal in the bend can be squeezed or *coined*. In coining, the entire thickness of the material in the bend is compressed above the yield point of the material.

Another method of compensating for springback is to overbend the material so that when it *springs back*, the correct amount of bend occurs. The shut height of air bending tooling can be easily adjusted to control the springback of bend angles.

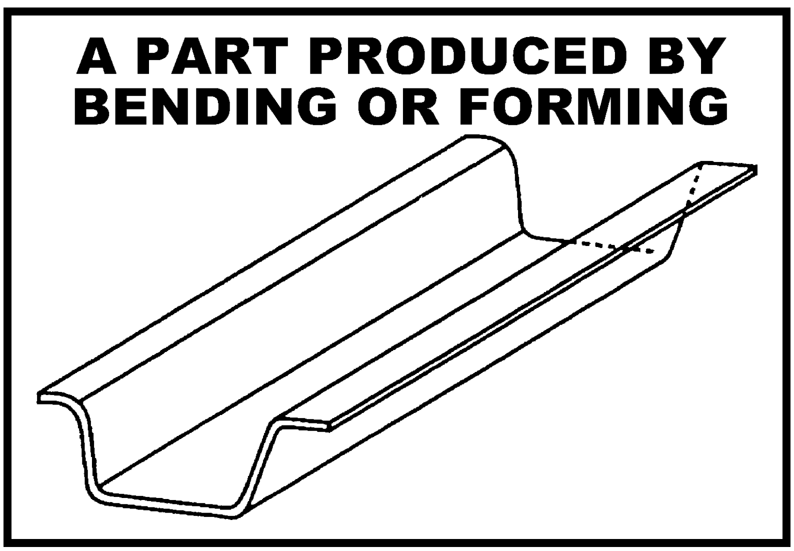

Figure 2. A simple part produced by a bending or forming process. The part can be produced in small quantities on a press brake. High volume production can prove more economically done by die or roll forming. *Smith & Associates*

Figure 2 illustrates an example of a part that may be made by bending in a die or with press brake tooling. Another process used to form such shapes is roll forming. Here, the flat strip passes through a series of forming rolls to produce the desired shape.

Roll forming is normally a continuous process. After rollforming, the desired length of part may be cut off with a die. To permit continuous rollforming, the cutoff die and press can travel at the same linear velocity as the forming process. This device is termed a track-mounted flying shear.

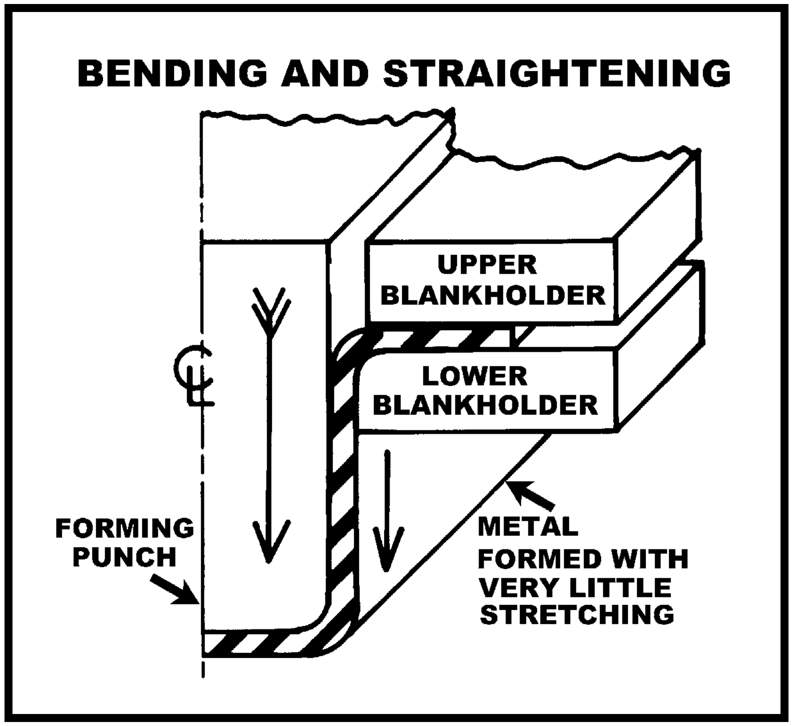

Figure 3. A bend and straighten operation in which the metal is bent and straightened in the die permitting very large deformations with little or no thickness change.
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Bending and Straightening Applications

A simple die employing bending and straightening to make U-shaped cross sections with right angle flanges as shown in Figure 3. Parts of this type serve many purposes. A typical application is stiffeners attached to flat panels. Examples are automotive body frame rails and cross members assembled by welding.

Bending and straightening operations used in conjunction with other forming processes serve to produce complex stampings. A simple example of bending and straightening occurs in the sidewalls of formed box shaped rectangular shells.

Stretching

Another process used to form metal is stretching. Forming processes involving cold working such as stretching often improve the mechanical properties of the material. Familiar products made by stretching include many automotive and aircraft skin panels.

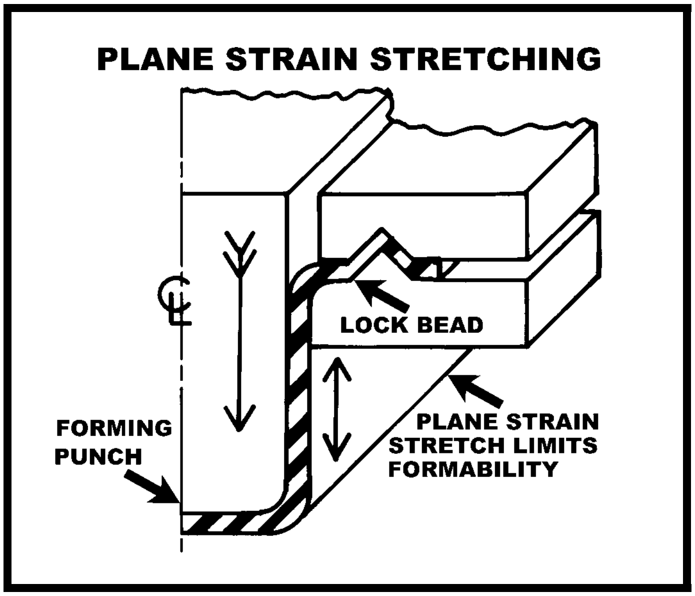

Figure 4. An example of plane strain stretching or deformation. This process permits less deformation before a fracture occurs than stretching the metal in two directions. *Smith & Associates*

Deforming the metal in only one direction is termed *plane strain* deformation. This process permits less deformation before a fracture occurs than stretching the metal in two directions. Figure 4 illustrates an example of plane strain stretching where the metal clamped by a lock bead in the blankholder. Forming metal by plane strain stretching rapidly thins the material. If the thinning is severe, a fracture may occur.

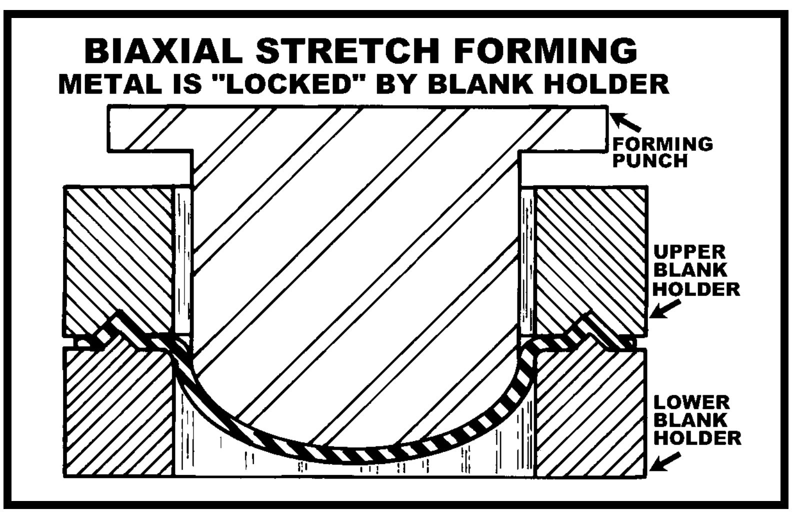

Figure 5. An example of a dome shaped part where the blank is tightly restrained by a blankholder, and biaxial stretch forming occurs. Biaxial stretch forming permits greater deformation than plane strain stretching. *Smith & Associates*

Biaxial Stretch Forming

Forming a dome shaped part illustrated in Figure 5 is an example of biaxial stretch forming. As illustrated, a lock bead prevents metal movement on the blankholder. Forming a dome in the mid section of a sheet is another biaxial stretch forming example. The flat area of the sheet prevents metal movement into the dome.

Drawing

Popular shop terminology often applies the term *draw die* to any die where metal is stretched or *drawn* into a die cavity. Many such operations form the part by stretching or bending, rather than drawing. Round cup drawing, where the metal is restrained by a blankholder as it is drawn into the die cavity by a draw punch, is an example of a simple true drawing operation. [1]

A large body of empirical data describes the known practical limits of this process when using conventional tooling. Large deformations may involve multiple *redrawing* operations.

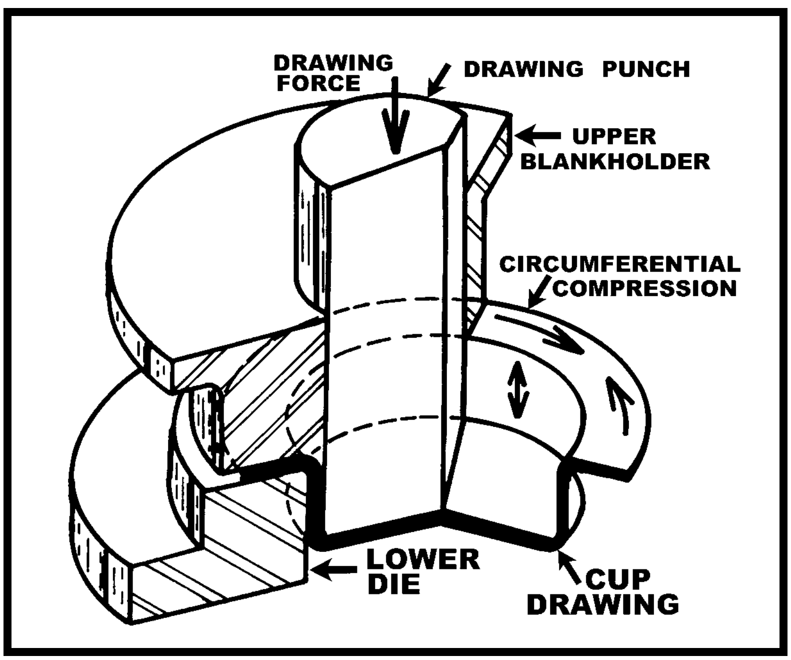

Figure 6. An example of a simple cup drawing die. The metal thickens or undergoes circumferential compression on the blankholder as it is drawn into the die cavity. As the metal is drawn over the die radius, it is thinned. *Smith & Associates*

[1] D. Smith, ***Die Design Handbook, Third Edition*** Section 10, Displacement of Metal in Drawing, The Society of Manufacturing Engineers, Dearborn, Michigan, © 1990. The material in this section has been drawn from numerous sources, nine of which are cited. All predate the second edition © 1965. Much of this data has been incorporated into some die design software programs where it is used as an expert system.

True Cup Drawing

In cup drawing, the metal thickens or is subject to circumferential compression while restrained by the blankholder as it is drawn into the die cavity. As the metal is drawn over the die radius, it is thinned. Fracture of the metal due to thinning limits the severity of this process.

Squeezing or Coining Operations

The coining process for cold forming metals is similar to cold forging. In coining, the metal deforms between two die surfaces under high pressure so the detailed shapes in the die surfaces fill by displacing the metal in a plastic state. Coining involves cold working deformation of the metal well below its recrystallization temperature resulting in strain hardening.

Squeezing operations where the thickness dimension of the metal is subjected to pressures that exceed the material yield point in order to change its thickness or shape are termed *coining.* This term is based on the most familiar example: the minting of coins. This is a familiar type of squeezing operation. An ancient coining press illustrated in Oberlin Smith's classic book "Press-Working of Metals published in 1896 is shown in Figure 7. The bed of the press is placed on an anvil and the ram struck with a hammer to form a coin from a blank called a planchet in the minting trade.

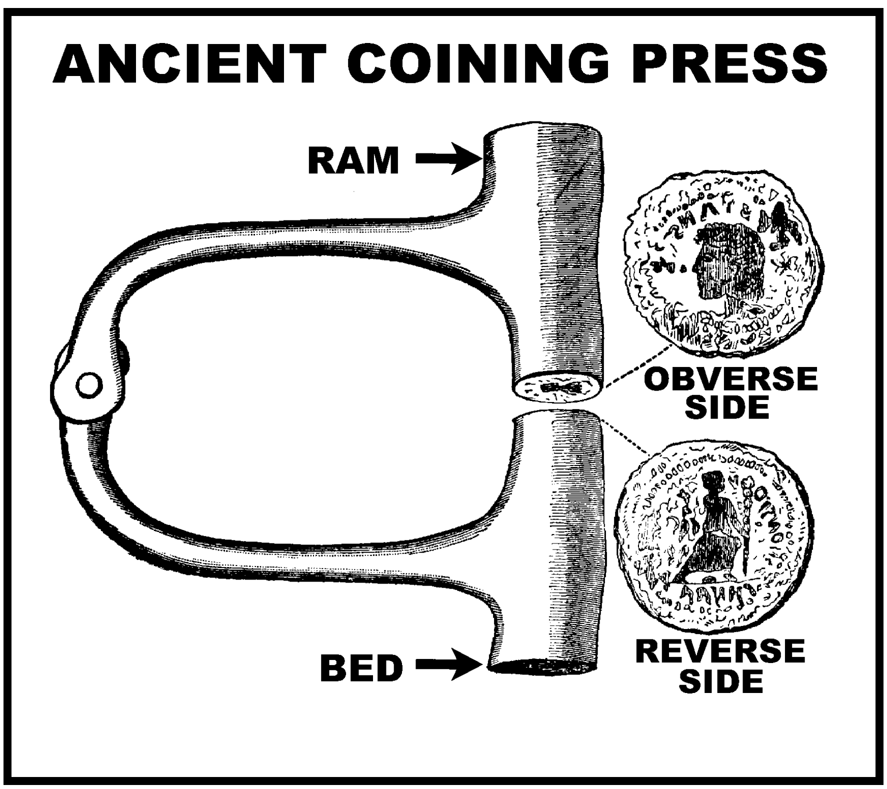

Figure 7. An ancient hinged coining press for minting. The illustration is from Oberlin Smith's "Press-Working of Metals" published in 1896.

Squeezing operations may also be called *cold forging* depending upon the purpose and severity of the operation. Depending on the material being worked and the type of operation, in-die pressures can exceed the yield strength of the material by a factor of two or more. It is important to use the hardness and area of the coined metal at the completion of coining when designing dies and determining press requirements.

If the metal is not constrained in a die cavity, the lateral movement can occur increasing the area being cold worked. Lateral metal movement in coining dies having fine detail or relief subjects any projections to shearing forces and metal fatigue problems leading to crack propagation. This tool failure mode frequently occurs in coining dies.

Using Analytical Tools

An objective understanding of the behavior of metal undergoing cutting, shaping and forming processes is a key to modern analytical techniques. Today we have the ability to design easily manufactured metal products and solve many problems quickly. [2] [3] [4] [5]

The analytical tools include *circle grid analysis* (CGA) and the forming limit diagram (FLD). Computer aided formability analysis is also used to determine if stampings can be successfully manufactured.

The large amount of data based on proven die designs and metal formability data have taken troubleshooting pressworking operations from a trial-and-error process to an engineering science.

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[2] ***Sheet Steel Formability***, the Committee of Sheet Steel Producers, American Iron and Steel Institute, Washington, DC, © August 1, 1984.

[3] S. Keeler, ***Circle Grid Analysis***, National Steel Corporation Product Application Center, Livonia, Michigan, 1986.

[4] M. Tharrett, ***Computer Aided Formability Analysis,*** presented at an SME Die and Pressworking Tooling Clinic, Dearborn, Michigan, August 25-27, 1987.

[5] D. Smith, ***Die Design Handbook, Third Edition***, Section 11, Product Development for Deep Drawing, contains a condensed version of references 3 and 4, The Society of Manufacturing Engineers, Dearborn, Michigan, 1990.

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