FORMING FLANGES AND PROCESS LIMITATIONS

Flanges on metal parts fall into three basic types. The simplest is the straight flange that is a straight bend. Concave flanges are termed stretch flanges because the metal formed into the flange stretches.

Convex flanges are shrink flanges, since the metal is compressed or shrunk. In addition, there are combinations of these types of flanges that occur in a single operation.

Some Limiting Factors In flanging

There are factors that place limits on the flanging process. These include:

1. The severity of deformation accomplished before fractures occur.

2. The amount of wrinkling or puckering that is permissible on a compression flange.

3. Press energy or force available for flanging large areas with conventional wipe flanges high in the press stroke.

Flange Types

Figure 1 illustrates a number of different flanges. The straight flange is the most common type. The problems associated with straight flanges are springback and scoring. Close tolerance bends should not be specified unless necessary to enhance the appearance or function of the part. A variation in elastic recovery or springback is a problem. This results from variations in material properties

Forming stretch flanges involves stretching the metal during the bending operation. The greatest amount of stretch occurs at the edge of the flange, and is essentially zero at the bend radius.

The metal in a shrink flange compresses causing it to shorten in length. The amount of shrinkage is greatest at the edge of the flange and diminishes to zero at the bend radius.

Irregular or curved flanges tend to have less springback problems than straight flanges. A reverse flange is a combination of a stretch and shrink flange. Another combination flange is the joggled flange. While the majority of the flange is straight, the corners are stretch and shrink flanges respectively.

A flanged hole is a type of stretch flange. Some flanged hole applications are locating bosses, holes for tapped threads, openings for heat transfer tubes, and non-chafing passages for wires. Flanging an opening in a stamping can greatly increase part rigidity.

Various Flange Types

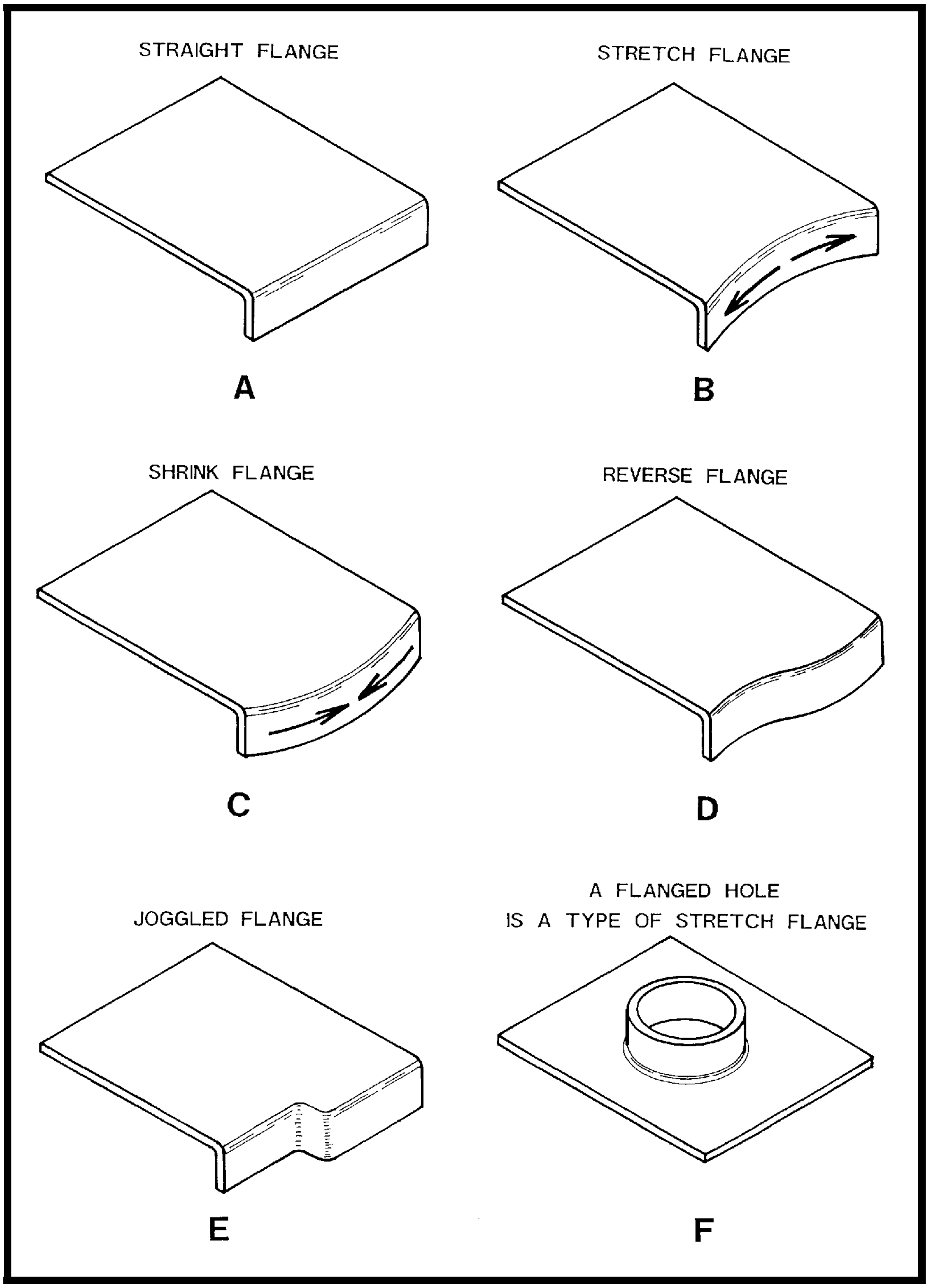

Figure 1. Examples of types of flanges: a straight bend or flange **(A).** A stretch flange **(B).** In shrink flanges the metal is compressed **(C).** A reverse flange is a combination of a stretch and shrink flange **(D).** A joggled flange **(E).** A Flanged hole is a type of stretch flange **(F).** *Smith & Associates*

Stretch Flanging Problems

Edge splitting can be a problem when stretch flanging as illustrated in Figure 22. The likelihood of splitting depends on the material properties, and the edge condition resulting from shearing or trimming. Tensile stress can reduced by shorter flange lengths or by providing notches or scallops. Notches will reduce the flange strength.

Stretch Flanging Problems

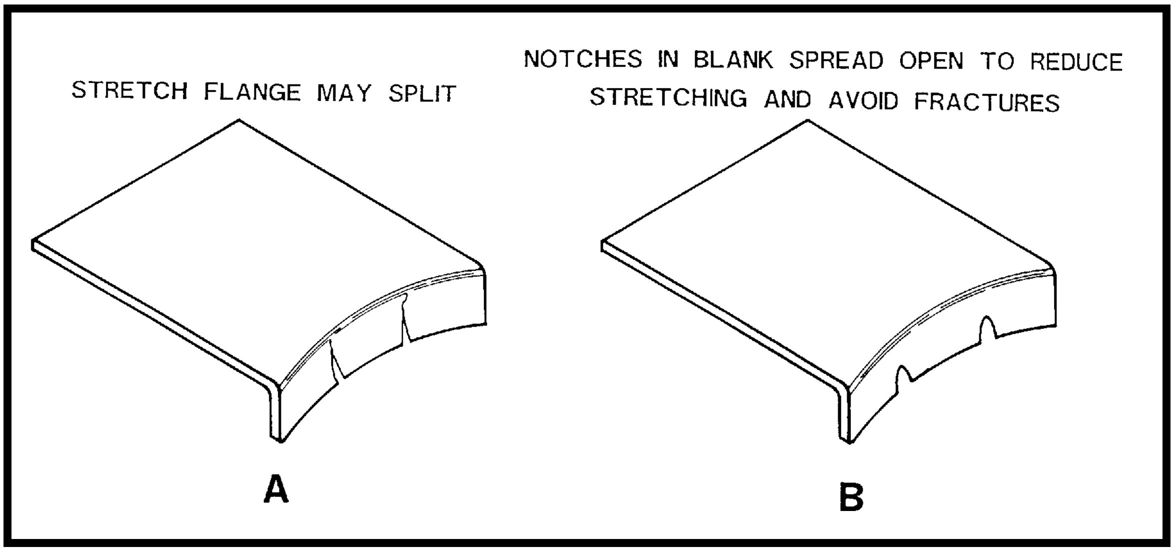

Figure 2. Edge splitting can be a problem **(A)** when stretch flanging. Reduce the tensile stress by providing notches or scallops **(B).** *Smith & Associates*

Minimum Bend Radii

The minimum bend radii vary depending on the type of metal. Most annealed metals can be bent to a radius equal to the thickness, although some softer metals can be bent to an inside radius one-half metal thickness. Short bend radius lengths reduce the minimum bend radius. This is not a practical consideration if the minimum bend radius length is eight or more times the metal thickness.

The rolling direction in sheet or strip metal limits the minimum bend radius. An angle of 90 degrees between the bend axis and the direction of rolling allows most metals to bend to the smallest possible radii.

A simple general equation expresses the strain at the edge of the stretch flange, where most failures begin:

$$e_x = \frac{R_2}{R_1} - 1 \qquad \textbf{(equation 1)}$$

Where:

e_x = strain at flange edge

R_1 = flange edge radius before forming

R_2 = flange edge radius after forming

Circle Grid Analysis (CGA) is an excellent method for determining the actual amount of strain at a flanged edge. Expanding a drilled, deburred hole with a lubricated conical punch to determine the forming limit may perform a simple comparative test for materials to be flanged.

Edge conditions such as burrs and rough fractured edges reduce stretch flange formability. Such edge conditions result in excessive cold working of the metal.

Bend Allowances

For close work, the exact length of metal required to make a bend requires trial and error. The assumed neutral axis varies depending upon the bending method used, the location in the bend, and the type of stock bent.

Direction of grain in a steel strip relative to the bend also has a slight effect on the length of metal required to make a bend. Bending with the grain allows the metal to stretch more easily than bending against the grain; however, this results in a weaker stamping. Bend allowance depends more upon the physical properties of the material such as tensile strength, yield strength, and ductility than on the actual metal composition.

Empirical Rules

An important factor that determines the neutral axis is how the bend is accomplished. Less metal is required for a bend made by a tightly wiped flange than for an air bend on a press brake. Wiping the flange tends to stretch the metal.

The exact bend allowance is the arc length of the true neutral axis of the bend. Above the neutral axis, metal stretches below it, metal is compressed. The problem is that neutral axis can only be approximated.

Many manufacturers calculate neutral axis as 33% of stock thickness from the inside radius of the bend for inside radii of less than twice stock thickness. For inside radii of two times stock thickness or greater, the neutral axis is often considered to lie approximately 50% of metal thickness from the inside radii. One reason less metal is required to make a tight bend is that the sharp radius tends to stretch the metal more.

Bending or Forming Die

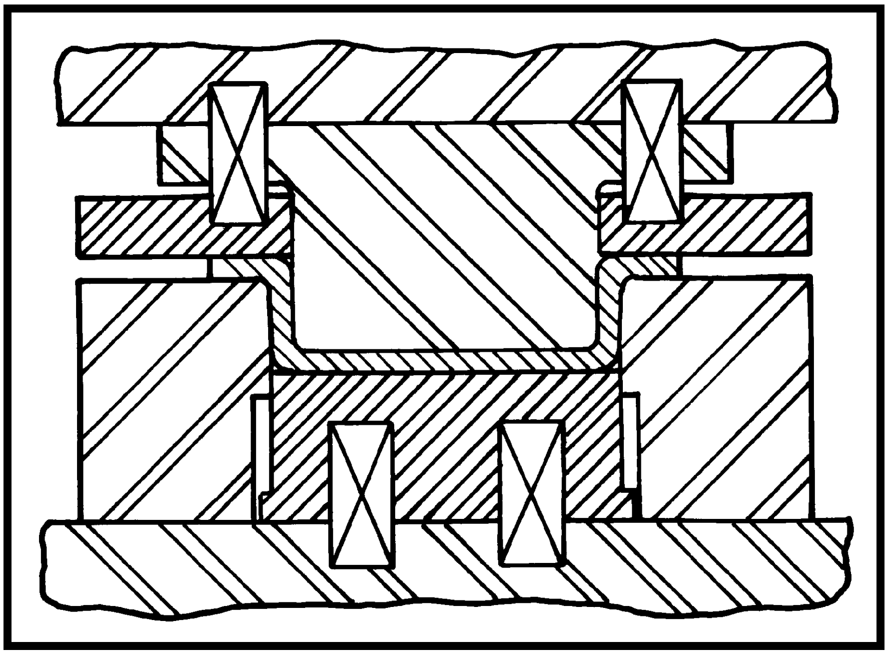

Figure 3. Sectional view of a typical bending or forming die illustrating forming stock of the correct thickness. *Smith & Associates*

For 90-degree bends, the radius of the assumed neutral axis is multiplied by 1.57 (the number of radians in 90 degrees) to determine the amount of metal required to make the bend. For bends that are not exactly 90 degrees, multiply the number of degrees of bend times 0.0175 (the number of radians in a degree) and substitute the result for the coefficient 1.57.

Formulas and Data

Tabular data for the length of material in radii including metric equivalents are available. The formulas used to develop these tables are based on extensive experimental data. Such tables were a necessity before the availability of the electronic calculator. [1]

[1] D. Dallas, ***Pressworking Aids for Designers and Diemakers***, The Society of Manufacturing Engineers, Dearborn, Michigan © 1978.

Correctly Formed Part

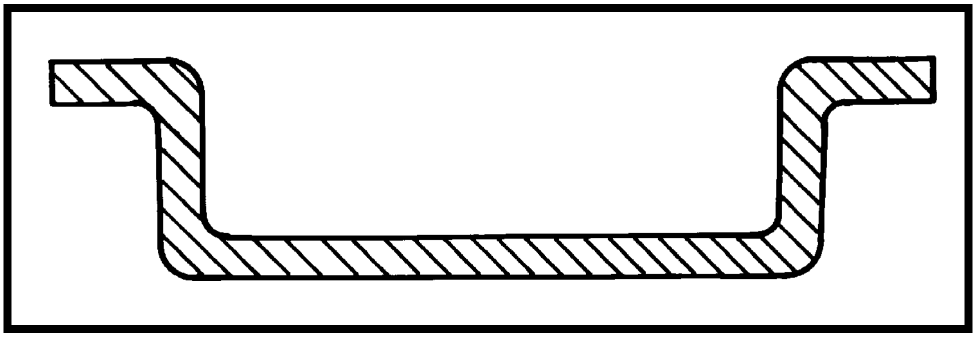

Figure 4. A correctly formed part produced in a die such as shown in Figure 3. Die clearances, die geometry and stock specifications must be correct to produce properly formed stampings. *Smith & Associates*

The Effect of Stock Thickness Variations

Producing close-tolerance stampings requires stock thickness variations to be held to a minimum. Figure 3 illustrates sections through a typical bending or forming die. If the stock thickness is correct, the part will be properly formed as shown in Figure 4.

Bending or Forming Die with Stock Too Thin

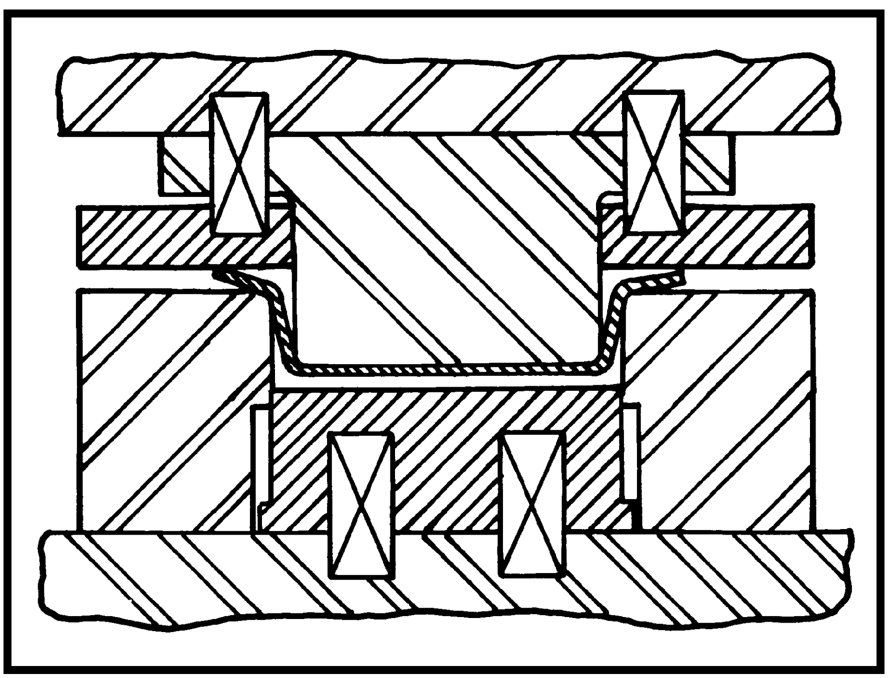

Figure 5. If the stock is too thin the angles will be under bent. . *Smith & Associates*

If the stock that is too thin, angles will be under bent as illustrated in Figures 5 and 6. Severe die damage can result from attempting to form stock that is too thick for the die clearances. Large lateral forces are developed that can greatly exceed the applied press tonnage. The force is multiplied by wedge-like action as shown In Figure 7. This type of damage often occurs should operator inattention or an automation malfunction result in two blanks being formed in the die at one hit as shown in Figure 8.

Incorrectly Formed Part—Stock Too Thin

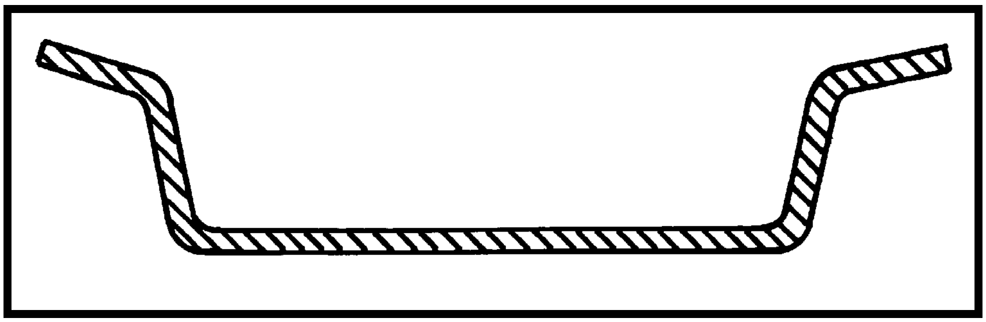

Figure 6. An incorrectly formed part produced in a die such as shown in Figure 5. If the stock is too thin, the bend or form angles will be less than required. *Smith & Associates*

Bending or Forming Die Damaged by Stock Too Thick

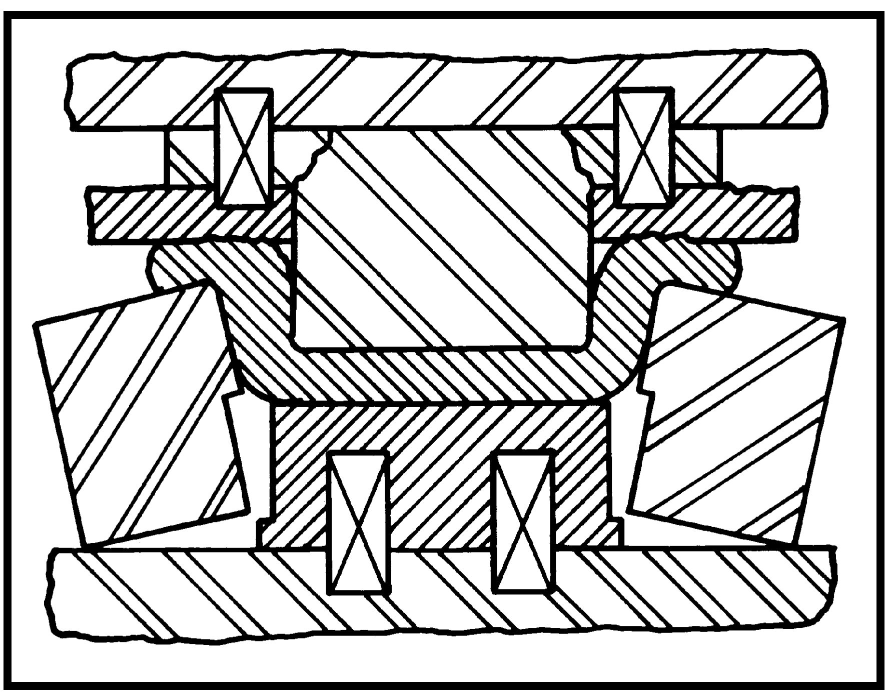

Figure 7. Section through a bending or forming die. If the stock is too thick misformed parts as well as severe damage can occur. *Smith & Associates*

Bending or Forming Die Damaged Two Parts in Die

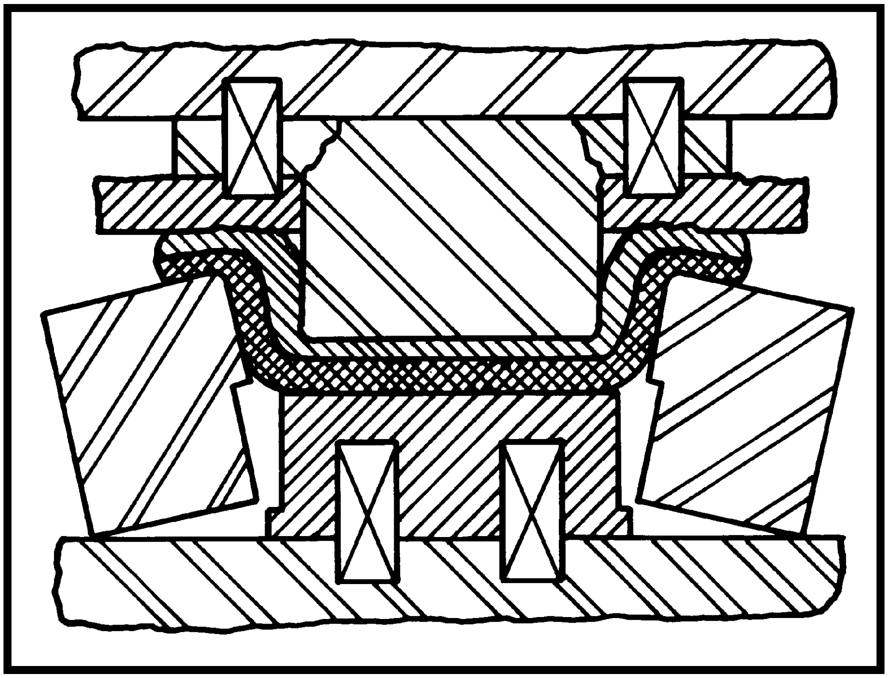

Figure 8. Section through a bending or forming die. Severe damage can occur if more than one thicknesses of stock is in the die. *Smith & Associates*

Hemming Operations

Hems are primarily used to provide a smooth rounded edge and for the attachment of one sheet metal part to another. They are a very effective way to eliminate a dangerous sheared edge. Hems find extensive use in automobiles to join closure panels.

A sharply bent flattened hem requires materials having high ductility. Materials that do not have the ductility required to form a flattened hem may require a teardrop or rounded edge hem. The same minimum bend radii considerations based on material formability apply to hems used for attachment to other sheet metal parts—see Figure 9.

Tooling for Hems

Flanges and hems made in one operation require complex tooling. However, in order to simplify tooling, hemming part that has been flanged in a previous operation may reduce overall cost. Figure 9 illustrates four different types of hems. [2]

[2] D. Smith, ***Die Design Handbook***, Section 6, Bending of Metals, The Society of Manufacturing Engineers, Dearborn, Michigan, © 1990.

Examples of Four Different Types of Hems

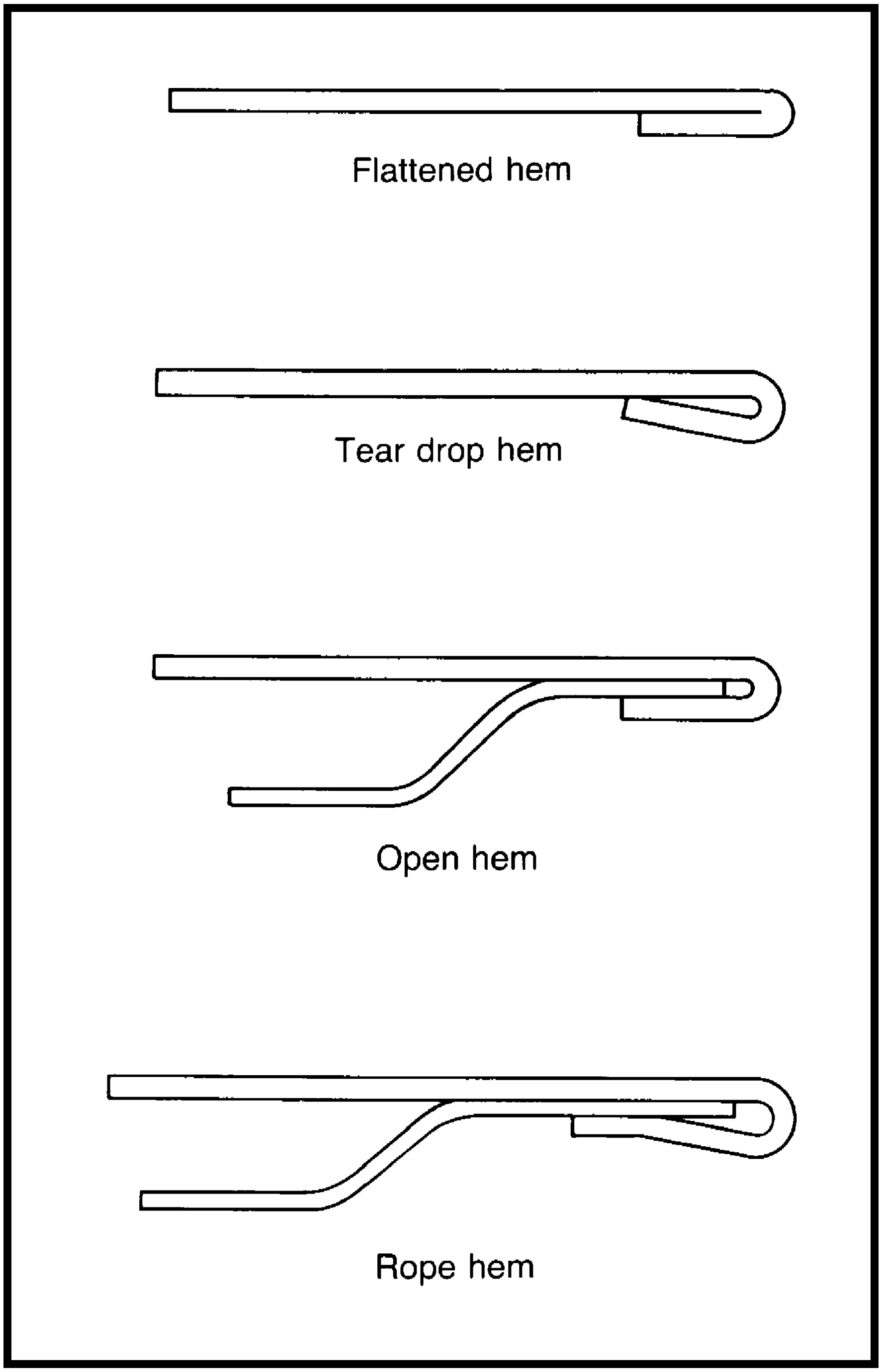

Figure 9. Examples of four different types of hems. The bottom two illustrations show hem types used to assemble stampings. *Smith & Associates*

Using Hems for Assembly of Stampings

The sequence of a typical hemming stamping assembly operation after bending a 90 degree flange in the outer panel is to place the inner panel in the flanged outer panel and bend the outer panel an additional 45 degrees. The partially assembled panels are next transferred to the hem die where the final assembly takes place by flattening the pre-bent hem.

Hemming Pressures

Typical hemming pressures, including seaming pressures, are generally seven times the forming pressures required for 90 degree bends, and may be as high as a ratio of 40:1. Variables are: stock thickness, tensile strength, size of area to be flattened or hemmed, and tightness of the hem.

Bending and Hemming Pressures

The amount of pressure required depends upon the thickness of the stock, the length of the bend, the width of the die, whether a lubricant is used, and the amount of wiping, ironing, or coining present.

Formula for V-bends and U-forming

A simple formula used to determine V-bending forces for air bending in a die such as that used for simple press brake tooling is:

$$F = \frac{KLSt^2}{W} \qquad \textbf{(equation 2)}$$

Where F = bending force required, in lbf (N)

K = die-opening factor: varies from 1.20 for a die opening of 16 times metal thickness, to 1.33 for a die opening of 8 times metal thickness

L = length of bent part, inches (mm)

S = ultimate tensile strength, psi (Pa)

t = metal thickness, inches (mm)

W = width of the V-channel, or U-forming lower die, inches (mm)

The use of equation 2 for deriving bending pressures is valid for V-shaped dies only. For channel forming and U-forming, multiply the result by 2. In forming a channel with a flat bottom, a blankholder is necessary. Multiply blankholder area in square inches by 0.15 to derive the approximate required tonnage, and add to the bending force derived from the equation.

Factors Which Determine Flanging Force Requirements

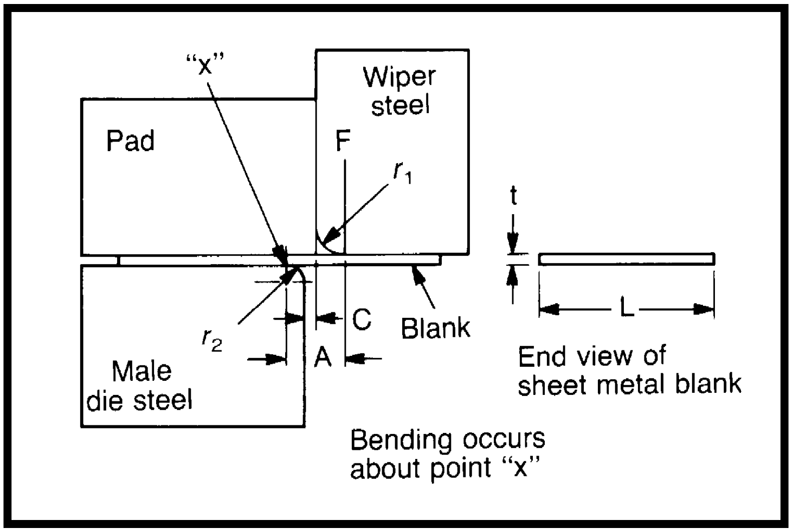

Figure 10. Factors that are entered to determine flanging force requirements. Please see references 2 and 3 on page 9. *Smith & Associates*

Formula for Flanging Forces

The approximate force required to bend or flange a sheet as shown in Figure 4 is given by:

$$F = 0.167 \frac{SLt^2}{A} \quad \text{theoretical} \quad \text{(equation 3)}$$

$$F = 0.333 \frac{SLt^2}{A} \quad \text{for wiping dies} \quad \text{(equation 4)}$$

Where **F** = bending force required, lbf (N)

K = a constant that varies from 0.167 for large die Radii and clearances to 0.333 for sharp die radii and high plastic working stresses

t = sheet metal thickness, inches (mm)

L = length of bend, inches (mm)

r1 = punch radius, inches (mm)

r2 = die radius, inches (mm)

C = die clearance, inches (mm)

S = Ultimate tensile strength, psi (Pa)

$A = r1 + C + r_2$

Flanging Pads and Required Pressure

The flanging pad must grip the part firmly to insure the part will remain in tight contact with the male die half during flanging. A rule of thumb for determining sufficient pad force is as follows:

$$\text{Pad force} = \frac{SLt}{3} \qquad \textbf{(equation 4)}$$

Where F = force, lbf (N)

S = ultimate strength of the material, psi (Pa)

L = flange length, in. (mm)

t = material thickness, in. (mm)

NOTES: ____

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