Minimum Die Radii

Stuart Keeler is best known worldwide for his discovery of forming limit diagrams, development of circle grid analysis and other press shop analysis tools. Stuart teaches PMA's one-day course on "Amateur Metallurgy for the Professional Stamper" and PMA's three-day course on "Analyzing Sheet Metal Forming for Success."

As the story goes, you call the doctor and are told "Take two aspirin and call again in the morning if not cured." While sounding like a brush-off, the doctor knew that the combination of aspirin and a good night's rest would correct many cases of not feeling good.

Donald Eary, sheet metal specialist and retired professor of manufacturing for General Motors Institute, would receive many calls from GM plants about vertical die wall and corner breakage. Don's "medical" advice was: "Open the die radius to 4t (four times sheet metal thickness) and call me in the morning if the breakage continues." Very few called back. Examining deformation over the die radius will help explain the effectiveness of Don's 4t limit.

The die radius has a dramatic effect on the load needed to pull the metal over the die radius. Fig. 1 illustrates how each element of the flange first must be bent to conform to the die radius and then must be straightened to conform to the die wall. The severity of this bending and unbending is related to the R/t (die radius to sheet thickness) ratio. The smaller the die radius for a given sheet thickness, the more the metal must stretch. To illustrate this effect, the outer fiber stretch (and also inner fiber compression) for pure bending is 11 percent for a die radius equal to 4t. This increases to 33 percent and 55 percent for die radii of 1t and 0.5t, respectively.

As the metal stretches or compresses, work hardening causes the metal to become stronger and requires a greater and greater force to continue deformation. Even worse, the amount of deformation is doubled because the bent element has to be restraightened as it moves into the die wall area.

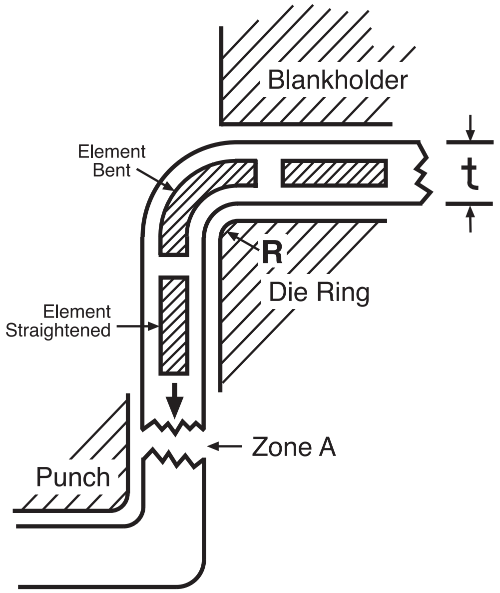

Fig. 1—Higher forming strains and greater work hardening are created when bending and unbending an element of sheet metal over a smaller die radius.

The required increase in pull force is shown graphically in Fig. 2 for AKDQ steel in the common thickness range of 0.75 to 1.25 mm (0.03 to 0.05 in.). The required pull force is shown as a ratio of the required pull force divided by the pull force plateau measured at a die radius of 6t. Note the rapidly increasing pull force ratio as the R/t ratio drops below 4.

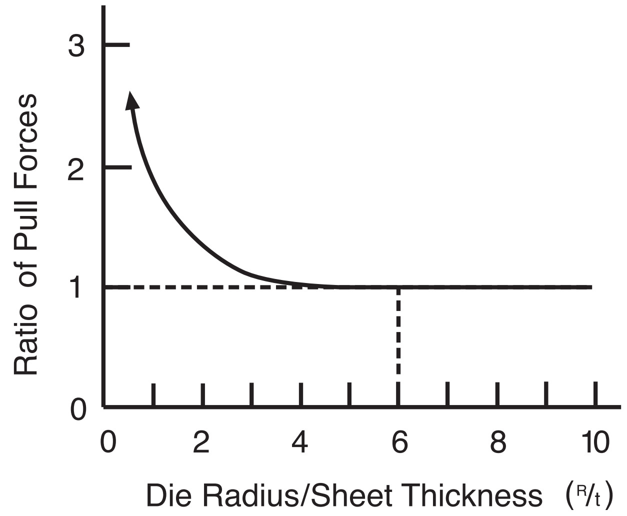

Fig. 2—Decreasing the die radius to sheet thickness ratio (R/t) below 4 causes the force required to pull the sheet metal over the die radius to increase rapidly.

While formulas were used to calculate the relationship between pull force and R/t ratio, experiments have confirmed these results. Additionally, graphs in Prof. Eary's book (Techniques of Pressworking Sheet Metal—an Engineering Approach to Die Design, by Eary and Reed, 2nd Edition, 1974, Prentice-Hall, Englewood Cliffs, New Jersey) show similar relationships.

Breakage of the workpiece in the die wall (Zone A in Fig. 1) occurs when the total force required to pull the metal from the flange (binder) into the die wall exceeds the pulling force capability of the metal already in the wall. The total force required to pull metal from the flange is the sum of: 1) bending and unbending force to move the metal over the die radius, 2) restraining force created by the blank size, flange holddown load, draw beads, etc., and 3) frictional force.

In many stampings, the restraining force or the frictional force can not be reduced without compromising the quality of the stamping. Reducing the bending and unbending forces may be the only process option remaining. If the die radii and flange areas are trimmed from the final part, then opening the die radius is a viable option. However, if the die radius and portions of the flange must remain on the final part, then a subsequent restrike of the die radius will be required.

Fig. 2 provides other important information for die tryout. The pull force remains almost constant for R/t ratios greater than 4t. Thus, breakage along the die wall in an area already having a die radius greater than 4t will not be significantly helped by additional increases in the die radius. Now the restraining force or the frictional force must be reduced.

Don Eary also suggested a maximum die radius of 10t. As can be visualized in Fig. 1, a very large die radius will cause loss of blankholder control long before the metal enters the die wall. Loss of blankholder control can mean loss of buckle control, resulting in a wavy surface and other possible defects. **MF**