



THE SCIENCE OF FORMING | STUART KEELER

Cups and Boxes Are Similar

Stuart Keeler (Keeler Technologies LLC) is best known worldwide for his discovery of forming limit diagrams, development of circle grid analysis, and implementation of other press shop analysis tools. Stuart's sheetmetal forming experience includes 24 years at National Steel Corporation and 12 years at The Budd Company Technical Center, enabling him to bring a very diverse background to this column and the many seminars he teaches for PMA.

The critical forming modes in deep-drawn boxes and cylindrical cups are very similar and both benefit from the same problem solutions.

Let's start with deep drawing a cylindrical cup with a punch radius R_p (Fig. 1). The maximum recommended blank radius R_B for low-carbon steel is about twice the punch radius or 2.0 to 2.2 R_p . This blank size creates a cup height approximately equal to its diameter.

Forming a deeper cup requires a larger-diameter blank (Fig. 1, shaded area). However, the force to reduce (compress) the larger blank circumference down to the circumference of the punch/die radii becomes too large and the draw wall tears. One can try to lower the coefficient of friction of the lubricant, increase the die radius, reduce blank-holder pressure, improve spotting of the blankholder or a combination of these process modifications to mini-

mize the breakage of the draw wall. However, the diameter of the blank relative to the punch/die radii remains the primary controlling factor to avoid tearing.

To minimize blanking costs, tryout often starts with a simple, square blank with dimensions equal to the blank diameter (Fig. 2). Even if the blank width is just below the critical blank dimension, tears may form in four locations around cup wall, coinciding with the corners of the blank. The triangular-shaped pieces of excess material act as dead material, requiring an increased force to move the blank toward the punch and into the cup wall.

Strain measurements within the triangle show zero deformation; as a quick check, use a business card to determine if the corner angle is still 90 deg. Even worse, the triangle of dead material also acts as a rigid reinforcement against the reduction of the circular blank cir-

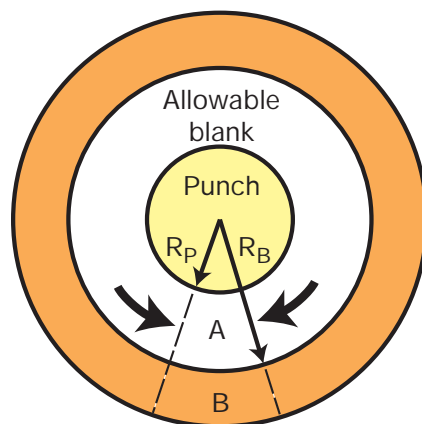


Fig. 1—When deep drawing a cylindrical cup, each segment of the allowable blank (A) undergoes compression as the circumference decreases during flow toward the die radius. Excess blank (B) greatly increases the forming force, causing the cylindrical cup to break.

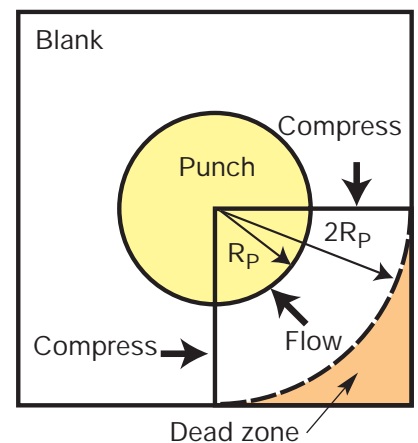


Fig. 2—Attempting to deep draw a cylindrical cup from a square blank creates a dead zone of material at each corner that restricts material flow and encourages early fractures in the cup wall.

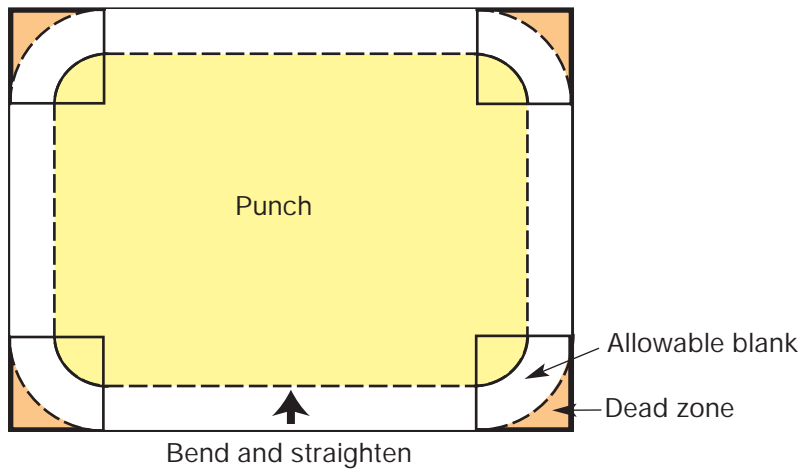


Fig. 3—The four corners of a rectangular box drawn from a rectangular blank generate problems almost identical to those in a cylindrical cup drawn from a square blank as shown in Fig. 2.

cumference, substantially increasing the draw force.

A common solution for this excess material is to miter the corners close to the blank diameter. While much of the excess material is removed, an octagonal blank is now created. This defeats the original goal of a simple square blank. If failures still occur, try cutting a circular blank to a diameter less than the allowable diameter.

To visualize a box, the preceding cup is cut into four equal quadrants to form the corners of the box (Fig. 3). Straight wall segments are inserted to complete the square or rectangular box. The forming mode for these wall segments is bend-and-straighten. The material in the flange moves toward the die radius, bends to the curvature of the die radius, flows over the die radius and finally straightens again as it becomes part of the box wall.

The four corners of the box remain the critical deformation areas, especially when using a rectangular blank. The problem corrections for the cylindrical cup now are applicable to the box corners: miter the corner, cut a circular blank, reduce the blank diameter, increase the die radius, improve the lubricant and minimize blankholder pressure.

Observing dies for many square and rectangular box dies, including oil pans, refrigerator crisper pans, consumer products, etc., one finds a draw bead completely around the perimeter of the

box. Metal-flow analysis suggests that a draw bead is the last tooling feature one should have in the corners. Draw beads (sometimes called speed bumps) usually are necessary along the straight sides of the box where material easily pulls in for the bend-and-straighten forming mode. However, deformation in the corners creates a large volume of material trying to be compressed and stuffed over a die radius with a much smaller circumference compared to the original dimensions.

Look back at Fig. 1. Would one want to insert a draw bead a short distance from the die radius and around the entire cylindrical cup blank? Inserting such a bead would greatly increase the severity of forming operation, reduce the allowable cup height generated in one stroke, increase the probability of failure and make the forming operation more difficult in general. The corners of Fig. 2 are even more severe and certainly not a location for a draw bead. Based on these two examples, why would it be advantageous to insert curved draw beads in the corners of a box (Fig. 3)?

There is one additional feature of the box corner that is absent in cylindrical cup drawing. For a given corner radius the allowable height of the box increases as the length of the longest side of the box increases. A computational analysis of box height with several examples will be presented in next month's column. MF