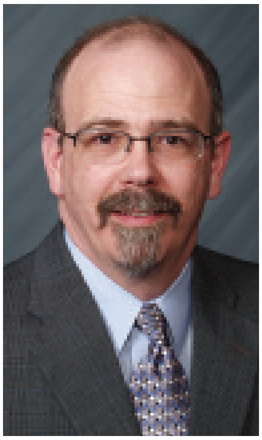

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Peter Ulintz will be a facilitator at PMA's Tool & Die Roundtable on May 8-9 in Nashville, TN. Check www.metalforming.com for this and other seminars.

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Deep-Drawing Guidelines—Boxes

Consider the four corners of any deep-drawn box: If the sides of the box were removed, the remaining corner radii could be assembled into a cup (Fig. 1). Subsequently, the corners of the box will form in a manner similar to cup drawing. The corners will be compressive on the material moving toward the die radius and tensile on the material that has been drawn over the radius. But material flow into the sides and ends of the box is bending and straightening. This puts the material between the corners—the side walls and flange areas—in tension. Since drawing stresses in the corners are relieved by allowing some excess material to flow sideways into the straight section, larger drawing ratios are achievable for box corners than for true cups of equal diameter.

Since different forming modes and complex material flow are required to generate the corners and side walls, stampers must consider several factors when deep drawing box shells, including: The size of the corner radius, the ratio between the corner radius and longest side, material thickness and type, size of the radius at the bottom of the shell, width of flange, shape of blank, blankholder spotting, the type of die and the type of press. But the two primary design factors are the corner radius through the center of material, and the ratio between the corner radius and the length of the longest side.

The size of the corner radius can be used to estimate the maximum draw depth for square boxes using tables similar to that shown Fig. 2. These tables are readily found in die-design and metalforming handbooks. Rectangular boxes will benefit from the formability curve in Fig. 3 to establish maximum draw depth (h) because it considers the ratio of the corner radii (Rc) to the largest

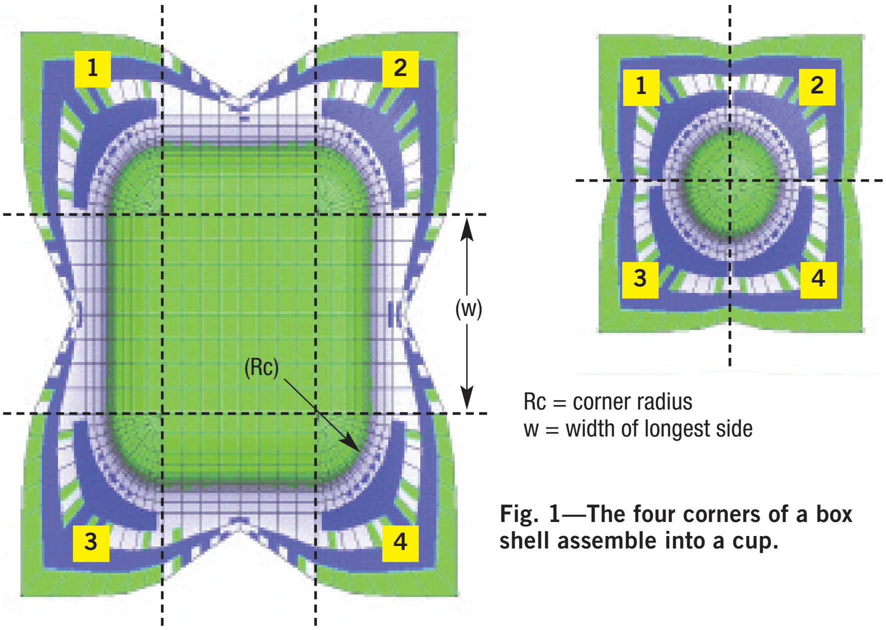

Fig. 1—The four corners of a box shell assemble into a cup.

Fig. 2—Draw-depth table for square boxes

Corner Radius through center of material	Depth of Draw times corner radius
0.000 - 0.187 in. radius	8
0.187 - 0.375 in. radius	7
0.375 - 0.500 in. radius	6
0.500 - 0.750 in. radius	5
more than 0.750 in. radius	4

length of the box (w). This ratio is commonly referred to as Rc/w.

To determine the maximum draw depth for a given box shell using the formability curve, we divide the corner radius (Rc) by the longest side (w) of the box, and plot this ratio on the horizontal axis. From there, a vertical line is plotted until it intersects with the first curve. Extend a perpendicular line from the intersection on the curve to the vertical axis, which provides a maximum height-to-width ratio (h_{max}/w). Using simple algebra we can solve for h_{max}; the maximum height to which the box can be safely drawn in one forming operation. For example, assume Rc = 2 and w = 30:

$Rc/w = 2/30 = 0.067$.

When 0.067 is plotted on the horizontal axis, it intersects the first curve at:

$h_{max}/w = 0.35$.

Substituting for w gives: $h_{max}/30 = 0.35$

Thus: $h_{max} = (30)(0.35) = 10.5$

In other words, a box shell with a corner radius of 2 and the longest side 30, the maximum depth of draw in a single operation is 10.5. From the formability curve it becomes easy to see that increases in corner radii and/or box length will allow deeper drawing, whereas reductions will reduce the maximum depth of draw. A benefit of the formability curve is that it allows analysis of inverse relationships, when one parameter (Rc) increases as the other parameter (w) decreases.

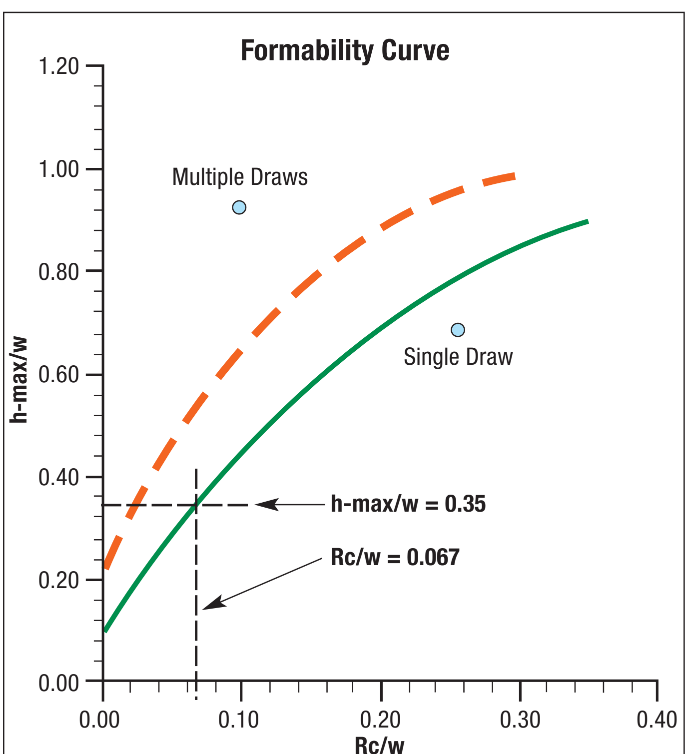

Fig. 3—Formability curve for rectangular boxes.

When the depth of the box is known by design, h/w and Rc/w can be plotted on the formability curve. If the plotted point falls within the large area under the solid curve, the part can be formed safely in one operation. If the point falls within the area between the dashed and solid curves, the part could be formed in one operation providing that all of the forming conditions were ideal and that superior materials and lubricants are used. If the point is located above the dashed curve, multiple forming operations are required.

With no formability curve available, use the following rule of thumb: For part depths less than five times Rc, one operation is required; part depths from five to 11 times Rc require two operations; part depths from 11 to 16 times Rc require three operations; and part depths from 16 to 21 times Rc require four operations.

Additional factors must be considered, but are often overlooked. They include:

• Provide additional punch-to-die clearance in the draw corners to accommodate material thickening. CNC machining the punch or die cavity with a simple offset for material thickness will not account for material thickening in these corners.

• The blankholder must be relieved (spotted in) to accommodate flange thickening in draw corners.

• Draw beads, not excessive blankholder force, may be required between the corners to retard material flow to prevent wrinkles or waves from forming in the walls.

• The drawing ratio may need to be reduced in the corners. Accomplish this by cropping material at 45 deg. at the corners. Referring back to Fig. 1, the assembled corner radii form a drawn cup but the cup is being drawn from a square blank. Cropping the corners at 45 deg. reduces the drawing ratio by more closely approximating a round blank.

• Forming severity can be further reduced by developing optimum blank shapes, increasing the die profile radius and improving lubrication.

• Boxes with nonvertical (tapered) walls are more susceptible to wall wrinkles. Blankholder force must be increased and allowable box height decreased. A box with tapered walls of 20 deg. may need to decrease in draw depth by 25 percent or more. **MF**