TOOLING BY DESIGN | PETER ULINTZ

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Peter Ulintz's next seminars are "PMA's Deep Draw Seminar" scheduled for April 3 in Cleveland, OH; and Simulation & Design Technology Seminar scheduled for April 24 in Cleveland, OH.

Check www.metalforming.com for this and other seminars.

Anatomy of a Deep-Drawn Cup

The engineering of deep-drawing tools relies quite heavily on data and guidelines found in die-design handbooks. These include draw reduction ratios, blankholder pressure, forming speeds, die clearances, radii sizes and other important parameters. Previous columns have addressed draw-reduction ratios, forming speeds, and punch and die radii. Other data, such as die clearances and blankholder pressure, can be better understood by examining the anatomy of a deep-drawn cup.

Fig. 1 illustrates what happens when a round blank is drawn into a cylindrical cup. As the blank is drawn into the die cavity, the remaining material (flange) compresses in the circumferential direction. As a result, large in-plane stresses build up in the flange, which can cause the blank to buckle or wrinkle, if not properly controlled.

A blankholder controls material flow by applying a restraining force onto the blank surface. The blankholder must provide sufficient force to prevent buckles and wrinkle formation but still allow the blank to flow toward the die cavity. If blankholder forces are set too high, excessive stretching and thinning can result, causing the material to rip, tear or split.

There are several ways to determine the amount of blankholder force required in drawing operations. The best practice: Use metalforming simulations. Forming simulations allow blankholder forces to be altered until a high limit (excessive stretching) and low limit (wrinkle formation) are established. The difference between the two limits is the blankholder's drawability window, illustrated in Fig. 2. The larger the window, the less sensitive the process will be to changes in blankholder pressure. As the depth of draw increases, the drawability window narrows considerably.

At the opposite extreme, a rule of thumb assumes blankholder pressure is approximately equal to one third of the drawing force. Where the process falls within the blankholder's drawability window is anyone's guess.

Another method, falling somewhere between the previous two, is to hand

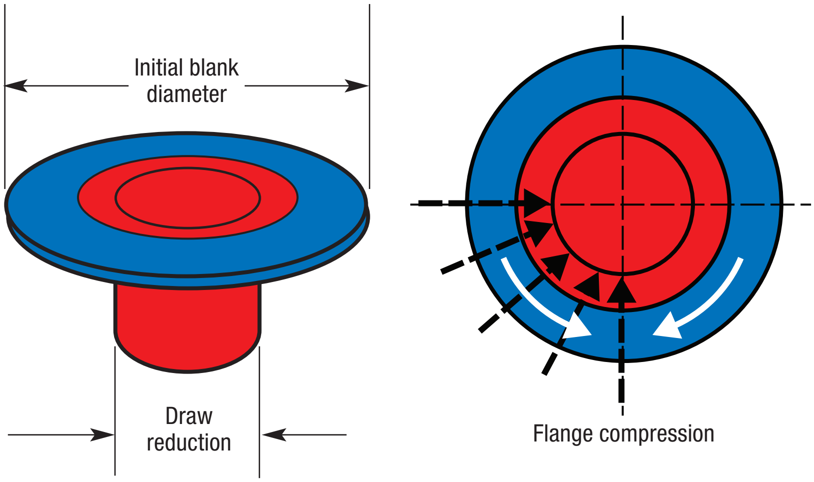


Fig. 1—Flange compression in a draw reduction

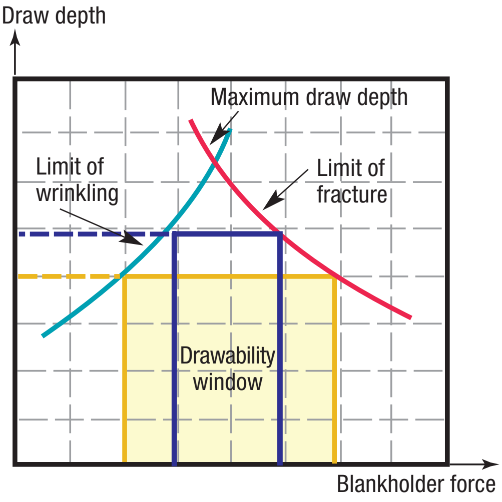


Fig. 2—Blankholder drawability window

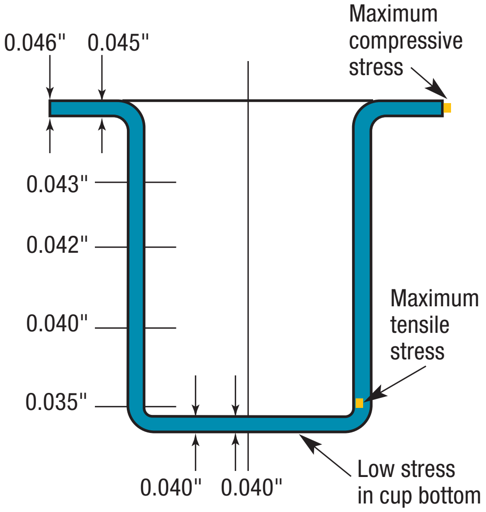


Fig. 3—Thickness distributions in a drawn cup

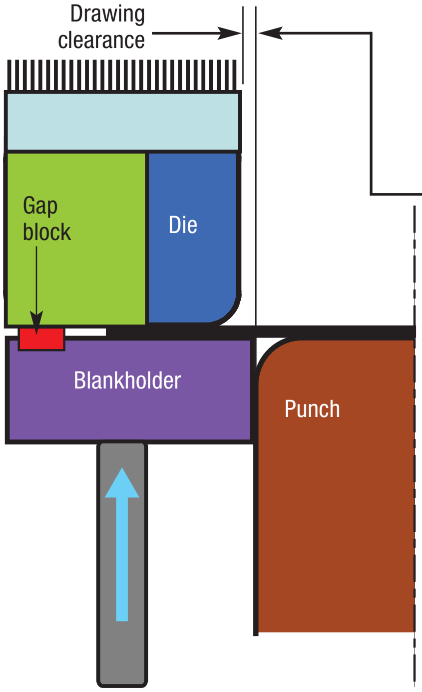
calculate blankholder-pressure requirements. To do this, multiply 600 lb. by the lineal inches around the draw punch circumference (600 x pi x punch diameter) for low-carbon steels. For HSLA and stainless steels, 1800 lb. of pressure per lineal inch is commonly assumed, while 400 lb. is typical for aluminum.

The problem of excessive blankholder pressure can be remedied by using adjustable gap blocks, also referred to as stand-offs. Gap blocks allow higher blankholding forces without restricting material flow by providing a constant gap between the die face and the blankholder. Gap blocks are initially set at material thickness plus an additional 10 percent to accommodate material thickening due to constancy of volume in the blank.

Constancy of volume is a familiar concept to anyone who has prepared hamburgers on a grill. If the hamburger patty is too large to fit on the bun, the cook may choose to reduce the burger diameter until it fits. Reducing the burger's diameter also causes it to thicken—the burger must get thicker in order to maintain its original volume. The same rule applies to cup drawing; As the blank diameter is reduced, its thickness must increase.

The cross section in Fig. 3 depicts a distinct pattern of thickening and thinning found in flat-bottom cup drawing. Large compressive stresses are found in the flange where the material has thickened considerably. In the cup wall, formed by a combination of compressive and tensile stresses, the amount of thickening diminishes as it approaches the die-impact (shock) line. Below the die-impact line, thinning occurs as the maximum tensile stress is found near the punch-nose radius. The small punch-nose radius, as shown, concentrates the maximum tensile stress near the cup bottom where little or no deformation has occurred. Deeper draws are possible when larger punch-nose radii are used because the larger radius shifts the maximum tensile-stress site further down the cup wall, where the material has been strengthened by cold working. No deformation takes place at the flat-cup bottom, thus the material retains its original thickness there.

Fig. 4 provides recommended tooling clearances for deep drawing cups from low-carbon steels. Having studied the anatomy of a deep-drawn cup, it becomes clear why these tooling clearances, gap blocks and larger radii are required in successful deep-drawing tools. **MF**



Suggested Draw Clearances			
Material Thickness, T	**First Draw**	**Redraw**	**Sizing Draw**
<0.016" (<0.41 mm)	1.08T	1.09 - 1.10T	1.04 - 1.05T
0.016" - 0.050" (0.41 - 1.27 mm)	1.08 - 1.10T	1.10 - 1.13T	1.05 - 1.06T
0.050" - 0.125" (1.27 - 1.18 mm)	1.10 - 1.13T	1.13 - 1.15T	1.06 - 1.08T
>0.152" (>1.18 mm)	1.13 - 1.15T	1.15 - 1.20T	1.08 - 1.10T

Fig. 4—Suggested draw clearances for low-carbon steel