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Peter Ulintz will be speaking on the advances in metalforming analysis on March 27 at METALFORM 2007 in Rosemont, IL. For more information, go to www.metalform.com/2007/attendees/conference.htm.

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Deep-Drawing Guidelines—Cups Part 2

Of all the forming processes, axis-symmetric cup drawing is the most predictable and has the most known design parameters. A design parameter of particular importance to the tool design is the drawing ratio.

The drawing ratio represents the relationship between blank and punch diameter. This relationship can be evaluated using a standard laboratory test method. The test method requires a tool set with a fixed 4-in. punch diameter, similar to that shown in Fig. 1. Blanks of known diameters are positioned in the tool set and drawn into round cups. The blank diameter is increased in small increments until reaching a diameter that fails to produce a fully drawn cup free of necks or splits. The ratio between the largest blank diameter and the draw punch is called

the limiting draw ratio (LDR).

To calculate LDR, divide the maximum blank diameter by the punch diameter. For example, if the maximum blank diameter was 8 in., the LDR would equal 2 (8-in. blank divided by 4-in. punch). Simply stated, the maximum ratio between the blank diameter and punch diameter is 2:1.

The LDR, commonly used in metalforming research and laboratory testing, is not well known to manufacturing or tool and die shops. These industries commonly work with a mathematically related expression known as percent reduction. To calculate percent reduction from the example above, the cup diameter through the centerline of stock is divided by the maximum blank diameter and then multiplied by 100. For 0.032-in.-thick material, the percent

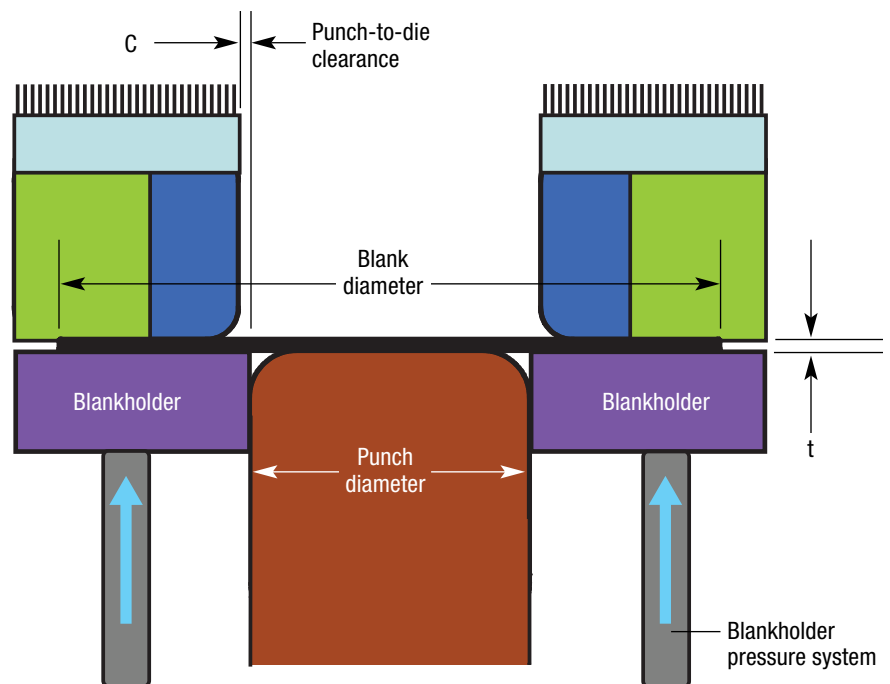
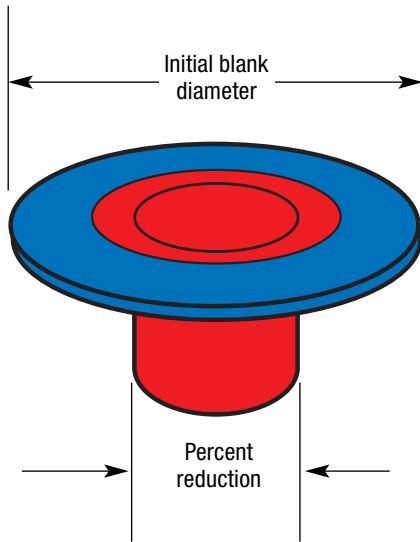


Fig. 1—Draw-tool setup.



reduction would be: 4.032-in. cup diameter divided by 8-in. blank times 100 equals 50.4 percent. This means a cup a diameter equal to 50 percent of the original blank diameter is the maximum possible reduction; a ratio of 2:1.

Most die-design handbooks contain draw-reduction tables similar to the one shown in Fig. 2. These tables incorporate safety margins that account for some process and friction variations likely to be encountered in production. Because thick materials can stretch further than thin materials, drawing reductions are reported as a function of material thickness. Due to differences in work-hardening behavior, surface topography and other factors; these tables are always material type and grade specific. Tables developed for low-

Draw-Quality Low-Carbon Steel			
Thickness of Material, in.	Percent Reduction from Initial Blank to First Draw	Percent Reduction from First Draw to Second Draw	Percent Reduction from Second Draw to Third Draw
0.010 - 0.014	27%	18%	17%
0.015 - 0.019	32%	20%	19%
0.020 - 0.024	35%	21%	20%
0.025 - 0.029	39%	22%	21%
0.030 - 0.034	42%	23%	22%
0.035 - 0.039	44%	26%	24%
0.040 - 0.044	46%	28%	25%
0.045 - 0.049	47%	28%	25%
0.050 - 0.054	47%	29%	26%
0.055 - 0.059	48%	29%	26%
0.060 - 0.069	48%	30%	27%
0.070 - 0.125	49%	31%	27%

Fig. 2—Draw-reduction table.

carbon steel cannot be used for high-carbon steel, brass, aluminum or any other alloy.

Often the finish part geometry is not obtainable in a single draw reduction. Additional draw reductions are required to obtain the final cup diameter and depth, accomplished by either direct redrawing or reverse redrawing. (Fig. 3)

Direct redrawing further reduces the cup diameter by redrawing the cup in the same direction as the first draw. In reverse redrawing, the cup is inverted in order to reduce its diameter. Regardless

of the method chosen, each having advantages and disadvantages, the percent reduction in the second draw is always less than the first draw. This is because metal alloys work-harden whenever deformed or cold-worked. Subsequent redrawing operations induce more work-hardening; thereby reducing the percent reduction for the additional redraws.

Most die-design handbooks provide data for the first, second and third draw reductions. So what if you need more than three draws to produce your part? I found the following to work reasonably well: Analyze the difference in the percent reduction between the second and third redraw. Apply this percent difference to every subsequent reduction beyond the third redraw. For example, the difference between the second and third draws for 0.060-in.-thick material (reference Fig. 2) is 3 percent. Applying this difference to subsequent redraws gives the following: fourth draw equals 24 percent, fifth draw 21 percent, and sixth draw 18 percent.

Next month, we'll examine how material flows in cup-drawing processes and the effect it has on our tool designs. **MF**

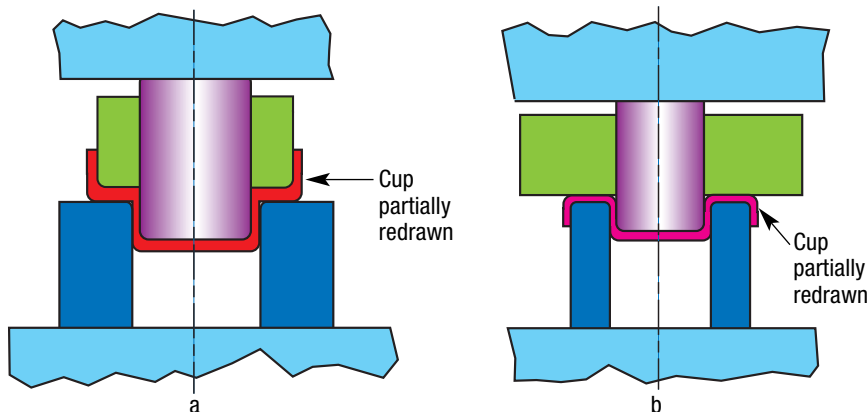


Fig. 3—Direct redraw (a) and reverse redrawing (b).