



THE SCIENCE OF FORMING | STUART KEELER

Process Changes Can Increase Cup Height

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.

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Stuart Keeler's next seminar is "Forming Difficult Stampings," scheduled for August 16-17 in Cleveland, OH. Check www.metalforming.com for this and other seminars.

The limiting draw ratio (LDR) for cylindrical-cup drawing was discussed in the May and June columns. The following conclusions were reached:

1) The critical forming parameter for cylindrical-cup drawing is the LDR, which is the ratio of the maximum blank diameter to punch diameter that can be drawn in one draw operation. In turn, this maximum blank diameter controls the height to diameter ratio of the drawn cup.

2) The material property that affects the LDR is the normal anisotropy ratio (r_m), which defines the resistance of the sheetmetal to deformation in the thickness direction. An advantageous r_m value (greater than 1) is found primarily in cold-rolled vacuum-degassed interstitial-free (VD-IF) steel or aluminum-killed draw-quality (AKDQ) steel.

3) Hot-rolled and higher-strength steels, as well as aluminum and other nonferrous materials, have r_m values around 1 and therefore have no deep-draw advantages.

In summary, deep-draw design limits are relatively easy to compute and fall into the "back-of-envelope" category. If r_m is around 1, the LDR or edge of the deformation cliff is approximately 2.0 to 2.2 and the permissible height of the cylindrical cup approximates the cup diameter. To avoid falling off the edge of the deformation cliff, the general practice is to keep the design draw ratio about 0.2 below the LDR. If sufficient cup height cannot be achieved in one operation for a given cup diameter, a redraw operation is added.

If the tool severity is close to the edge of the cliff and there is no

room for a redraw stage, what can be done to save the tooling? First, reduce the unnecessary frictional forces. These forces do not contribute to the shape of the cup but certainly increase the total forming force. A major improvement in the lubricant will help. A dry or barrier lubricant applied to the sheetmetal completely isolates the sheetmetal from the tooling. These lubricants have a

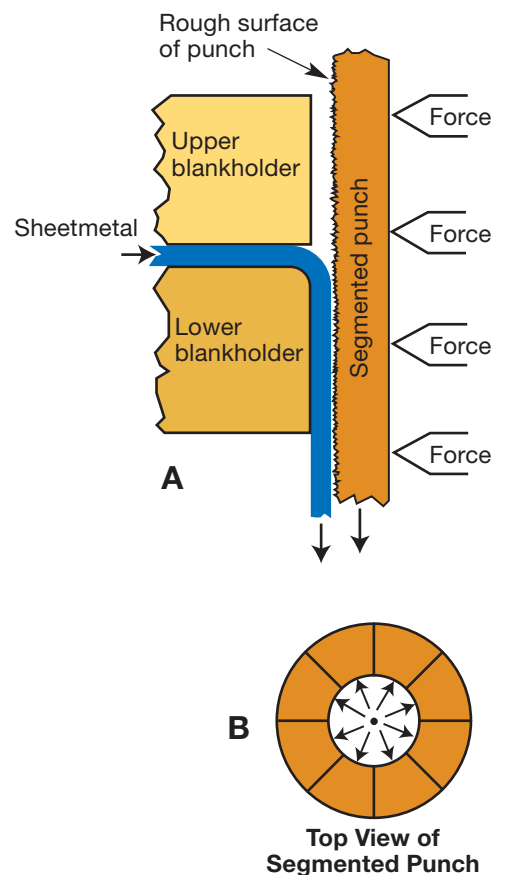


Fig. 1—Schematic A illustrates how work-hardened sheetmetal locked between an expanding punch with a serrated surface and the lower blankholder can be used to pull a larger blank into the cup wall. Schematic B shows a plan view of the expanding segments of the punch.

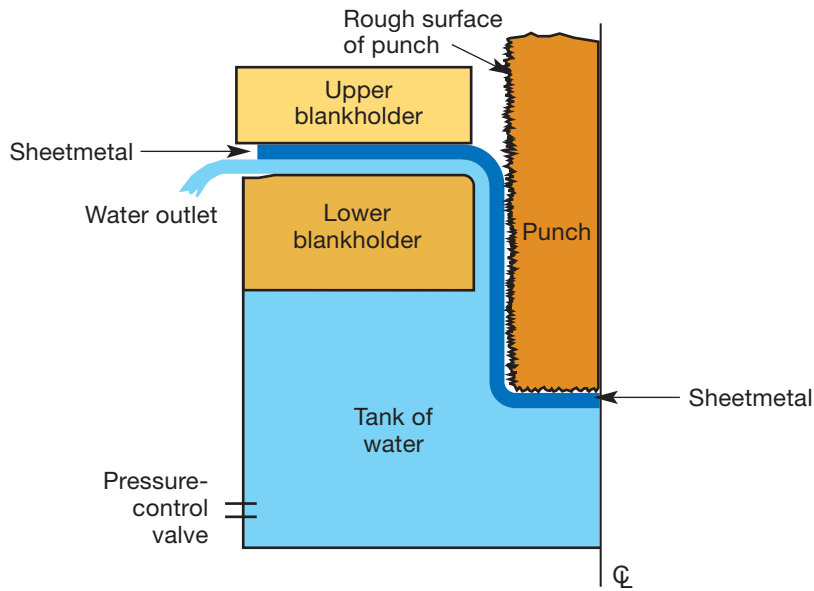


Fig. 2—High-pressure water created by driving the punch into a sealed tank of water can lock the sheetmetal to the serrated punch to pull increasingly workhardened metal into the cup wall.

coefficient of friction of 0.03 to 0.04 compared to 0.12 to 0.15 for the better liquid lubricants. This can reduce the frictional force by a factor of four or more depending on the surface condition of the tooling. In addition, these dry or barrier lubricants also are temperature insensitive and do not degrade when heated.

The maximum cup-drawing force occurs about one-third of the way through the stroke. Clearing that critical depth without failure means noncritical forming all the way to home depth. Procedures to reduce the peak blankholder force only near the maximum force help successful cup forming. Various techniques range from programmable blankholder forces on hydraulic presses to controlling the pressure in cylinders built within the die.

The bending/unbending over the die radius is another major contribution to the forming force. Therefore, increasing the die radius will reduce the forming force. If the cup has a remaining flange with a required radius, a restrike in a subsequent stage might be easier than attempting to insert a new redraw station. The radius must not be so large, however, that a large quantity of buckles occur at the end of the stroke as the

blank pulls out early from under the blankholder.

A very special technique has been found to radically increase the LDR for materials having higher n values. These include VD-IF steel, 3xx-series stainless steels, brass, copper and other materials

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with n greater than 0.25. For those with n values around 0.4 or 0.5 the LDR can increase by a factor of 2 or more. The mechanism for forming these cups is to transfer the load application from the lower wall of the cup (where the punch radius joins the vertical wall) to the wall location just inside of the die radius. Here, the sheetmetal has been workhardened by the deformation in the binder and the bending/unbending over the die radius. A greatly increased punch force can be applied to this stronger material to pull in a larger blank.

Mechanically, the application of the

punch load to the sheetmetal just entering the cup wall is accomplished by squeezing the material tightly against a rough or serrated punch surface. One tool design is shown in Fig. 1A. A segmented punch expands circumferentially to force the sheetmetal between a highly polished lower blankholder and the serrated surface of the punch. The sheetmetal “locks” onto the punch and is pulled downward. New sheetmetal entering the locking zone is stronger than the previous sheetmetal, thereby allowing a larger pulling force. A number of punch designs can be used. In Fig. 1B the segments of the punch are pushed out by a central tapered shaft. Outward movement of the segments is very small because they only are used to generate the locking force and not any circumferential stretching of the sheet.

Another procedure for locking the sheetmetal is mechanically much simpler (Fig. 2). Here the punch is pushed into a sealed tank of water. This causes high water pressure that forces the water between the lower blankholder and cup wall. Now the entire length of the cup wall is locked against the serrated punch. Even better, the water also acts as an ideal lubricant between the lower blankholder and the moving blank. Water pressure on the sheetmetal increases until a preset pressure-control valve opens to maintain a constant maximum pressure. If failure does occur, it will be at the blankholder location and not at the bottom of the cup wall.

Many press-shop techniques are discovered by trial and error. In contrast, the benefits of transferring the load to the blankholder zone were first proved by theoretical calculations and knowledge of the n value. Laboratory experiments then confirmed the predictions. This should be the primary role for the science of forming—to create new metalforming technologies rather than only explain why existing techniques work. **MF**