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Deep-Drawing Guidelines—Cups Part 1

One of the most complex metal-forming operations is the deep-drawing process. In most sheet-metal-forming operations the finished part is stretched or squeezed into a desired shape. This is particularly true for bending, flanging, extruding, embossing and coining. But in deep drawing the objective is to force the sheetmetal to flow into a die cavity to produce the required shape with minimal stretching and thinning of the material.

Deep drawing can be defined as a metalforming process in which a part is produced from a flat sheetmetal blank by the action of a punch force onto the blank. The blank is pulled (drawn) into a die cavity, which causes the flange of the blank to compress in the circumferential direction while material flow is controlled by a restraining force provided by a blankholder.

Fig. 1 illustrates the basic components in a typical draw-tool arrangement. These components include: the blankholder and related pressure system, a draw punch, a die cavity and a sheet-metal blank. Each of these components contains important features critical to the success of the drawing operation.

The draw punch applies the required force onto the sheetmetal blank in order to cause the material to flow into the die cavity. The critical features of the draw punch include the punch face and punch-nose radius (Rpn). The punch-nose radius cannot be too small as it will try to pierce or cut the blank rather than force the material to bend around the radius. The minimum punch-nose radius depends on material type and thickness. Limitations have been established through years of empirical testing

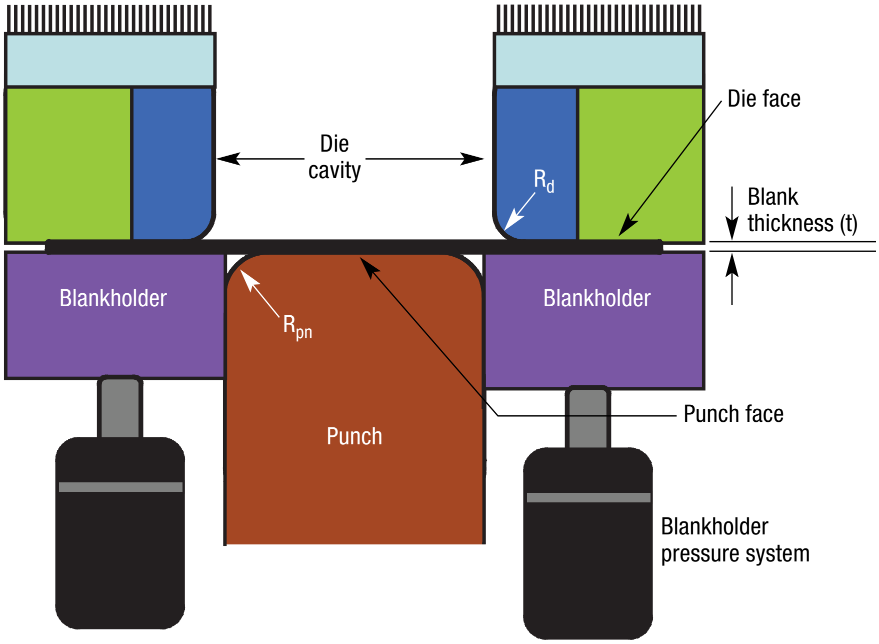

Fig. 1—Draw-tool nomenclature.

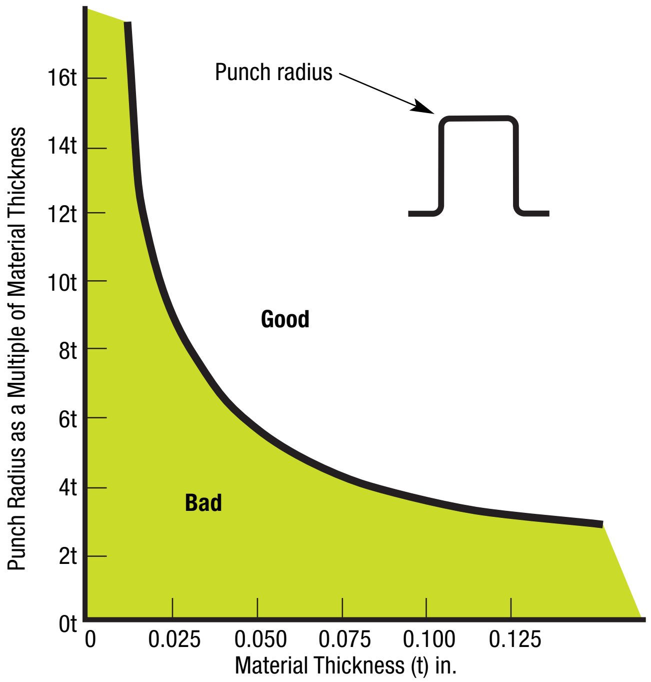

Fig. 2—Minimum punch-nose radii as a function of material thickness.

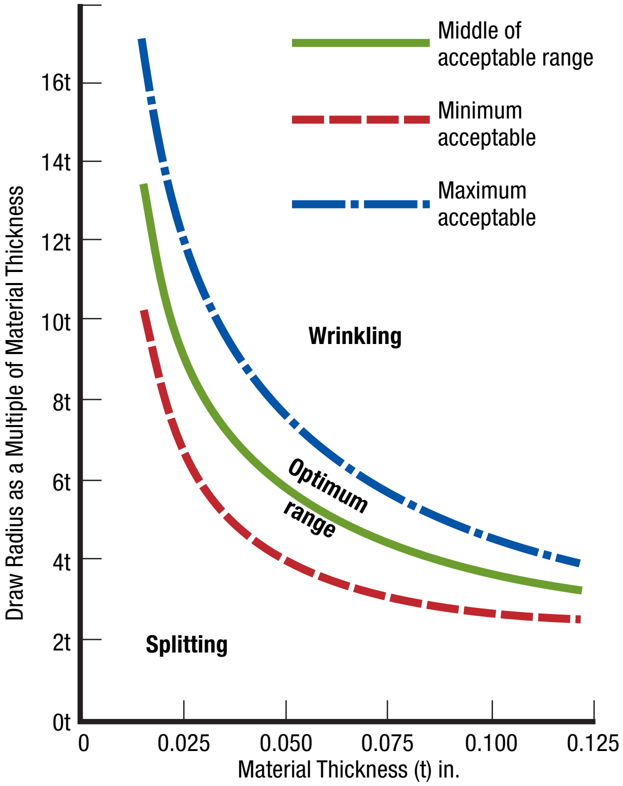

Fig. 3—Optimizing the draw radius.

and field study. Fig. 2, the result of such testing with low-carbon steels, identifies minimum punch-nose radii related to the material thickness of the blank. This ratio of radius (r) to material thickness (t) is commonly referred to as the r/t ratio.

It is equally important to understand that as the punch-nose radius is increased the blank will tend to stretch on the punch face rather than draw-in the blank edge. A large radius, especially one that is highly polished, reduces the amount of friction on the punch-face surface. Reducing friction here allows the material to stretch more easily across the punch, the path of least resistance, instead of drawing-in the blank edge.

When a large punch radius is required it often is helpful to leave the punch face rough. This increases the coefficient of friction over the punch-face surface and discourages material flow, thus helping to pull in the blank flange in toward the die cavity. Avoiding lubrication between the punch face and the blank surface also will help retard material flow. Remember, the objective is to cause the blank edge to flow toward the die cavity, not to stretch the blank over the punch face.

The die radius (Rd) and die-face surface are probably the most influential features in a draw tool that uses a flat blankholder. The flat blankholder distinction is made because some draw tools, with complex product geometry, often have blankholders that are not flat but have curvature that wraps the blank prior to forming. In these tools the blankholder geometry is extremely critical and highly engineered with fully developed surfaces to ensure that the blank wrap does not impede material flow after the die closes. But in cup drawing, flat blankholders are nearly always used.

If the draw radius is too small the part may split as the material deforms. This is due to the high restraining forces caused by bending and unbending of the sheetmetal over a tight radius. Drawing over a tight radius also produces a tremendous amount of heat. This can lead to microscopic welding of the sheetmetal to the tools, known as galling. On the other hand, an excessive die radius causes the blank to wrinkle in the unsupported region between the punch face and the die face. When the blank wrinkles, the engineered clearance between the punch and die cavity is reduced by the wrinkle height and material flow is impeded and fractures in the stamping result.

It is apparent that there must be some range of die radii to select from that will work; not too small and not too big. The die radius, similar to the punch radius, depends on the r/t ratio. The graph in Fig. 3 helps select die radii when deep drawing low-carbon steels.

Finally, attention to detail in the die-design and tool-build process should reflect the importance of the draw-die radius. The die radius must be absolutely smooth, highly polished in the direction of material flow, and blend perfectly into the die wall.

Next month, we'll discuss draw-reduction ratios and blankholder forces.

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