Controlling material flow in drawing operations

CNC hydraulic cushions help improve drawability

BY ALI FALLAHIAREZOODAR, ZEMING YIN, AND DR. TAYLAN ALTAN

In deep drawing, with or without draw beads, a blank holder restrains the sheet metal blank at its periphery while a punch forces the metal to flow into the die cavity. The quality of the formed part is determined by the amount of material drawn into the die cavity. Excessive material flow and low blank holder force (BHF) may cause wrinkling, and insufficient material flow will cause excessive thinning, which can cause tearing or fracture (see **Figure 1**).

Generating Blank Holder Force

Typically, the BHF is generated by one or more pneumatic cushions or hydraulic cushion cylinders and transmitted via the pressure box and cushion pins to the blank holder.

Pneumatic cushions generate the BHF by moving a piston activated by compressed air. The maximum pressure in such a system usually is limited to about 240 pounds per square inch (PSI), and a very large piston area is needed to generate the required force.

The motion and pressure of pneumatic cushions are difficult to control because the air is compressible, but the use of a hybrid (air and hydraulic) system can help alleviate this problem. Pneumatic cushion systems produce a constant BHF and usually are used with spacers that are 10 to 15 percent thicker than the initial blank thickness.

Nitrogen cylinders built into the die provide pressure and force that increase 10 to 20 percent with stroke during the forming operation.

Hydraulic cushions generate the required BHF by pressurizing the hydraulic fluid. Computer numerical control is used to control the BHF time and stroke, which controls the oil flow to the cushion cylinder. While modern systems are reliable, some drawbacks of hydraulic cushions are slow response time, requirements for cooling the hydraulic oil, and possible system leaks.

Controlling Material Flow

In high-strength, low-ductility materials, such as advanced high-strength steels and 6xxx and 7xxx aluminum alloys, forming a complex geometry requires precise control of material flow into the die cavity. This control can be achieved using spacers (standoff blocks) with a specific height or a CNC cushion system to deliver constant or variable BHF (see **Figure 2**).

Spacers. When spacers are used, the die and blank holder are pressed against each other and the spacers. At the start of the stroke, the blank is free to flow into the die cavity with the relative movement of the punch against the die. As deformation and punch stroke proceed, the edges of the blank become thicker and some minor wrinkling may occur in the flange region. The blank thickness and wrinkle height increase but cannot exceed the clearance between the die and blank holder, provided by the spacers, if the BHF is sufficiently large.

At this stage in drawing, the blank holder controls the material flow. The force exerted by the deforming blank upon the die and blank holder increases while the contact among the die, blank holder, and spacers is maintained.

The heights and locations of the spacers usually are determined during tryout through several trial-and-error stampings. Recently Audi developed an "intelligent" tool—a laser sensor that measures the flange draw-in. A control algorithm activates an adjustable spacer to the optimal value (see **Figure 3**). About 20 tools with this technology, implemented in 2012, have been used in the Volkswagen Group.

CNC Hydraulic Cushions. Modern stamping presses can be equipped with CNC hydraulic cushions. These sys-

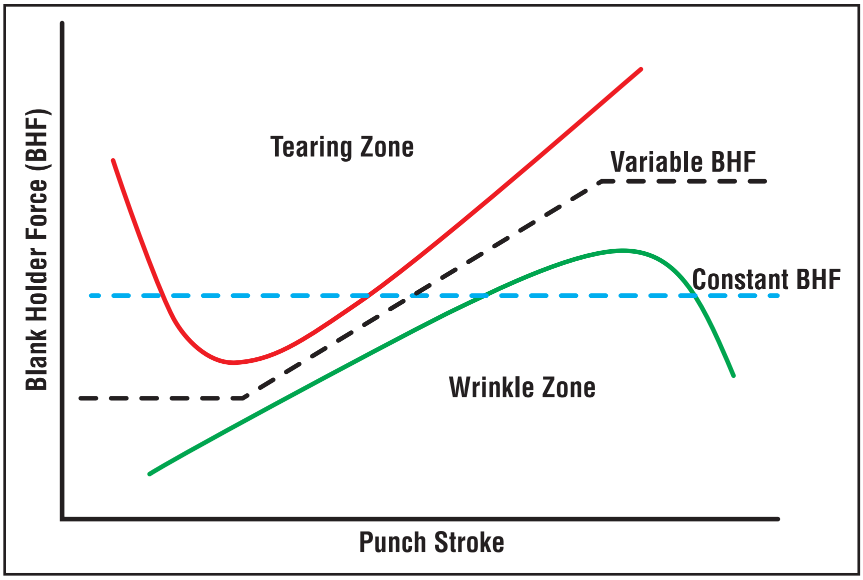

Figure 1

The BHF/stroke curve is a determining factor in drawability without tearing or wrinkling.

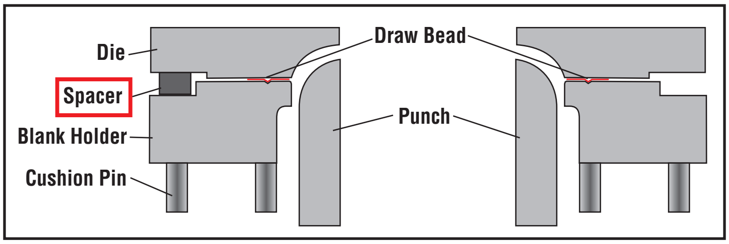

Figure 2

Two methods of applying BHF in deep drawing of sheet material are spacers (left) and CNC cushion systems (right).

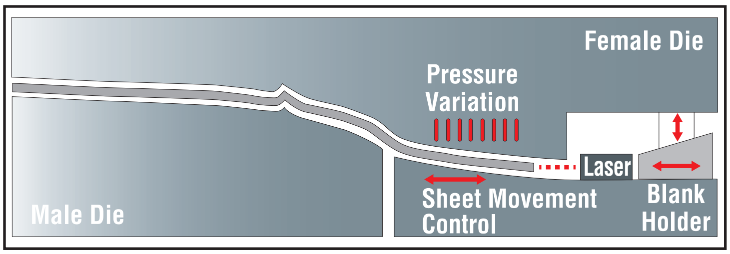

Figure 3

Audi uses this tool to control drawing by modifying the spacer height during the drawing process. Drawing courtesy of J. Spindler.

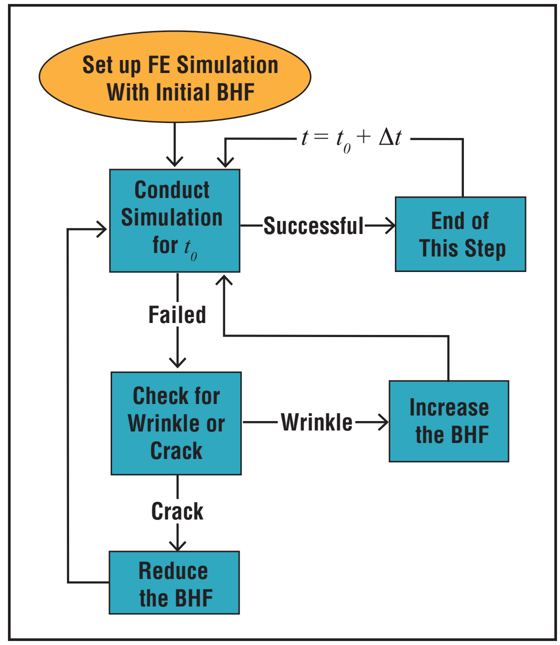

Figure 4

This methodology for determining optimum variable BHF in function of press stroke or time (t) is currently being tested.

tems can vary the BHF during the press stroke. Thus, within the limits of inertia of the hydraulic systems, CNC cushions offer flexibility to control the metal flow from the flange into the die cavity during the punch stroke.

Some advantages of the CNC cushions are:

•**Pre-acceleration:** Before the die hits the blank, the relative velocity between the blank holder and die should be reduced. So the cushion begins to travel in the direction of the moving die (or punch) before the die contacts the blank and deformation starts. This reduces sudden shock on the press and tooling and prevents the lubricant applied on the blank from being disturbed and squeezed out.

•**Variation of the BHF:** During the stroke, BHF variation helps to control metal flow into the die cavity to reduce wrinkles and prevent excessive thinning and fracture in the drawn part.

•**Increase of the BHF:** Near the end of the deformation process, increased BHF results in increased tensile stresses in the walls of the drawn part, which reduces springback without the need for more complex die design.

•**Possible elimination of draw beads:** In certain applications the BHF, controlled by the CNC cushion, may provide sufficient force to restrain excessive metal flow into the die cavity, thus reducing the amount of flange material to be trimmed.

•**Restraining force:** It is possible to increase the amount of strain and hardening in drawing exterior body panels, thereby increasing dent resistance.

Several methods are being developed to estimate the BHF variation with press stroke. One method is through experimentation during tryout. Another is to use computer simulation to predict the potential formation of wrinkles and fracture and the effect of BHF on springback.

The Center for Precision Forming, in cooperation with Hyson and AIDA America, is doing research to develop a computer simulation-based method to determine the optimum BHF versus stroke curve for a given part, material, and thickness (see **Figure 4**).

Ali Fallahiarezoodar (fallahiarezoodar.1@osu.edu) and Zeming Yin (yin.317@osu.edu) are graduate research associates and Dr. Taylan Altan (altan.2@osu.edu) is professor emeritus and director of the Center for Precision Forming (CPF) at The Ohio State University, 1971 Neil Ave., Room 339 Baker Systems Engineering Building, Columbus, OH 43210, https://cpf.osu.edu and https://ercnsm.osu.edu.

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