Improving drawability by using a servo (CNC) hydraulic cushion

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Introduction

In deep drawing, with or without draw beads, the sheet metal blank is subjected to restraining force at its periphery by the blankholder while it is forced to flow into the die cavity by the punch. The quality of a 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 may cause tearing or fracture, as shown in Figure 1, for the example of using a constant BHF.

In general, the BHF is generated by one or more pneumatic or hydraulic cylinders and is transmitted via the pressure box and cushion pins to the blankholder. In using new generations of materials with higher strength and lower ductility, i.e. advanced high strength steels and 6xxx and 7xxx aluminum alloys, forming a complex geometry requires precise control of material flow into the die cavity. There are two different methods to control metal flow in drawing: a) use of spacers (stand-off blocks) with specific height, and b) use of variable blank holder force by using a CNC cushion system, Figure 2.

Pneumatic (Air) cushion and nitrogen cylinder

In using a pneumatic cushion (air cushion), the BHF is generated by moving a piston activated by compressed air. Pneumatic cylinders are seldom used in modern presses because the maximum pressure in such a system is limited, usually to about 16 bar (240 psi) and a very large piston area is needed to generate the required force. Furthermore, it is relatively difficult to control the motion and pressure of a pneumatic cushion because the air is compressible. In pneumatic cushion systems, the BHF is constant and is applied instantaneously when the die contacts the blankholder or the blank. Therefore, usually spacers, that are 10 to 15% thicker than the initial blank thickness, are used, Figure 2. The nitrogen cylinders are built into the die and provide pressure and force that remains approximately constant during the forming operation.

Hydraulic cushion

In hydraulic cushion systems, the required BHF is generated by pressurizing the hydraulic fluid. The BHF can be controlled in time and stroke (CNC control) controlling the oil flow to the cushion cylinder.
Using spacers (stand-offs or position stops) to improve drawability

When spacers are used, the die and blank holder are pressed against each other and the spacers while, 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. At this stage in drawing, the blank holder (binder) controls the material flow. The force exerted by the deforming blank upon the die and blank holder increases while the contact between the die, blankholder and spacers is maintained.

The heights and locations of the spacers are usually determined during “try-out” through several trial and error stampings. Recently an “intelligent tool” has been developed at Audi. A laser sensor measures the flange draw-in. A control algorithm activates an adjustable spacer (possibly by a small servo motor) to the optimal value, Figure 3. This system is implemented in 2012 and around 20 tools with this technology have been used in the Volkswagen Group.

Using CNC hydraulic cushions

Modern stamping presses can be equipped with CNC hydraulic cushions. These systems have the capability to vary the blank holder force during the press stroke. Thus, within the limits of inertia of the hydraulic systems, CNC cushions offer great flexibility, during the punch stroke, to control the metal flow from the flange into the die cavity. Some advantages of the CNC cushions include:

- **Pre-acceleration**: Before the die hits the blank, it is desirable to reduce the relative velocity between the blank holder and the die. Thus, the cushion begins to travel in the direction of moving die (or punch) before the die contacts the blank and deformation starts. This capability:
  a) Reduces sudden shock on the press and tooling,
  b) Prevents the lubricant, applied on the blank from being disturbed and squeezed out.
- **Variation of the BHF**: during the stroke BHF variation would help 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 deformation process, allows to increase tensile stresses in the walls of the drawn part, thereby reducing springback
- **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.
- **Providing 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 try-out. The other is to use computer simulation that requires the ability to predict, with reasonable accuracy, the potential formation of wrinkles and fracture as well as the effect of BHF upon springback.

At the Center for Precision Forming research is in progress, in cooperation with Hyson and Aida America, to develop a computer simulation based method to determine the “optimum” BHF versus stroke curve for a given part, material and thickness. The principles of this method are described schematically in Figure 4.

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Resource
Fig 1: The effect of BHF/stroke curve in determining drawability without tearing (fracture) wrinkling.

Fig. 2: Two methods for applying BHF in deep drawing of sheet material. Left: use of spacer, right: use of CNC cushions system.
Fig 3: Schematic of the intelligent tools used at Audi to control the drawing by modifying the spacer height during the drawing process [2]
Fig 4: The methodology which is under investigation to determine optimum variable BHF in function of press stroke or time, t.