Practical Use of Servo Hydraulic Cushions
In Stamping Operations

by

Ali Fallahiarezoodar (1), Darrell Quander, Jr. (2), Pratik Mehta (1), Taylan Altan (1)

(1) Center for Precision Forming, The Ohio State University, (2) Hyson Metal Forming Solutions

In deep drawing, with or without draw beads, the sheet metal blank is restrained at the periphery of the
die by the Blank Holder Force (BHF). The relative motion between the punch and the blank holder
forces the metal to flow into the die cavity, as seen in Figure 1. The quality of the formed part is
determined by the amount of material drawn into the die cavity. Excessive metal flow may cause
wrinkling while insufficient metal flow will cause excessive thinning and fracture in the drawn part.
Metal flow into the die cavity is primarily controlled by the BHF as seen in Figure 2. In case “spacers” are
used between the die and blank holder, the thickness of the spacers also regulates the material flow.
The adjustment of the thickness of the spacers is usually done during die try out and may require
considerable know-how and experience, as well as time. A laser and servo-motor based system that
controls spacer height during production, from one stroke to the next, was developed by Audi and was
described in an earlier R&D Update (Stamping Journal, May/June, 2016, p. 16).

Servo Hydraulic Cushions. In forming without spacers, the control of BHF during the stroke of a press can
be achieved using a hydraulic cushion. With Servo control, the cushion force can be varied during the
stroke. Thus, the BHF can be varied to obtain the “optimum” metal flow control, based on part
geometry and sheet material thickness and properties. As an example the effect of constant BHF upon
part quality and achievable draw depth is illustrated in Figure 2. When the BHF, assumed to be constant
throughout the stroke in this example, is “too large” the drawn part fails by fracture or tearing. When
the BHF is too small then wrinkles occur in the flange and sometimes on the part wall.

Servo Hydraulic cushions allow to change the BHF, within the limits of the specific inertia of the
hydraulic system, during the press stroke. This level of accuracy is made possible due to the closed loop
control inherent in Servo Hydraulic Cushion systems. There is a constant monitoring of linear position,
pressure, and temperature which is being fed back to the controller and servo valve. This capability
offers several advantages in sheet metal forming using hydraulic, mechanical or servo drive presses.

Pre-acceleration and Delayed Return Motion. The cushion can be accelerated in the direction of the die
motion just before the die hits the blank, as seen in Figure 3. Thus, the relative velocity between the die
and the blank holder is reduced. As a result, sudden shock on the press, the tooling and the blank is
eliminated. This helps to reduce maintenance problems in the press and to maintain the lubricant on
the blank. After the forming operation, the return motion of the die cushion can be delayed at Bottom
Dead Center (BDC) to avoid back to back contact of the blankholder with the formed part, as seen in
Figure 3.

Reduction of wrinkles and thinning When spacers (or distance blocks) are not used, with a servo
hydraulic cushion, the BHF can be varied during the press stroke to obtain the desired metal flow..
Often it is not very simple to select the BHF curve versus stroke in order to avoid part failure, due to
fracture or forming of wrinkles in the part. As seen in Figure 4, this can be done either (a) by experience
during die try-out, or (b) by computer simulation. In a study, conducted jointly by CPF and Hyson Metal Forming Solutions, forming of a stainless steel part was successfully achieved in a servo press using BHF that was variable during the press stroke. The part geometry used in this study is seen in Figure 5.

**Forming of exterior body panels.** It is possible to increase the stretching, and consequently the strain hardening and dent resistance, of exterior body panels of an automobile, by increasing the BHF, at the start of deformation, as seen in Figure 6. Similarly, by increasing the BHF towards the end of deformation, it is possible to reduce springback and increase the straightness in the wall of drawn parts.

**Increase in Draw Depth Through BHF Vibrations.** Research in drawing using low frequency BHF vibrations, 10 Hz to 50 Hz, showed that it is possible to reduce thinning and fracture in deep drawing. Vibrations reduce friction and heat buildup in the flange, due to sliding of the blank under BHF and pressure. As a result, it is possible to increase the achievable draw depth. The practical application of this technique, however, requires additional try-outs and experimentation to ensure that this method does not reduce cycle time and productivity in deep drawing certain difficult to form materials.

**Variation of BHF between successive strokes.** The majority of AHSS exhibit variations of mechanical properties from coil to coil, or batch to batch. In forming without spacers (distance blocks), it is possible to adjust the BHF to compensate for variations in material properties. This adjustment can be easily made using a servo hydraulic cushion, to maintain quality of the formed parts.

**Possible Elimination of Draw Beads.** Draw beads are extensively used in forming low strength alloys. In such applications, nitrogen cylinders or air cushions are used to generate the BHF or the force applied upon the spacers. With increased use of AHSS the shape of the draw beads is modified to reduce the amount of strain hardening caused by drawbeads. When deep drawing without draw beads, relatively large BHF or cushion pressure is required. In some cases, the use of servo hydraulic cushions may help to eliminate draw beads and spacers. As a result, the amount of trimmed flange can be reduced and material savings can be achieved.

In this paper, potential applications of servo hydraulic cushions are discussed. Some of these applications are already in use, others are being explored and further developed.

Darrell Quander, Jr. ([dquander@asbg.com](mailto:dquander@asbg.com)) is Sales and Product Manager at Hyson Metal Forming Solutions, 10367 Brecksville Road, Brecksville, OH 44141. Ali Fallahiarezoodar ([Fallahiarezoodar.1@buckeyemail.osu.edu](mailto:Fallahiarezoodar.1@buckeyemail.osu.edu)) and Pratik Mehta ([mehta.345@buckeyemail.osu.edu](mailto:mehta.345@buckeyemail.osu.edu)) are graduate research associates, Dr. Taylan Altan ([altan.1@osu.edu](mailto:altan.1@osu.edu)) is Professor Emeritus and Director, at the Center for Precision Forming (CPF) at The Ohio State University, 1971 Neil Ave., Room 339 Baker Systems Engineering Building, Columbus, OH 43210, 614-292-5063, [https://cpf.osu.edu](https://cpf.osu.edu) and [https://ercnsm.osu.edu](https://ercnsm.osu.edu)

References
Figure 1: Schematic of deep drawing tooling where the Blank Holder Force (BHF) is provided by a cushion (no spacers)

Figure 2: Schematic to illustrate the effect of blank holder force (BHF) upon potential failure modes in deep drawing for given part heights or draw depths.
Figure 3: Example ram displacement and cushion displacement over crank angle of a mechanical press with (a) pre-accelerated die cushion, to provide a “soft hit” of the die or punch upon the sheet blank, and (b) delayed upward motion to facilitate part pick-up or transfer.

Figure 4: Variations of BHF vs. time/stroke to draw the part, seen in Figure 5, without any tearing or wrinkles (courtesy Hyson Solutions).
Figure 5: Hyson Part Geometry

Figure 6: Schematic representation of using large BHF (or servo hydraulic cushion force) at the start of deformation to increase strain hardening and dent resistance in drawn panels. Due to system inertia, the actual cushion force does not follow exactly the prescribed values.