Lubrication and galling in stamping of galvanized AHSS

Part II: Evaluating the deep-drawing performance of stamping lubricants

Editor's Note: This article is Part II of a three-part series discussing a study of lubrication and galling in forming zinc-coated advanced high-strength steels (AHSS). Part I, which appeared in the January/February issue, discussed the use of the twist-compression test (TCT) for preliminary evaluation of galling conditions. Part III, which will appear in the April issue, will cover the evaluation of lubricants and die materials and coatings to form AHSS in laboratory tests.

Lubrication plays an important role in stamping, as it reduces friction at the tool-workpiece interface, thus enhancing formability to produce a good-quality part. Especially when forming advanced high-strength steels (AHSS), it is important to understand the influence of the material properties and friction conditions on stamping performance.

Improved lubrication can increase the process window (see **Figure 1**), which is the relation between the blank holder force (BHF) and the drawing ratio (the ratio of the initial blank diameter to the punch diameter in forming round parts). Forming limit lines 1 and 2 in Figure 1 indicate when the drawn part fails by fracture or wrinkling.

Deep-drawing Test for Lubricant Evaluation

In deep drawing, the most severe friction usually takes place at the flange area near the die corner radius. The lubrication condition in the flange area influences the thinning and failure of the side wall in the drawn cup, as well as the draw-in length, L_d, in the flange (see **Figure 2**).

As the blank holder pressure (BHP) increases, the frictional stress also increases based on Amonton-Coulomb's law:

$$\tau = \mu \times P_b$$

Where:

τ = Frictional shear stress

μ = Coefficient of friction

P_b = Blank holder pressure

Therefore, lubricants can be evaluated in deep drawing by determining the maximum applicable BHP without failure in the cup wall.

In the deep-drawing test, qualitative and quantitative analyses can be made to determine the effectiveness of lubricants based on the following criteria:

- Maximum punch force attained (the lower the force, the better the lubricant)
- Maximum applicable BHF (the higher the BHF applied without fracture in the drawn cup, the better the lubricant)
- Visual inspection of galling and zinc-powdering
- Measurement of draw-in length, L_d, in the flange (the larger the draw-in length, the better the lubricant)
- Measurement of the perimeter in the flange area (the smaller the perimeter, the better the lubricant)

The tests are conducted under process conditions (ram speed, blank material and thickness, and die material) that are present in practical stamping operations. Major emphasis

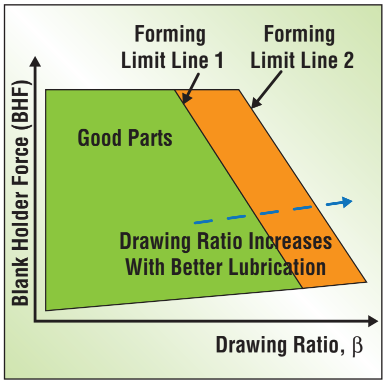

Figure 1

The process window increases as friction is reduced.

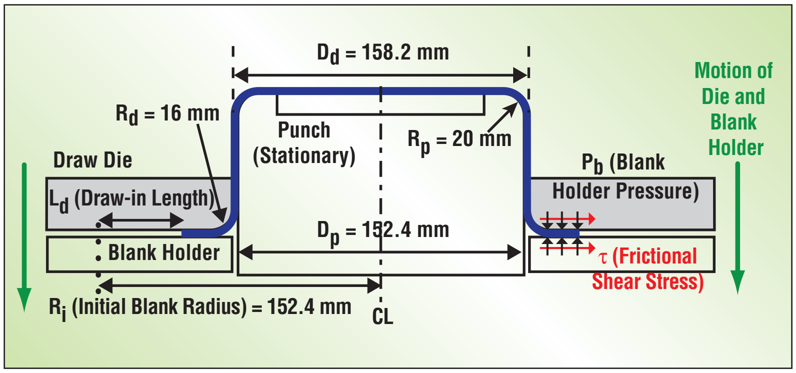

Figure 2

The deep-drawing test was applied to evaluate several automotive stamping lubricants.

is put on emulating the sheet-die interface pressure levels that occur in production by adjusting BHF and using punch speeds that are similar to those found in industrial stamping presses.

Test Results

These deep-drawing tests were used successfully to evaluate lubricants used in automotive stamping operations.

DP590 GA sheet specimens 12 inches in diameter were tested with six wet lubricants at two different BHFs. Ram speed remained constant at 2.7 IPS. Two levels of BHF were selected based on the preliminary finite element (FE) simulations of deep drawing for DP590 and experimental trials.

The load-stroke curves were compared for a low BHF of 30 tons (see **Figure 3a**). The maximum punch force was influenced by the friction condition at the tool-sheet interface. Lubricants A and B showed about 5 tons' lower punch force than other lubricants as the stroke increased.

As the BHF increased from 30 to 70 tons, sheet blanks coated with Lubricants A and B were successfully deep drawn, while sheet specimens coated with other lubricants were fractured during deep drawing. **Figure 3b** gives a comparison of load-stroke curves between fully drawn versus fractured cups at 70 tons' BHF. This fracture was caused by the breakdown of lubricant film at high contact pressure.

As an alternative to measuring side wall thinning distribution in the drawn cup as the friction indicator, the perimeter and draw-in length of the flange were measured. The evaluation criteria (BHF, flange draw-in length, perimeter, and maximum punch force) gave consistent results in the ranking of lubricants tested.

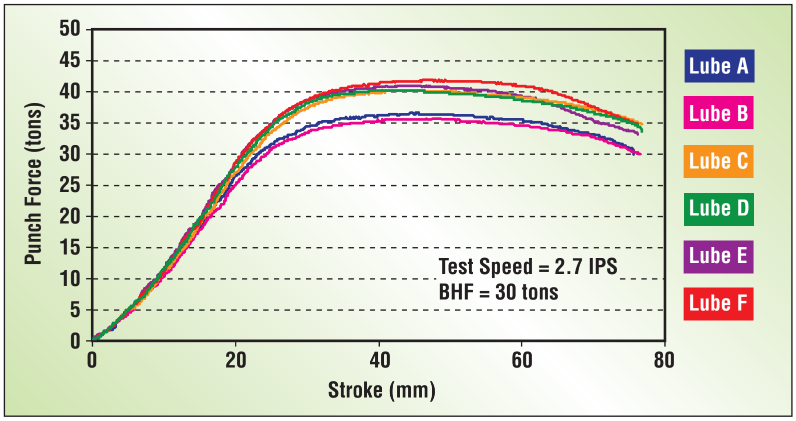

Figure 3a

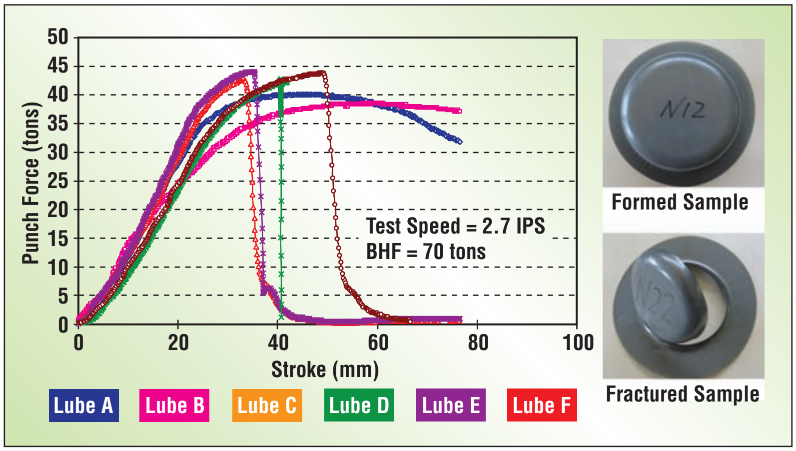

Figure 3b

These load-stroke curves show lubricant performance at low BHF (a) and high BHF (b).

Conclusions

This study illustrated that the deep-drawing test was able to distinguish the performance of different stamping lubricants in forming AHSS under near-production conditions.

Based on performance evaluation criteria, Lubricants A and B were most effective, regardless of BHF. Lubricants C, D, E, and F resulted in good drawn parts at a BHF of 30 tons, but all showed fractures at a BHF of 70 tons. In deep drawing, no severe galling or powdering was observed.

The lubricants' performance was found to change with the contact pressure at the sheet-tool interface and the forming speed. Therefore, it is critical to evaluate lubricants under process-relevant test conditions.

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