Evaluating lubricant using the cup drawing test

BY CLIFF HOSCHOUER, JEFF JEFFREY, FRANK KENNY, DAVID DIAZ INFANTE, AND DR. TAYLAN ALTAN

Lubrication plays an important role in sheet metal forming by affecting metal flow and reducing the possibility of fracture during forming. A number of tests are used to evaluate lubricant performance, including the strip draw test, the twist compression test, and the cup drawing test.

The cup drawing test (CDT) does a good job emulating the pressure, velocity, and temperature conditions of a stamping operation.

At the Hyson facility, researchers from the Center for Precision Forming tested 24 lubricants from four different companies. They used a 300-ton servo press and CDT tooling, designed and built by IRMCO, to test lubricants on blanks made from mild steel; high-strength, low-alloy steel; stainless steel; and advanced high-strength steel (AHSS).

Average part temperatures were measured using a FLIR® infrared camera.

Cup Drawing Test

The schematic of a CDT is shown in Figure 1. The cup is always drawn to the same depth of 80 millimeters. During the test, the sheet is not drawn completely, and some flange remains at the end of the operation. The perimeter of the flange is measured for each specimen.

The length of the flange perimeter is an indication of the lubricant performance. The smaller the perimeter for a given blank holder force (BHF), the better the lubricant and the lower the coefficient of friction (COF).

If the flange perimeters don’t show reasonable differences for different lubricants, the load versus stroke data can be used to determine the lubricant performance. The lower the maximum forming load, the better the lubricant.

Experimental and Finite Element Simulation Results

During this set of experiments, a total of 390 samples (blanks of 12 inches diameter) were used, and four different variables were measured to evaluate the lubricant performance:

1. Average flange perimeter of the formed cup
2. Average blank temperature
3. Average die temperature
4. Punch force

While some materials such as mild steel may not show a significant temperature increase during forming, others such as AHSS may reach temperatures higher than 200 degrees F in high-volume production. Because the blank generates heat, the tooling might expand thermally, reducing the clearance between the punch and the die and creating undesirable forming conditions. Therefore, in these cases, selecting a lubricant that performs well at high temperatures and also has a cooling effect is very important.

The temperature of the drawn cup was recorded using the infrared camera, which was triggered manually as soon as the cup was visible (see Figure 2). While the part surface can lose heat when the cup is ejected, this measurement gives a good estimation of the temperature generated during forming. The forming speed was kept constant during the experiments; however, the BHF was selected according to the blank material and thickness.

In ranking the lubricants, researchers used the average temperature and the average flange perimeter as the main parameters. The lubricants used with mild steel and AHSS blanks are shown in Figure 3. For each material, the best five lubricants were selected based on average flange perimeter and average temperature. Lubricants X and J consistently performed best for all the materials tested.

A finite element (FE) model was set up using PAM-STAMP® software. The

Figure 1

Schematic of deep-drawing tool used in this study.

Figure 2

Temperatures of the drawn cup were recorded with an infrared camera during experiments, after the drawn cup was ejected from the tool.
Figure 3

Average flange perimeter and the temperature measured in the drawn cup (dots indicated in the figure) were used as the main parameters to evaluate lubricant performance on mild steel blanks and advanced high-strength steels.

experimental parameters, such as forming speed and draw depth, used in the experiments were reproduced in the simulations. Using this methodology it is possible to estimate the COF of the lubricant by matching the flange perimeter measured on the experimental samples with the corresponding values obtained through FE simulation (see Figure 4). As a comparison, the COF estimated for the lubricant E shown in Figure 3 was used in the simulation to predict temperatures. Figure 4 also shows that the maximum temperatures estimated using simulations were close to the experimental values for the tested case.

Figure 5 shows that the highest temperature caused by material deformation occurred around the die corner radius, as estimated using FE simulation. Conversely, the temperature in the cup near the punch corner radius did not show any significant change in temperature, since the deformation in that region was small.

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References


Figure 4

Shown here is a comparison of finite element simulation with experimental results.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FE Simulation (COF=0.12)</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flange</td>
<td>781 mm</td>
<td>781 mm</td>
</tr>
<tr>
<td>Max. Temperature</td>
<td>49°C (120.3°F)</td>
<td>50.9°C (123.5°F)</td>
</tr>
</tbody>
</table>

Figure 5

Shown here are temperature distributions on the cup according to FE simulations. Materials: 2-mm mild steel (270-MPa UTS) and 1.2-mm DP980. Ram speed: 80 mm/sec. Initial temperature: 20 degrees C.