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Examining lubricant performance in forming of AHSS

The effects of ram speed and stroking rate

BY ALI FALLAHIAREZOODAR, SURAJ APPACHU, AND TAYLAN ALTAN

Lubrication plays an important role in stamping, as it reduces friction at the tool-workpiece interface. Reducing that friction also reduces die and tool wear in large-volume production, which in turn increases tool life. It also allows smoother flow of the sheet material into the die cavity and reduces the energy and load required to form the part.

With good lubrication, failures associated with wrinkling and premature fracture can be reduced or even prevented. Therefore, it is extremely important to use a lubricant well-suited to the tool-workpiece interface and the process parameters.

Lubricants for AHSS Forming

Two basic types of fluids—synthetic water-based and petroleum oil-based—are used as lubricants for sheet metal forming. They are combined with such additives as:

- Emulsifiers, which promote stable emulsions and oil cleanability.
- Extreme-pressure additives, which prevent excessive friction when the fluid alone does not.
- Thickeners, which alter viscosity.
- Antimisting agents, which prevent or reduce airborne particles of lubricant.
- Passivation, which prevents staining of the metal surface.
- Antifoaming agents.
- Suspended solids for heavy-duty forming applications.
- Corrosion inhibitors, which protect the material during production and storage.
- Oxidation inhibitors, which prevent oxidation and degradation of the lubricant.
- Antimicrobial agents, which inhibit growth of bacteria, fungi, and yeast in the lubricant.

Forming of advanced high-strength steel (AHSS) generates higher contact pressures and temperatures than forming of conventional steels, because AHSS has higher strength and higher strain hardening. The higher pressures and temperatures at the interface are detrimental to the performance of liquid and dry-film lubricants, causing commonly used lubricants to fail.

Therefore, lubricants for forming AHSS must contain high-pressure and high-temperature additives that are activated during extreme forming conditions to enhance the lubricants' performance. The lubricants must also act as a coolant, removing the heat generated from cold working and friction at the interface, and provide a thermal barrier to prevent excessive heat transfer from the part to the tools.

Cup Draw Test for Evaluating Lubricant Performance

At The Ohio State University, Center for Precision Forming (CPF) in cooperation with EWI, researchers conducted the cup draw test (see **Figure 1**) using a 160-ton hydraulic press with a CNC hydraulic cushion to evaluate the performance of lubricants and determine the coefficient of friction. The press was used at a forming speed of about 40 mm/sec.

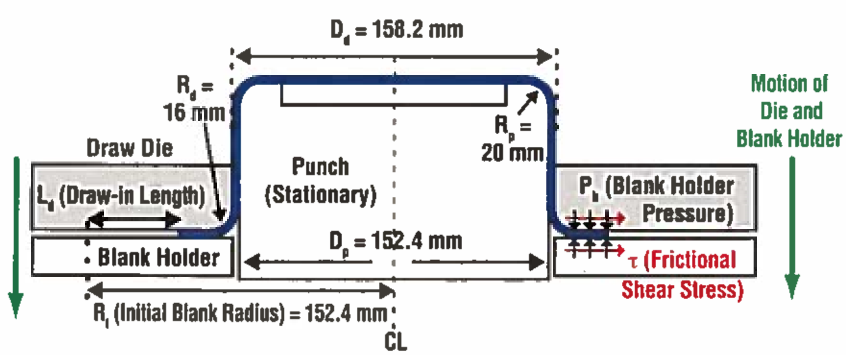

Figure 1

Researchers conducted the cup draw test to evaluate lubricant performance.

Provider Company	Lubricant Designation
IRMCO	136-492
IRMCO	156-892
Daubert	NoxRust R-573-72
Zeller+Gmelin	Multidraw KTL N 20
Zeller+Gmelin	Multidraw ALS 80
TruChem	TC 1889
Houghton	Fenella Oil B 2814-LV
Houghton	Drawsol 3694
Quaker	Drycote 5 (dry lubricant)
Houghton	Drawsol 4000

Figure 2

Ten different lubricants were tested in the cup draw experiment.

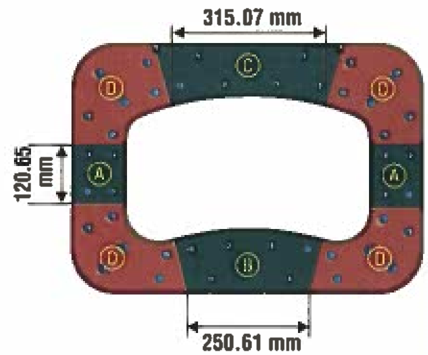

Figure 3

The servo press deep-drawing study used a die designed specifically for the experiment.

They performed cup drawing tests on DP590 and DP980 using 10 different lubricants (see **Figure 2**) to determine lubrication quality and reduction of friction while forming AHSS materials. The coefficient of friction (COF) for each lubricant was estimated using finite element simulation.

The results of this study were used to recommend the best lubricants and application methods for reducing the scrap rate in forming of nonsymmetric, industrial-sized parts. Comparison of experimental results with simulations shows that the lubricant that gave the best performance had a COF of 0.09.

Lubrication Performance in Servo Press Forming

Researchers then conducted a study to investigate whether the COF predicted in the cup draw test would remain valid when the materials were formed in a nonsymmetric, industrial-sized die using a servo press with a ram speed of about 300 mm/sec. They hypothesized that because of the high strength and low formability of AHSS materials, the temperature increase during high-speed forming would reduce lubricant performance and increase the COF compared to what was obtained in the cup draw test.

Researchers performed deep drawing of several different AHSS materials, including CP800, DP590, DP980, and TRIP1180, using a specific die designed jointly with Shiloh Industries (see **Figure 3**). The lubricant that showed the best performance in the cup draw test was used to form the parts with a 300-ton Aida servo press with a CNC hydraulic cushion, and the process also was simulated using PAMSTAMP®.

Researchers compared the maximum ram forces observed in the experiments with a database obtained from a set of simulations assuming several different COF values. The value that provided similar ram forces in simulation and experiments was considered to be the real COF.

In the servo press experiments, which used a higher ram speed than the cup draw test, simulation results showed that with a lubricant COF of 0.09, the maximum ram force was lower than what was observed in experiments. Results showed that a COF of about 0.12 provided a maximum ram force close to what was observed in experiments (see **Figure 4**).

So in forming of AHSS with high ram speed using a servo press, the performance of the lubricant is not similar to what is observed in a cup draw test using a hydraulic press and relatively lower ram speed. Increase of temperature is one of the factors that affects lubricant performance when the part is formed at high speed. A study is in progress to investigate the increase of temperature in forming of AHSS materials using a servo press.

Ali Fallahiarezoodar and Suraj Appachu are graduate research associates and Taylan Altan is professor and director of the Center for Precision Forming (CPF) at The Ohio State University, 339 Baker Systems, 1971 Neil Ave., Columbus, OH 43210, 614-292-5063, fallahiarezoodar.1@osu.edu, altan.1@osu.edu, www.cpforming.org, www.ercnsm.org.

This study was conducted in cooperation with EWI-Forming Center (Dr. Hyunok Kim), Shiloh Industries (Dr. Cliff Hoschouer), and AIDA-America (Mr. Shrini Patil). The authors gratefully acknowledge this assistance.

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Material (Thickness)	Draw Depth (mm)	Blank Holder Force (kN)	Average Max. Total Ram Force (kN)	Max. Total Ram Force From Simulation (kN) COF=0.09	Max. Total Ram Force From Simulation (kN) COF=0.12
DP590 (1.3 mm)	70	200	753	677	724
CP800 (1.4 mm)	50	250	875	792	842
DP980 (1.2 mm)	55	250	874	815	871
TWIP900 (1.2 mm)	70	200	719	652	695
TWIP980 (1.3 mm)	70	200	815	744	794
TRIP1180 (1.2 mm)	48	250	894	839	909

Figure 4

Calculated ram forces from the experiments are compared with simulations for different COF.