Lubrication and galling in stamping of galvanized AHSS

Part I: Using the twist-compression test for evaluation

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

Galvanized advanced high-strength steel (AHSS) is being used increasingly in automotive chassis construction to reduce corrosion and rust formation. As a result, galvanizing technology is becoming an important issue.

The quality of galvanized and galvannealed coatings is influenced significantly by the characteristics of the steel substrate, such as the finish, microstructure, and chemical reactivity of the steel surface.

The structures of galvannealed (GA) and galvanized (GI) coatings are very different. GA coating has multiple layers of different phases and hardnesses, while GI coatings have a single layer above the steel substrate. The hardness of GA usually is four to five times higher than that of GI. Also, GA is known to have better weldability compared to GI, while GI offers better surface quality.

**Lubricant Failure, Powdering, and Galling**

Forming of galvanized AHSS involves higher contact pressure and temperature at the tool-workpiece interface than does forming of mild steel. These unfavorable interface conditions can cause the failure of commonly used lubricants, leading to powdering and galling.

Powdering is zinc buildup on the die, and galling is material transfer from the workpiece to the tool surface. Both can significantly increase the coefficient of friction at the tool-workpiece interface, which can lead to scoring and reduced tool life (see Figure 1).

**Twist-Compression Test (TCT) to Evaluate Galling and Powdering**

The twist-compression test (TCT) was used to evaluate galling and powdering of selected GI and GA AHSS and mild steels. The tests were conducted in cooperation with IRMCO, which provided the TCT machine and experimental setup, and Bohler-Uddeholm, with support from the International Lead Zinc Research Organization (ILZRO) and materials provided by AcelorMittal, U.S. Steel, and FOSCO.

In the TCT, a rotating annular tool is pressed against a fixed sheet metal specimen while the pressure and torque are measured (see Figure 2). The coefficient of friction (COF) between the tool and the specimen is calculated with the following equation:

\[ \mu = \frac{T}{r \cdot P \cdot A} \]

Where:
- \( \mu \) = COF
- \( T \) = Torque transmitted from the tool to the sheet metal specimen
- \( r \) = Mean radius of the tool (0.43 inch)
- \( P \) = Contact pressure exerted by the tool on the sheet metal specimen
- \( A \) = Cross-sectional area of the tool (0.34 sq. in.)

The test conditions are given in Figure 3. In each experiment, the test was continued until the COF reached 0.5. Thus, COF = 0.5 was used as an indicator for the start of metal-to-metal contact, based on experience obtained in laboratory tests. The tool-workpiece contact pressures were selected based on the preliminary finite element simulations of the cup-drawing operation for DP 600 steel.

After each test, the specimens and the tools were inspected visually for powdering (before cleaning with acetone) and for galling (after cleaning with acetone). Thus, the severity of galling and powdering was determined qualitatively (from 0 = no galling/powdering to 3 = most severe galling/powdering).

The quantitative severity of galling for two interface pressures is compared in Figures 4 and 5.
Test Results

Galling and powdering became severe as the contact pressure increased. In real stamping operations, then, stampers can predict the area on the die surface where the highest contact pressure will occur and treat that area with polishing, coating, and lubrication to prevent galling and powdering.

No galling was observed in the TCT at 7-KSI interface pressure, regardless of the sheet materials, galvanized coatings, and lubricants used in the tests.

In the test at 15-KSI, DP 600 hot-dipped galvanized (HDGI) with lubricant A showed moderate galling (1.5), while the other galvanized coatings showed minor galling (0 to 1). Clearly, the lubricant had a major effect on preventing galling and powdering.

In the test at 25-KSI interface pressure, compared with other materials, DP 600 HDGI with lubricant B showed the best effectiveness in reducing galling. However, in the majority of the tests with lower interface pressure, the hot-dipped galvalume (HDG) coating resulted in less galling than the HDGI. This may be explained by the fact that HDGAs hardness value is about five times higher than HDGIs.

The results of the study illustrated that the TCT is a useful and efficient tool for preliminary evaluation of lubricants and coatings. This test considers several different testing parameters (sheet coatings, lubricants, pressures, and speeds) that are required for the investigation of galling behavior in stamping AHSS.

![Figure 3](image-url)

**Figure 3**

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<tr>
<th>Qualitative Evaluation of Galling at 15-KSI Interface Pressure</th>
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<td>Pressure (KSI/MPa)</td>
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