

Aluminum sheet forming for automotive applications, Part II The effects of lubricants, surface finish, and coatings

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Editors Note: This is Part II of a two-part series that discusses the forming of aluminum sheet for automotive products. Part I, which appeared in the January/February 2013 issue of STAMPING Journal®, discussed material properties and design guidelines.

In aluminum forming, lubrication is critical because the surface of aluminum sheet is smoother than that of steel. The right lubrication can increase the drawing ratio, thus increasing the process window.(1) Besides lubricants, surface finish and coatings also are important in aluminum sheet forming.

Lubricant Choices for Aluminum Forming

Generally, three types of lubricants are used for aluminum sheet metal forming:

1. Water-soluble, dry-film lubricants typically are applied at the rolling mill in amounts from 0.5 to 1.5 g/m².(2)
2. Water-free, dry-film lubricants (or hotmelts) usually do not run off the panel surface and provide good drawing performance.
3. Mineral oil-based lubricants are applied in front of the press line in amounts between 1.0 and 3.0 g/m². (3)

Recent studies have shown that dry-film lubricants can provide better lubrication conditions in aluminum forming than oil-based lubricants. In October 2003, BMW group switched to water-free, dry-film lubricants in forming aluminum front fender and hood assembly parts in the BMW 7 series.(4)

The Surface Finish Factor

Surface finish of the sheet also affects its friction behavior during forming. Aluminum sheet is commercially available in three surface finishes (see **Figure 1**):

1. Mill finish (MF) – Produced with ground rolls, this finish is used for interior parts.
2. Electric discharge texture (EDT) – Produced with EDT rolls, this finish is used for skin panels.
3. Dull finish (DF) – Produced with shot-blasted rolls.

MF is the standard surface used in North America for aluminum sheets. EDT surface texturing is used commonly in Europe for aluminum sheets. It imparts lubricant pockets and isotropic

surface, improving paint appearance and formability. The EDT and DF samples have higher roughness values (Ra) than MF samples (see **Figure 2**).

Other surface textures for aluminum sheets include precision texturing (PRETEX) and laser texturing (LT).(5)

Coatings

The two options for aluminum sheet coating are chemical conversion coatings and anodizing.

Chemical conversion coatings are adherent surface layers of chromate compounds produced by the reaction of suitable reagents with the metal surface.(6) The three kinds of chemical conversion coatings for automotive applications are:

1. Chromium based - These treatments can provide the maximum corrosion protection to aluminum parts and can be an excellent base for paint adhesion. However, they are toxic.
2. Titanium/zirconium based - These treatments are used for inner and outer applications, especially in Europe.
3. Silicon based - These coatings are used for applications requiring full structural adhesive bonding.

Anodic coatings are formed by an electrolytic reaction process in which the thin film on the aluminum surface is converted to an anodic coating.(7) These coatings can form two types of film:

1. Thin, barrier-type oxide film - This film is similar to the titanium/zirconium-based coating. The voltage applied between the anode and cathode determines the thickness of film. Maximum film thickness built at 700 V is less than 1 μm .(8)
2. Thicker, porous film - The thickness of this type of film may reach 100 μm . It provides better bond durability than the thin oxide film.

Summary

The press forming of aluminum alloys presents different challenges than forming steel because of aluminum's smooth surface and higher galling tendency, as well as the inability of conventional lubricants to prevent galling under high-pressure forming conditions.

Researchers hope to optimize the friction condition in the contact area between the tool and aluminum sheet by choosing the right lubricant, surface finish, and sheet coating to form more complex aluminum parts.

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Notes

1. M. Meiler and H. Jaschke, "Lubrication of Aluminum Sheet Metal Within the Automotive Industry," *Advanced Materials Research*, Vol. 6–8 (2005), pp. 551–558.
2. Ibid
3. Ibid
4. M. Meiler, M. Pfestorf, M. Merklein, and M. Geiger, "Tribological Properties of Dry Film Lubricants in Aluminum Sheet Metal Forming," in proceedings from the second International Conference on Tribology in Manufacturing Processes (ICTMP), Lyngby, Denmark, 2004.
5. P. Groche et al, "Tribology in Sheet Metal Forming With Regard to Challenges in Lightweight Construction," *Advanced Materials Research*, Vol. 6-8 (2005), pp. 93-100.
6. "Aluminum: The Corrosion Resistant Automotive Material," The Aluminum Association, Publication AT7, 2001, p. 14.
7. Ibid
8. www.substech.com

Surface finish	Ra value in transverse rolling direction	Ra value in longitudinal rolling direction
EDT	~0.75	~0.75
DF	~0.52	~0.51
MF	~0.25	~0.06

Figure 1. Roughness values differ for EDT, DF, and MF samples. Source: S. Hartfield-Wunsch et al, "The Effect of Surface Finish on Aluminum Sheet Friction Behavior," 2011-01-0534, SAE International, 2011.

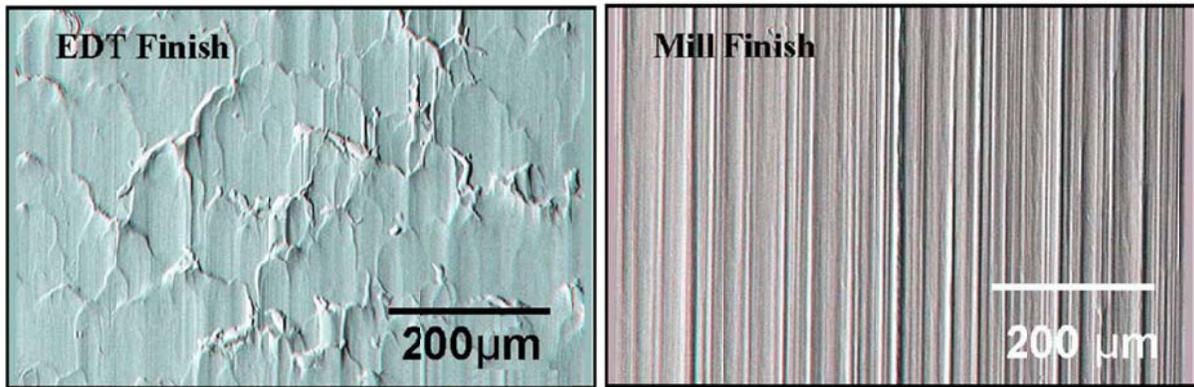


Figure 2: Scanning electron microscope images of EDT and MF surfaces on AA 6016 sheet show EDT's higher roughness. Source: "The Aluminum Automotive Manual," European Aluminum Association, 2002.