Effects of Lubrication, Temperature and Surface Topography in Aluminum Sheet Forming

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In order to investigate the tribological system in aluminum sheet forming, pin-on-plate tests were performed on three types of lubricated aluminum plates at room temperature (RT) and at 100 °C. The lubricant compositions were analyzed using high resolution mass spectrometry. Additionally, the surface topographies of the aluminum plates were investigated using an optical 3D profiler. The results showed remarkable increase of the coefficient of friction (COF) at 100 °C. The COF was in the ranges of 0.07-0.10 and 0.13-0.29 at RT and 100 °C, respectively. The main wear mechanisms during the friction tests were flattening of the asperities and ploughing.

Keywords: aluminum blanks, sheet metal forming, coefficient of friction, surface topography, lubricant.

1. Introduction

Blanks of aluminum alloys with electric discharge texture (EDT) or milled finish (MF) surface condition are widely used in the automotive industry. The tribological system in forming processes influences both the product quality and the tool life [1]. The COF between the forming tools and the blank is affected by different process parameters including surface topography, surface temperature and contact pressure [2]. Moreover, the local increase of the surface temperature may considerably alter the properties of the lubricant [3]. Hence, the present work investigates in detail the influence of these parameters on the COF.

2. Materials and methods

2.1. Friction tests
A pin-on-plate tribometer was used for determining the COF. Three types of lubricated aluminum plates were investigated, i.e., EN AW-5182-MF, EN AW-5182-EDT and EN AW-6016-EDT. Friction tests were performed at the nominal contact pressure of 10 MPa. The surface temperature of the aluminum plates was RT or 100 °C.

2.2. Mass spectrometry
For analyzing the lubricant compositions high-resolution mass spectrometry was performed at both negative and positive modes using a LTQ Orbitrap XL hybrid tandem.

2.3. Surface topography
After friction testing the surface topography of each aluminum plate was investigated using a Keyence VHX-6000 optical 3D profiler.

3. Results and discussion

The results of the friction tests shown in Figure 1 indicate that EN AW-5182-MF and EN AW-6016-EDT had the highest and the lowest COF values at RT, respectively. Increasing the surface temperature from RT to 100 °C increased the COF for each of the alloys and caused more instability of the COF during sliding. The increase of the COF was more considerable for EN AW-5182-MF. The differences between the COF of the three alloys might be attributed to types and amounts of lubrication. The results of the mass spectrometry show that the lubricant compositions are totally different for each aluminum plate. The different lubricant composition is one of the reasons for the unique COF behavior of each three aluminum plates at each contact conditions.

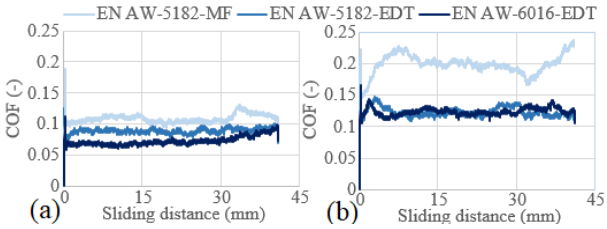

Figure 1: COF over sliding distance, (a) RT, (b) 100 °C.

Figure 2 shows typical remarkable plastic deformation of surface asperities after friction testing. This deformation was more distinct at 100 °C. The main wear mechanisms were flattening of the asperities and ploughing.

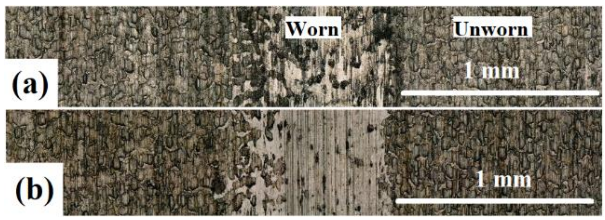

Figure 2: Surface topography of EN AW-5182-EDT after friction testing, (a) RT, (b) 100 °C.

4. References

[1] Groche, P. et al., "Tribology in Sheet Metal Forming with Regard to Challenges in Lightweight Construction", Adv Mat Res, 6, 2005, 93–100.

[2] Shafiee Sabet, A. et al., "Tribological Investigations on Aluminum Alloys at Different Contact Conditions for Simulation of Deep Drawing Processes", J Manuf Process, 68, 2021, 546–557.

[3] Hazra, S. et al., "Effect of Material and Process Variability on the Formability of Aluminium Alloys", J Mater Process Technol, 211, 2011, 1516–1526.