Published in the Proceedings of the 16th International Aluminum Alloys Conference (ICAA16) 2018
ISBN: 978-1-926872-41-4
by the Canadian Institute of Mining, Metallurgy & Petroleum

CHARACTERISTICS OF ALUMINUM ALLOY SHEET PRE-COATED WITH HIGH LUBRICATING AND REMOVABLE FILM

*Yosuke Ota, Makoto Tawara, and Tetsuya Kojima

Aluminum Sheets & Coil Research Department, Moka Plant, Aluminum & Copper Company, KOBE STEEL, LTD., 15 kinugaoka, Moka, Tochigi 321-4367, Japan
*(*Corresponding author:ota.yosuke@kobelco.com)*

ABSTRACT

Dry-lube has been used in Europe to enhance formability of aluminum sheet for automotive applications, but it is difficult to ensure degreasing performance with lower degreasing bath temperature. However, newly developed, highly lubricating pre-coats utilizing a urethane resin, which is soluble in water, have been found to show excellent degreasing performance. Furthermore, a richer pre-coat weight coincides with a lower friction coefficient and better formability. Combined use of anti-rust liquid oil showed different friction coefficient depending on applied surface pressure.

KEYWORDS

Pre-coat, Lubricity, Degreasing, Friction coefficient, Forming limit height, Drawing

INTRODUCTION

The global demand for aluminum alloy products, especially for automotive application, has been increasing because aluminum alloys can offer excellent corrosion resistance with good strength and low density compared with steel. Aluminum alloys can contribute to saving much more energy and greenhouse gas emissions over the lifetime of the product. On the other hand, the amount of aluminum alloys in vehicle architectures is still somewhat limited due to relatively low formability. As a consequence of this low formability, it is necessary to set a certain limit to the shape of an aluminum alloy panel for automotive applications. So far hot melt wax dry lubricants have been in use especially in Europe as they have been recognized to provide better lubrication than conventional rust protection oils (Meiler & Jaschke, 2005). The benefit of hot-melt wax for automotive manufacturing is associated with a more stable forming process and the possibility to avoid extra lubrication in the press shop. But because of the low poorer solubility of hot-melt wax in degreasing aqueous bath solution, a higher degreasing temperature is required so that no remnant of hot melt wax can be carried over to the next manufacturing process. This temperature control is difficult to impress upon a manufacturing degreasing bath originally designed for liquid oil, especially in Japan. The typical temperature of degreasing bath in Europe is around 60°C, while it is only around 40°C. in Japan. Various types of pre-coats other than hot-melt with high lubricity have been reported (Tawara, 1993; Ueda, Hatsuno & Totani, 2013), but a balance between sufficient degreasing performance and high lubricity has not yet been achieved for an actual production process line.

The aim of this work is to examine the newly developed, highly lubricating pre-coat utilizing a urethane resin, which is expected to enable both excellent degreasing performance and better formability due to its high solubility in water and enhanced lubricity (Tawara, Ota & Kojima, 2017). Because of its hydrophilic property, combined use of liquid oil has also been investigated for maintaining an anti-rust property.

EXPERIMENTAL

Test samples were prepared from AA6022-T4 sheet product with 1.0 mm thickness. After alkaline degreasing and acid pickling, test samples were pre-coated with an aqueous solution of water-soluble urethane resin, followed by drying at 80°C. The pre-coating weight was varied in the manner listed in Table 1. Dry-lube and liquid oil were also applied onto pre-cleaned test samples and pre-coated test samples for comparative purposes.

Table 1. Tested lubrication on aluminum sheet

	Coating weight (g/m^2)	Substance	Comments
Pre-coat	0.5, 1.0, 1.5	Water soluble urethane resin	Originally developed coating
Dry lube	1.5	Hot melt wax	Commercially in use especially in Europe
Liquid oil	0.5	Mainly mineral oil	Commercially in use in Japan

An Erichsen testing machine was utilized for square cup deep drawing test to identify forming limit height as is shown in Table 2 and Figure 1.

Table 2. Forming test condition for square cup drawing

Punch (mm)	40 × 40, R4.5, Corner R10
Die (mm)	42.5 × 42.5, R3, Corner R11
Blank (mm)	90 × 90
BHF (ton)	1, 5, 10
Speed (mm/min)	20
Measurement	Forming limit height

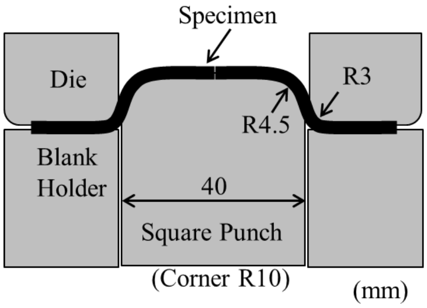

Figure 1. Dimensions of square cup deep drawing test

Dynamic friction coefficients were measured by flat sliding tests. Details of test condition are shown in Table 3.

Table 3. Sliding test condition for friction coefficient measurement

Die (mm)	90 (w) × 40 (L), R4
TP (mm)	25 (w) × 200 (L)
Test load (N)	800, 4000
Speed (mm/min)	500
Sliding length (mm)	50
Measurement	Withdrawal load @ 30 mm

Degreasing performance was evaluated using a commercially available weak alkaline detergent solution, which is commonly used in Japanese automotive manufacturing processes. All three types of lubricated test samples were immersed into this detergent solution for two minutes at 40°C, followed by water rinse for 30 seconds. The wetting surface area was then visually inspected by identifying how much percentage of the surface of each test sample is wetting just after the water rinse process.

The dissolving behavior of each type of lubricant on the aluminum alloy test samples in water was identified by gravimetrically weighing the test samples before and after immersing in potable water (at 35°C without stirring). Then remaining ratio of lubricants was determined as a function of immersion time ranging from 10 seconds to 120 seconds. Test samples were re-weighed after ultrasonic cleaning with acetone in order to identify the remaining amount of lubricant on the sheet.

RESULTS AND DISCUSSION

The result of the square cup deep drawing test is shown in Figure 2. Forming limit height was dependent on blank holder force and coating weight of the pre-coat. Forming limit height of the pre-coat was the highest at 1 ton of BHF. Although it was lower at 2 tons and 5 tons of BHF, it still showed its superiority to that of liquid oil. The difference in the forming limit height between coating weights with 1.5 g/m^2 and 1.0 g/m^2 was almost negligible at 2 tons and 5 tons of BHF, while it was significant at 1 ton of BHF. These results suggests that higher coating weight of the pre-coat basically leads to better lubricity and can allow more metal flow during deep drawing process. But when BHF gets higher, metal flow during deep drawing is more restricted and the effect of higher lubricity gets lower.

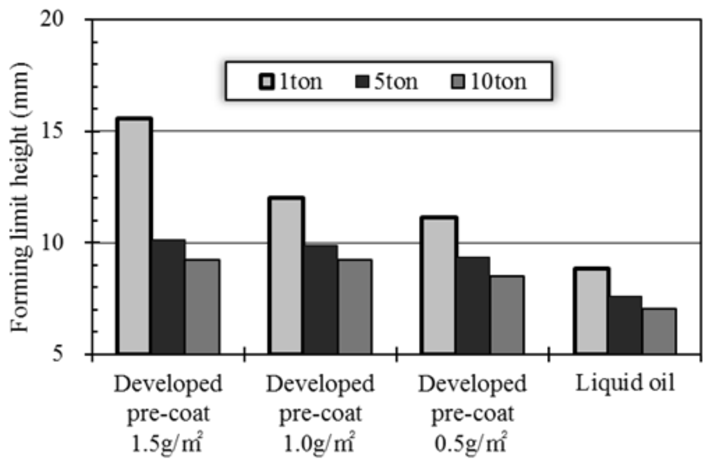

Figure 2. Forming limit height by square cup deep drawing test

Figure 3 shows the results of friction coefficient measurement. The friction coefficient decreased as the coating weight of the pre-coat was increased. This corresponds to the results of square cup drawing test as was shown in Figure 2. Difference of the test load between 800 N and 4000 N did not significantly affect the results. The effect of applying liquid oil onto the pre-coat was also examined via the sliding test. The application of liquid oil did slightly affect each friction coefficient result depending on the test load. That is, when test load is 800 N, the friction coefficient increased, while it decreased as test load was increased to 4000 N. As liquid oil itself does not have high lubricity, this result suggests that the application of liquid oil onto the pre-coat improved lubricity at 4000 N. the cause of this benefit is not well understood at this time and requires further investigation.

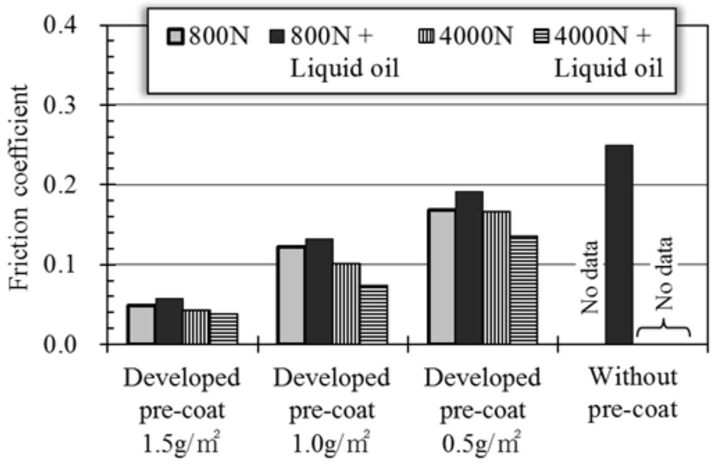

Figure 3. Friction coefficient with and without liquid oil

The degreasing performance of pre-coated test sample was similar to that of the pre-coated test sample with liquid oil applied, which in turn was better than that of the pre-coated test sample with dry lube applied, as is shown in Figure 4. Applying liquid oil onto the pre-coat additionally did not affect degreasing performance at all.

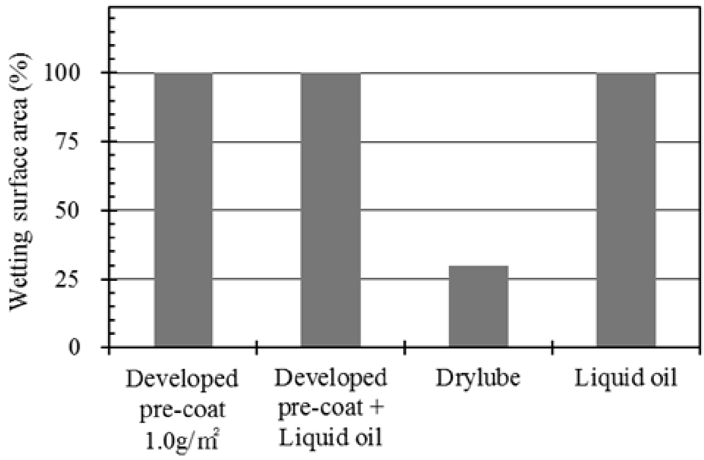

Figure 4. Degreasing performance of each lubrication

The dissolving behavior of applied lubricant schemes in potable water is shown in Figure 5. The remnant of pre-coat was less than 1% after immersion in the potable water for 30 seconds. On the other hand, liquid oil and dry lube remained more than 70% on the substrate after immersion for even 120 seconds. This result explains the better degreasing performance shown in Figure 4. That is, high solubility of pre-coat into water should have exhibited a better degreasing performance. As alkaline detergent includes emulsifying chemicals to effectively dissolve oils on a substrate into detergent bath, pre-coat may not have significantly affected this emulsifying function.

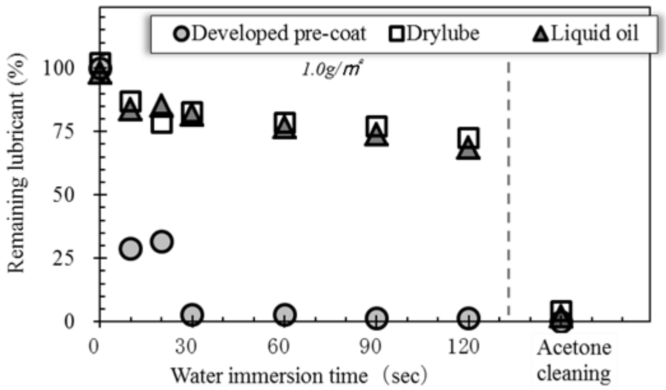

Figure 5. Dissolving behavior into water of each lubrication

CONCLUSIONS

A newly developed pre-coat, which is made of water soluble urethane resin, showed lower friction coefficient and higher forming limit height for deep drawing process. And it also showed better degreasing performance than dry lube. These results show promise for the utilization of this pre-coat in production processes that use a weak alkaline degreasing bath that cannot remove dry lube because of its low temperature. The pre-coated film can easily dissolve into potable water. This property contributes to better degreasing performance than dry lube at low detergent temperature. Combined use of anti-rust liquid oil also showed good lubricity and degreasing performance, although friction coefficient was slightly affected by the applied surface pressure.

REFERENCES

Meiler, M., & Jaschke, H. (2005). Lubrication of aluminium sheet metal within the automotive industry. *Advanced Materials Research*, 6–8, 551–558.

Tawara, M. (1993). *Proceedings of the 84th Conference of the Japan Institute of Light Metals*, pp. 55–56.

Ueda, K., Takeda, I., Hatsuno, K., & Totani, Y. (2013). Formability improvement using the removable lubrication pre-coat on the automotive aluminum sheet. *Proceedings of the 124th Conference of the Japan Institute of Light Metals*, pp. 319–320.

Tawara, M., Ota, Y., Kojima, T. (2017). Characteristics of aluminum alloy sheet pre-coated with high lubricating and removable film. *Proceedings of the 133rd Conference of the Japan Institute of Light Metals*, pp. 229–230.