DEVELOPMENT OF HIGH FORMABILITY PRE-COATED ALUMINUM SHEET

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ABSTRACT

In order to extend applicability of aluminum that excels in recycle efficiency, weight-reducing and heat-conducting performance, formability of aluminum sheet was improved by coating of organic resin in which lubricant is dispersed. This report describes the performance that is not only formability but also spot weldability and UV printability of the resin coated aluminum sheet.

Keywords : aluminum, pre-coating, resin, formability, wedability, printability

1. INTRODUCTION

In recent years, the world-wide tendency to try to relieve the global environment from pollutions, people have been thinking it necessary to attach importance to execution of recycling of industrial products as a part of the energy-and-resources-saving program. In this connection, pertinent legal restriction are also being executed at the same time. Under these circumstances, more and more aluminum products have become used in place of plastic and steel products. This is because aluminum excels these conventional materials in weight-reducing and heat-conducting performance as well as in recycling efficiency.

Aluminum sheets, however, has such a drawback as to be inferior to steel sheets in press forming performance. And, from time to time, this fact can give rise to such a problem that a product is unable to be formed exactly and accurately.

And therefore, in order to extend applicability of aluminum products, a developmental work has been executed to improve the formability by providing it with a surface treatment.

In actual manufacturing of a product, the work has to take such steps as joining, painting and printing processes after the forming work. And therefore, when a product of this material was being designed, studies were also made with respect to spot weldability and UV printability of this material.

2. STUDIES OF HOW TO IMPROVE FORMABILITY

2.1 Relations between Friction Coefficient and Formability

Prior to commencement of the studies of how to improve formability, a research was made on how to relate friction coefficient with drawability and also with stretching formability because this coefficient is an important value to show press formability. Pre-coated aluminum sheets of different coefficients were prepared, and then, their friction coefficient values were measured by a Bowden type friction analyzer and their drawability and stretching formability were also checked by an Erichsen tester. Fig.1 shows principle of the Bowden type friction analyzer. Fig.2 and Fig.3 illustrated conditions of the drawability and stretching formability test, respectively, and results of these tests are depicted in both Fig.4 and Fig.5. It is possible to tell from these data that the drawability and the stretching formability have negative correlations with the friction coefficient and that the formability of aluminum sheet tends to become better when values of the friction coefficient get smaller.

2.2 Coating Films on Aluminum Surface and Friction Coefficient

A study was on how to provide an aluminum sheet with surface treatment to keep its friction coefficient to a low value so that its on friction coefficients of the sheets whose surface were treated by anodizing, boehmite and coating processes.

Aluminum sheets were provided with surface treatment by the process shown in Table 1. Two kinds of resin were used. Type A contains lubricant, but type B contains no lubricant. Values of friction coefficient of all the coatings are as shown in Fig. 6. It indicates that a coating of organic resin containing lubricant took the smallest value for its friction coefficient.

With respect to the way of improving the formability, we chose the lubricating organic resin pre-coating process which is capable of keeping the friction coefficient minimum value and maintaining high productivity.

3. FOMABILITY

3.1 Lubricant Concentration and Formability

Aluminum alloy sheet (Al-5.9mMg-0.25Cu; the sheet thickness is 1.0mm.) were provided with 0.5 μm-thick organic resin coatings which had lubricant concentrations of 0%, 5%, 10% and 15%, respectively. And then, their drawabilities and stretching formability were checked on the foregoing conditions. And, Fig. 7 shows results of these tests. It is considered possible to tell from these data that an improvement of formability should be achievable by controlling the lubricant concentration to 5wt% and more.

3.2 Coating Thickness and Formability

By providing JIS A-5182 aluminum alloy sheets that the sheet thickness is 1.0 mm with organic resin coating having thicknesses of 0.1, 0.3, 0.5 and 1.0 (μm), their respective drawability and stretching formability were examined on the foregoing conditions, and the results are as shown in Fig. 8. These data are indicating that an improvement of formability can be obtained by controlling thickness to 0.5 μm and more. If a coating is too thick, it is possible to cause powdering to a sheet surface. And therefore, in order to prevent possible occurrence of this powdering problem, it is advisable to keep the coating rather thin.

3.3 Bead holding Force and Drawability

Drawability of JIS A-5182 aluminum alloy sheets that the thickness is 1.0 mm and those of organic resin coated sheets (0.5 μm) were checked on the foregoing conditions, and the results are as shown in Fig. 9. Tests were also made on GA steel sheets that the sheet thickness is 0.8 mm for gathering reference data. A low-viscosity lubricating oil was coated on the A-5182 aluminum alloy sheets and also on the GA steel sheets. It is possible to tell from these data that the formability is remarkably improved by providing these metallic sheets with the organic resin coating as compared with non-coated bare sheets. When the bead holding force exceeded 44100N, formability of the resin coating provided aluminum sheets and GA steel sheets were reversed.

It is conceivable that although a non-coated GA steel sheet excels a 5182 aluminum alloy sheet in formability, when the bead holding force increased, flow-in resistance of the resin-coated 5182 aluminum alloy sheet decreased because of its better surface lubricity, and as a result, its drawability exceeded that of the GA steel sheet.

4. SPOT WELDABILITY

4.1 Coating Thickness and Welding Resistance

Welding resistance of bare sheets and organic resin coated sheets (0.1 μm, 0.3 μm and 0.5 μm in thickness) of JIS A-5182 aluminum alloy that the thickness is 1.0mm were tested, and the results are as shown in Fig. 10. As the coating is non-conducting, the resistance tends to take larger values with increase in the coating thickness.

4.2 Coating Thickness and Electrode Tip Life

Weldabilities of bare sheets and organic resin coated sheets (0.1 μm and 0.5 μm in thickness) of JIS A-5182 aluminum alloy that the thickness is 1.0mm were examined, and the results are as specified in Fig. 11. Evaluation is to be made by number of welding spots up until shearing load per spot becomes less than 1401N. While continuous welding is possible over 1000 spots on a bare sheet, the number of spots remarkably decrease in the case of a resin coated sheet depending on the coating thickness, that is, 421 spots for 0.1 μ m and 21 spots for 0.5 μ m.

This is considered to be caused by the possibility that the welding resistance becomes larger when the coating gets thicker and heat generation becomes excessive when electricity is switched on.

5. UV PRINTABILITY

5.1 Lubricant Concentration and Surface Tension

JIS A-5182 aluminum alloy sheets that the thickness is 1.0mm were provided with organic resin coatings of 5%, 10% and 15% in lubricant concentration, and then, their surface tension values were measured in conformity to JIS K-6768. And, Fig. 12 shows the results. It is conceivable from these data that lubricant concentration on the surface of a sheet becomes higher in proportion to increase in lubricant concentration and that the surface tension becomes small because surface tension of the lubricant is small.

5.2 Lubricant Concentration and Printing Adhesion Performance

JIS A-5182 aluminum sheets that the thickness is 1.0mm were provided with organic resin coatings of 5%,10% and 15% in lubricant concentration, and then, UV printing was conducted on these specimens to check their printing adhesion performance. And, the results are as shown in photo 1. Used for this printing were SEIKO ADVANCE RIG-710 ink, a 350-mesh screen, a 120W/cm UV lump and an integrated UV lighting volume of 1000mJ/cm^2. The evaluation of adhesion was made by observing how exfoliation was taking place at the time when the printed section was undergoing a cross-cut test.

While no exfoliation occurred lubricant concentration was 0%, the exfoliation become more and more remarkable as the lubricant concentration rose higher. It is conceivable that the printing adhesion tends to become worse as the coating's surface tension value gets smaller.

5.3 Curing Temperature and Surface Tension

Fig. 13 shows a correlation between the peak metal temperature used for curing of organic resin on a JIS A-5182 aluminum alloy sheet that the thickness is 1.0 mm and the surface tension of thus formed coating. It indicates that the surface tension tends to become smaller as the peak metal temperature gets higher. It also indicates that the important things to improve the printability is not only to adjust volume of the lubricant but also to control the baking temperature.

6. SUMMERIZED COMMENTS

- Studies on the ways of providing surface treatment for improving the fomability of aluminum alloy sheets resulted in clarifying that the best way to achieve this is to provide a bare sheet with a organic resin coating.
- It clarified that by providing a JIS A-5182 aluminum alloy sheet with the organic resin coating and using a high bead holding force, it is to become possible to improve the formability exceeding that of a GA steel sheet.
- In order to improve spot weldability of a organic resin coated sheet, it is necessary to reduce the coating thickness and the welding resistance.
- It clarified that for improving the UV printability of the organic resin coated sheet, it is advisable to lessen volume of the lubricant and heighten surface tension of the coating. And, it is also advisable to keep the curing temperature low.
- With respect to preparation of the organic resin coated sheets, it is important to make appropriate adjustment and control on lubricant concentration of the resin and the manufacturing conditions separately by individual applications.

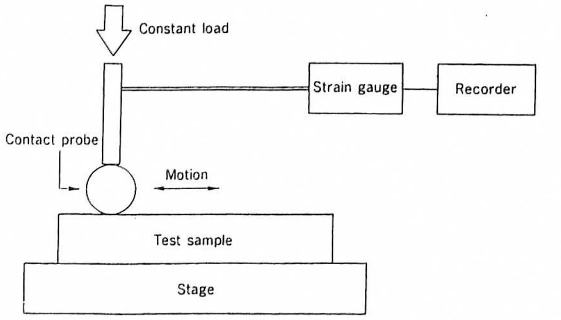

Fig. 1 Operating principle of a Bowden type friction analyzer

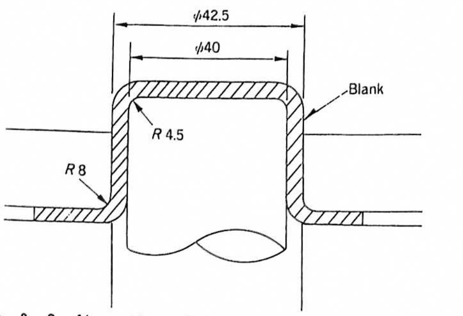

Fig. 2 Configuration of die used in drawability test
Bead holding force is 44100 N.

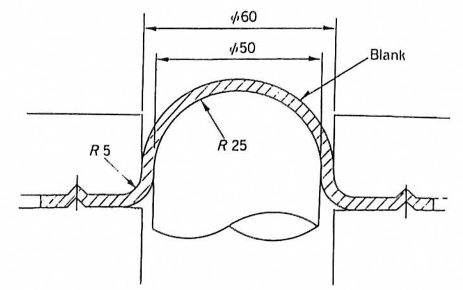

Fig. 3 Configuration of die used in stretching formability test
Bead holding force is 44100 N (lock bead).

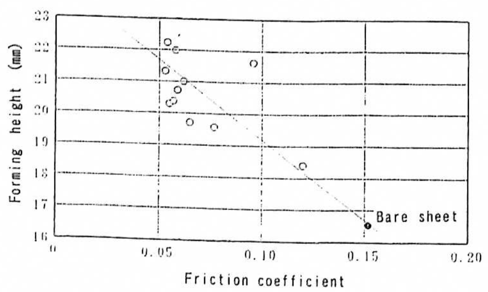

Fig. 4 Correlation between drawability and friction coefficient

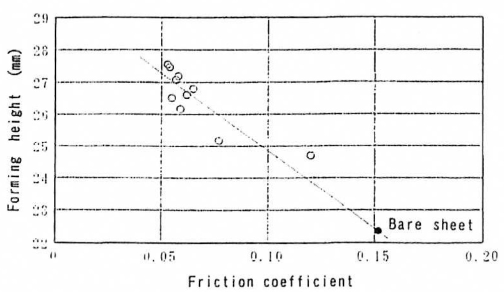

Fig. 5 Correlation between stretching formability and friction coefficient

Table 1 Surface treatment procedure

<table>
<tr><th></th><th>Pretreatment</th><th>Treatment</th></tr>
<tr><td>Anodizing</td><td rowspan="2">①degreasing
②desmutting with 30wt%HNO_3</td><td>Anodizing in 15wt%H_2SO_4</td></tr>
<tr><td>Boehmite</td><td>Dipping in boiling pure water</td></tr>
<tr><td>Resin coating</td><td>①degreasing
②desmutting with 30wt%HNO_3
③chromate conversion coating</td><td>Coating resin with a coating rod and curing in an oven</td></tr>
</table>

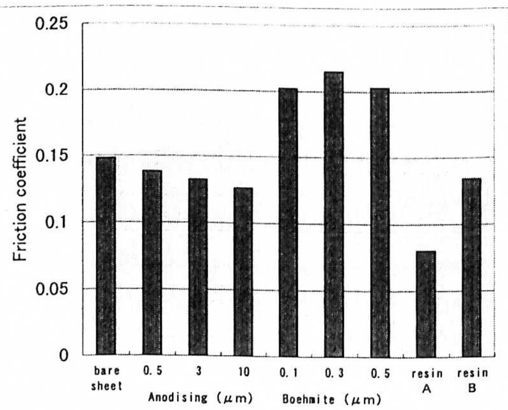

Fig. 6 Friction coefficient of surface treated aluminum alloy sheets

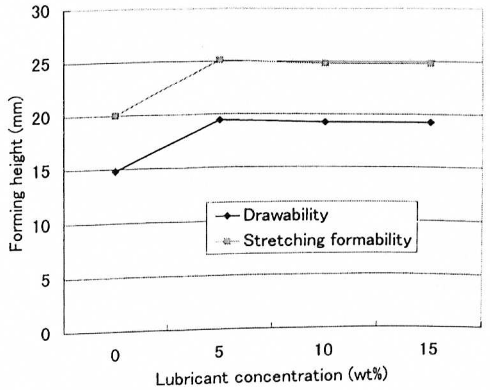

Fig. 7 Correlation between forming height and lubricant concentration

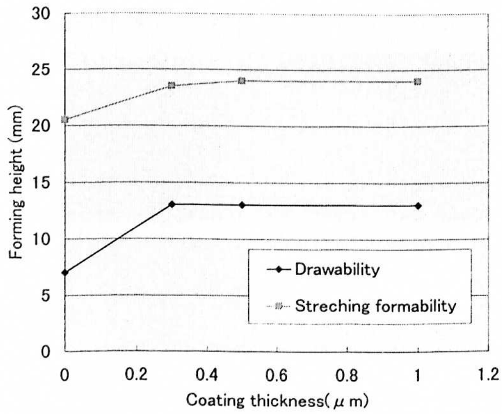

Fig. 8 Correlation between forming height and coating thickness

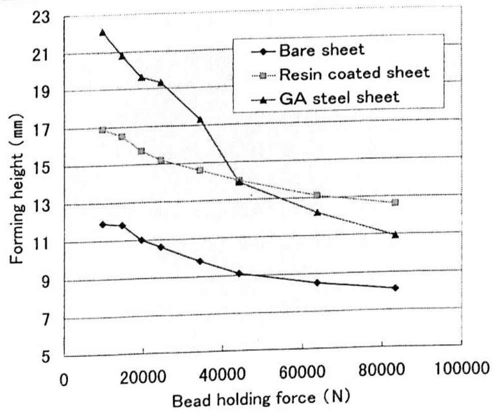

Fig. 9 Correlation between forming height and bead holding force

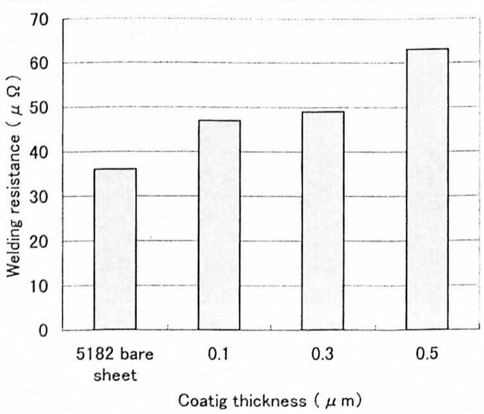

Fig. 10 Correlation between welding resistance and coating tickness

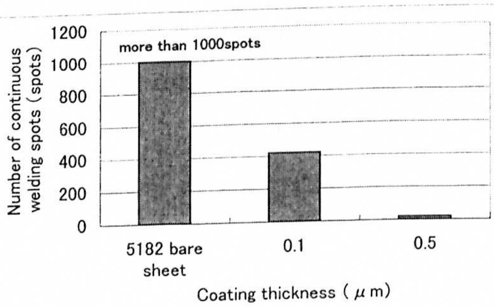

Fig. 11 Correlation between electrode tip life and coating thickness

Current type:Single-phase current
Electrode material:Chrome steel
Welding current:22500A
Welding cycles:5cycles
Welding force:3920N

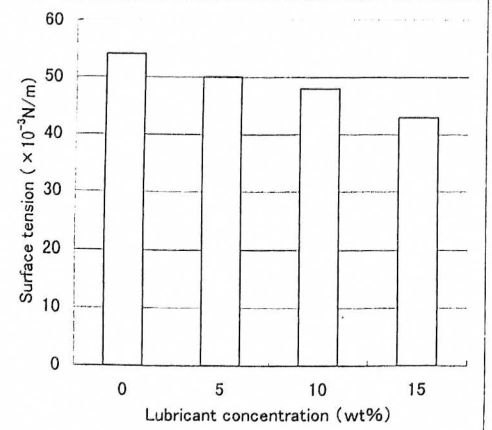

Fig. 12 Correlation between surface tension and lubricant concentration

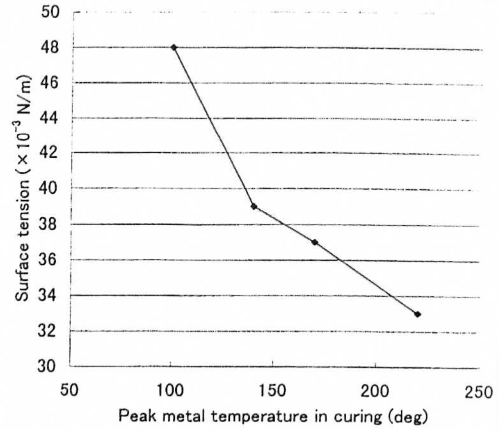

Fig. 13 Correlation between surface tension and curing temperature

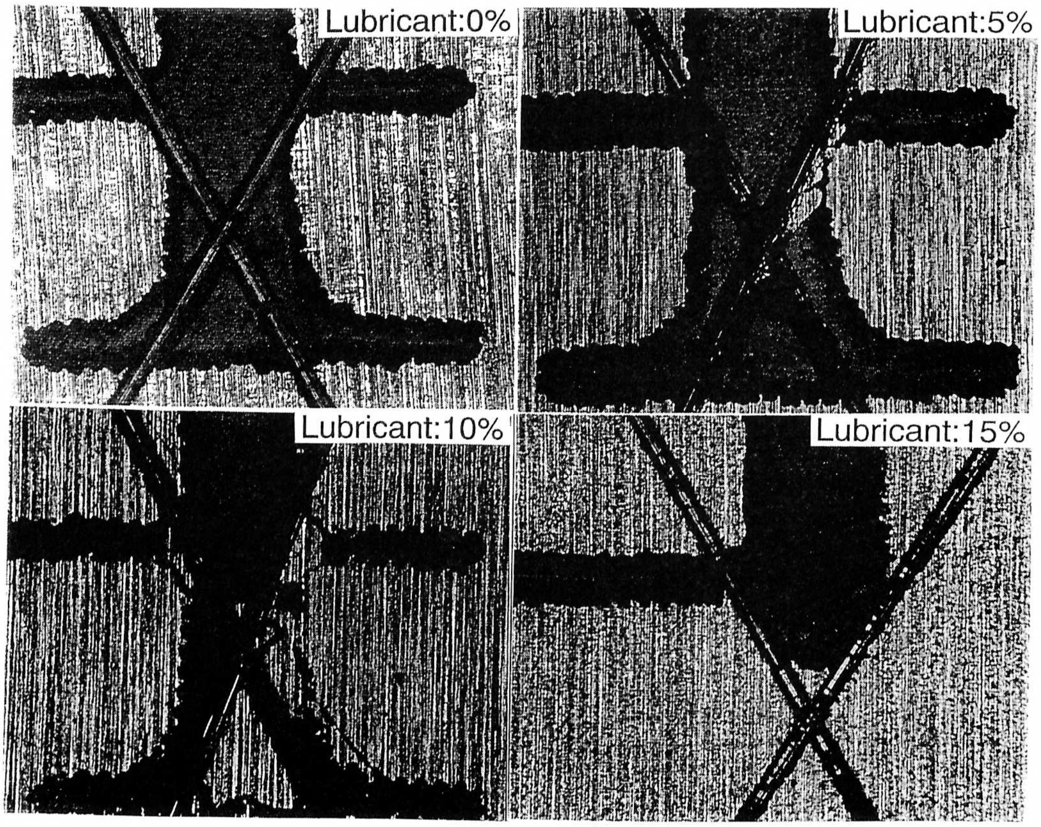

Photo 1 Correlation of printability and concentration of lubricant