LINING OF ALUMINUM ALLOYS WITH HARD METAL FOILS USING SHOT PEENING

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ABSTRACT
A method for lining aluminum alloys with hard metal foils using shot peening is proposed. The foil is welded to the surface of the workpiece due to plastic deformation generated by the hit of the shots. In an experiment of point lining using a single shot, the workpieces are aluminum alloys A1070, A2017 and A5056, and the foils are titanium, nickel, steel and stainless steel ones of 0.1mm in thickness. The hard foils are welded to the aluminum alloy workpieces by rising the processing temperature. To heighten the weldability at room temperature, a pure aluminum foil is inserted between the hard metal foil and aluminum alloy workpiece in the shot peening.

Keywords: *lining, shot peening, pressure welding, hard metal foil, foil insert*

1. INTRODUCTION

Because of an intensive demand for the decrease in weight of cars and aircraft, the use of aluminum products is increasing. Although the aluminum products are characterized by a large ratio of the strength to the weight, the application is still limited owing to a low wear resistance. The high wear resistance is requisite to machine parts and components. To enhance properties of aluminum alloys, the molecular orbital method of electronic structures has been applied [1]. Even using such a method, the improvement of the wear resistance is not easy.

Since the wear resistance is a surface property, only the surface property is improved, and not that of the aluminum. For that purpose, the metal lining processes are useful, i.e., the lining of aluminum alloy with a hard metal foil. The plating, PVD, CVD and thermal spraying are employed as the lining processes. The wear resistance of aluminum alloys was improved by dispersing the silicon-carbide particles to the surface [2] and by mixing PVD with ion implantation [3]. In addition, the wire explosion spray coating method was utilized for increasing the wear resistance [4]. The plated parts, however, are unacceptable for the use under severe conditions because of a thin plating layer. Although comparatively thick layers are formed by the thermal splaying process, the bond strength is not high. On the other hand, the wear resistance was improved by plasma transferred arc overlaying process with metal and ceramic powders [5]. However, the hardness of alloyed layer is not high.

If hard metal foils are welded to the surface of the aluminum products, the wear resistance is improved. Two metals are bonded by applying large pressure and plastic deformation in rolling and extrusion processes [6]. The pressure and plastic deformation break up the oxide film and contaminants at the interface between the two metals, and new and clean surfaces suitable for the welding are generated. In these processes, however, the welding becomes difficult in the case of a large difference between flow stresses of two metals because the deformation is concentrated at the metal having a small flow stress, particularly the welding of thin foils. The authors have proposed a lining method using shot peening [7]. In this method, large plastic deformation and pressure generated by the hit of shot are utilized for the welding.

In the present study, a method for lining aluminum alloy workpieces with hard metal foils using shot peening is proposed. The hard metal foils are welded to the surface of aluminum alloy workpieces due to plastic deformation caused by the hit of the shot. The bond strength of the lining of aluminum alloy A2017 workpieces with hard metal foils is mainly examined.

2. LINING METHOD USING SHOT PEENING

2.1 Method of lining

In the shot peening process, a metal workpiece undergoes plastic deformation near the surface due to the hit of a large number of shots at a high speed. This plastic deformation is utilized for lining aluminum workpieces with hard metal foils in the present study. The foil set on the workpiece was hit with the shot. Since the shot directly collides with the hard metal foil, plastic deformation of the aluminum workpiece is small. Deformation of reactive aluminum is requisite for the welding, and thus the lining of the aluminum workpiece with the hard metal foil is not easy.

2.2 Experimental procedures

The hard metal foils of 0.1mm in thickness were welded to aluminum alloy workpieces. The dimensions of the workpieces and foils used for the experiment are summarized in Table 1. The surface of the workpiece was cleaned with emery papers prior to the shot peening.

To evaluate the possibility of welding, the point lining using a single shot was performed. Since it is not easy to accurately control the impact speed of the shot and the position of the collision in the actual shot peening machine, the peening apparatus of a single shot shown in Fig. 1 was constructed. In the experiment, the foil set on the workpiece was hit with a shot under a free fall.

A steel shot was attached to the bottom of a steel cylinder in the free fall. By changing the weight of the cylinder and the fall height, the plastic deformation of the foil and workpiece was controlled. The diameter D of the shot is 4mm, the weight of the cylinder is between 25g and 2kg, the impact speed of shot is 4m/s and the processing temperature is from room temperature to 500 ℃. The experiment was performed in air.

Table 1 Conditions of model experiment of shot peening.

Base metal	A1070, A2017, A5056
Sheet metal (thickness: 0.10mm)	Mild steel, Nickel, Titanium, SUS304
Shot diameter d / mm	4
Temperature T / ℃	R.T. ~ 500
Impact speed / $m \cdot s^{-1}$	4
Weight / g	25 ~ 2000
Atmosphere	Air

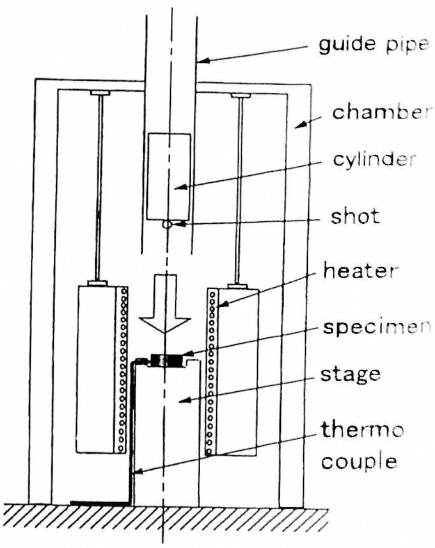

Fig. 1 Model experiment equipment of peening using single shot

The degree of welding is evaluated by tearing the hard metal foil from the workpiece. The degree is classified into the following two categories:
(1) complete: a piece of the hard metal foil is still welded to the surface of the workpiece after the tearing,
(2) failed: the hard metal foil is not welded to the workpiece.
In the tearing test, the tensile force was applied in the direction perpendicular to the surface of the workpiece.

3. POINT LININGT

3.1 Lining with mild steel foil

The degree of welding between the commercially pure aluminum A1070 workpiece and mild steel foil is shown in Fig. 2, where the ratio of depth of depression is defined as the depth at the centre of the depression divided by the diameter of the shot. The ratio of depth of depression represents the degree of plastic deformation. The degree of welding is improved by increasing the processing temperature, whereas the weldability at 500 ℃ is low because of the oxidation. For the pure aluminum, the complete welding is attained even at room temperature.

The degrees of welding for the aluminum alloys A2017 and A5056 workpieces are illustrated in Figs 3 and 4. In the temperatures above 200 ℃ and 250 ℃ for A2017 and A5056, the welding is possible, whereas the welding at room temperature is not successful. The reactivity of the pure aluminum is higher than those of the aluminum alloys.

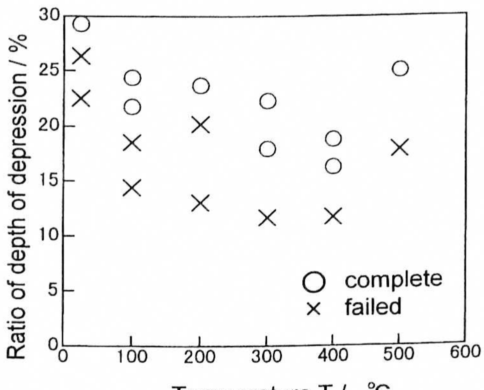

Fig. 2 Degree of welding between A1070 workpiece and mild steel foil.

3.2 Lining with titanium, nickel and stainless steel foils

The degree of welding between the aluminum alloy A2017 workpiece and pure titanium foil is shown in Fig. 5. Since the pure titanium is as reactive as the pure aluminum, the welding is possible even at room temperature.

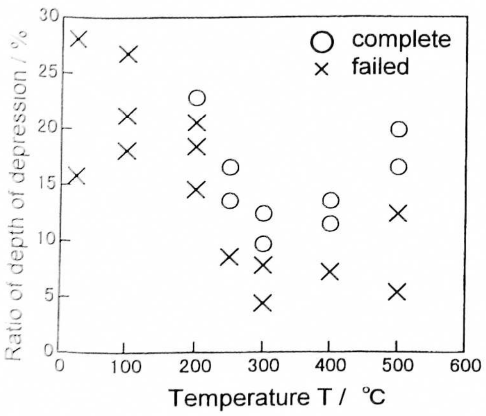

Fig. 3 Degree of welding between A2017 workpiece and mild steel foil.

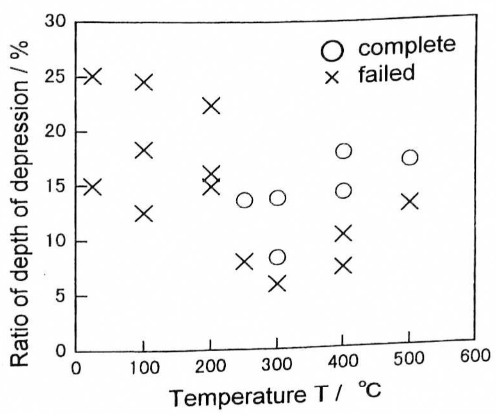

Fig. 4 Degree of welding between A5056 workpiece and mild steel foil.

The degree of welding for the pure nickel and the stainless steel foils are given in Figs. 6 and 7, respectively. The nickel and stainless steel foils were welded to the workpiece in the temperatures above 100 ℃ and 300 ℃, respectively. However, the two foils are not welded at room temperature.

4. POINT LINING USING ALUMINUM INSERT

4.1 Method of lining using aluminum insert

Since it is not easy to control the processing temperature of the workpiece in the actual shot peening process, the lining at room temperature is desired. As mentioned in Chapter 3, the aluminum alloys are not lined with the mild steel, nickel and stainless steel foils at room temperature. To improve the weldability at room temperature for the aluminum alloys, a reactive metal foil is inserted between the hard metal foil and aluminum alloy workpiece in the shot peening. Since the pure aluminum is welded even at room temperature as shown in Fig. 2, a commercially pure aluminum foil of 0.02mm in thickness is employed as the metal insert.

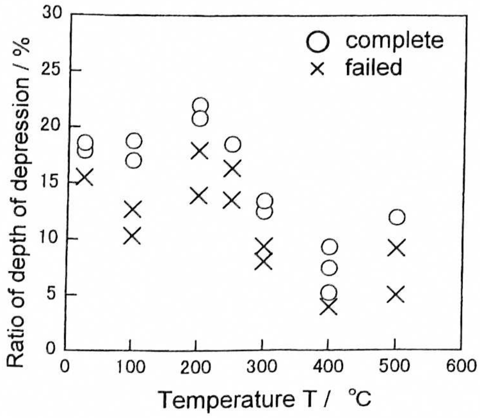

Fig. 5 Degree of welding between A2017 workpiece and titanium foil.

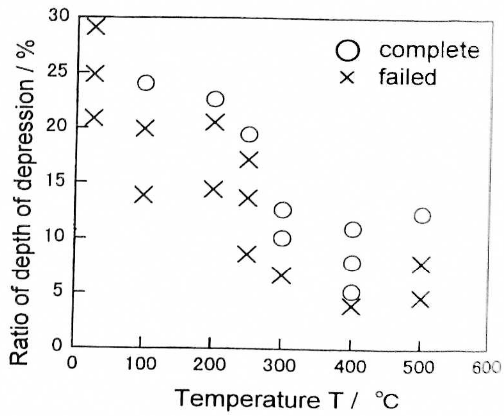

Fig. 6 Degree of welding between A2017 workpiece and nickel foil.

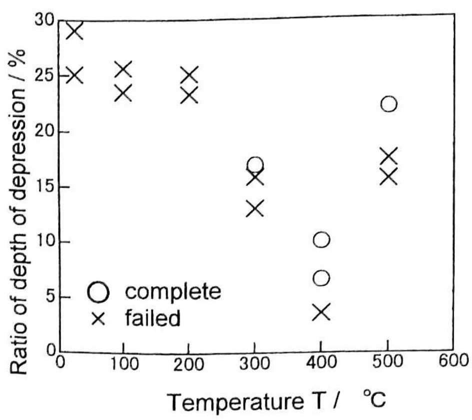

Fig. 7 Degree of welding between A2017 workpiece and SUS304 foil.

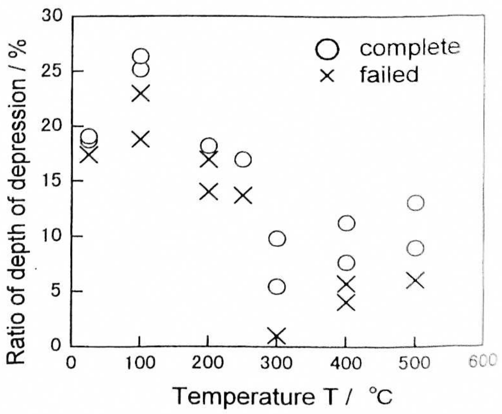

Fig. 8 Degree of welding between A2017 workpiece and mild steel foil using insert.

4.2 Lining with hard metal foil using aluminum insert

The degree of welding between the aluminum alloy A2017 workpiece and mild steel foil using the pure aluminum insert is shown in Fig. 8. In comparison with the lining without the insert shown in Fig. 3, the degree of welding increases, and the complete welding is attained even at room temperature. The SEM photograph of the surface of the welded A2017 workpiece using the insert at room temperature after the tearing test is given in Fig. 9. The foil is still welded to the surface after the tearing.

The degree of welding between the aluminum alloy A5056 workpiece and mild steel foil using the insert is shown in Fig. 10. Using the insert, the hard metal foil is welded to the workpiece even at room temperature.

The degrees of welding for the nickel and the stainless steel foils using the insert are shown in Figs. 11 and 12, respectively. In comparison with the lining without the insert (see Figs. 6 and 7), the degrees of welding increase, and the complete welding is attained even at room temperature.

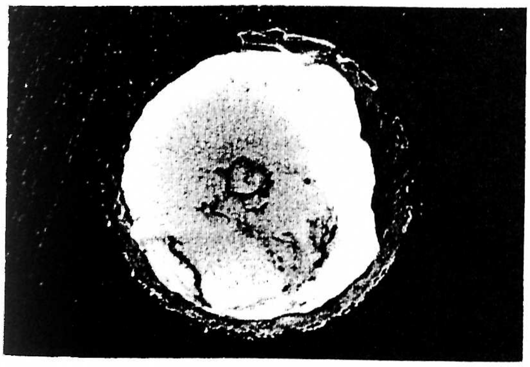

Fig. 9 SEM photograph of surface of welded A2017 workpiece using insert at room temperature after tearing test.

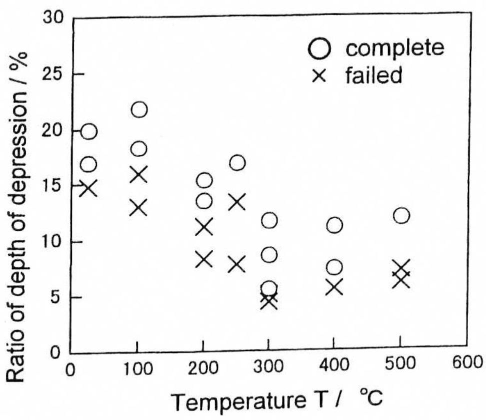

Fig. 10 Degree of welding between A5056 workpiece and mild steel foil using insert.

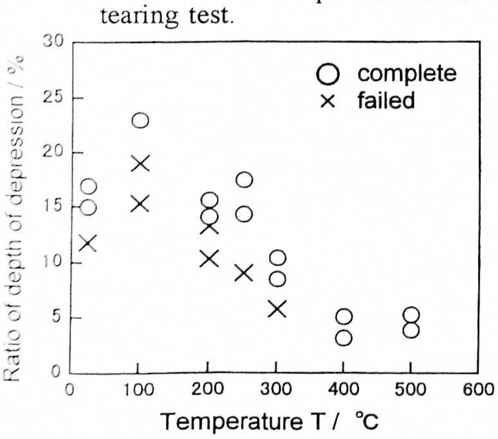

Fig. 11 Degree of welding between A2017 workpiece and nickel foil using insert.

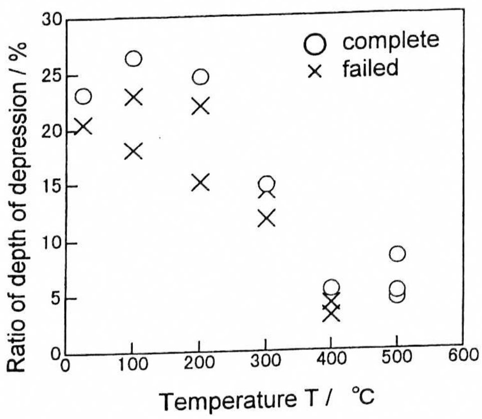

Fig. 12 Degree of welding between A2017 workpiece and SUS304 foil using insert.

4.3 Effect of shot size

In the present experiment, the size of the shot is considerably large in comparison with the actual process. To examine the effect of the shot size on the degree of welding, the lining of the aluminum alloy A2017 workpiece with the mild steel foil was performed at room temperature. The variation of critical ratio of depth of depression with the ratio of the diameter of the shot to the thickness of the hard metal foil, d/t, is given in Fig. 13. As d/t increases, the critical ratio decreases. This is due to the increase in plastic deformation near the surface of the aluminum workpiece with the increase in the diameter of the shot.

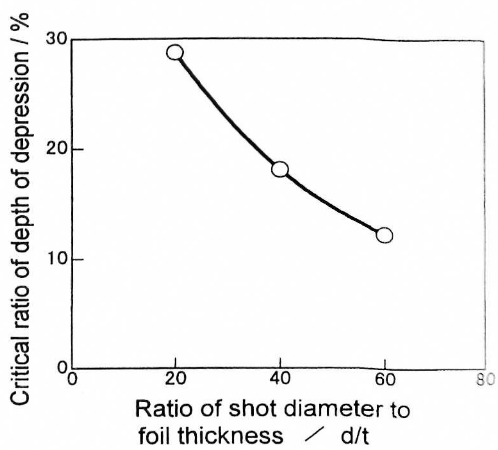

Fig. 13 Variation of critical ratio of depth of depression with ratio of shot diameter to foil thickness for A2017 workpiece and mild steel foil at room temperature using insert.

5. CONCLUSIONS

To improve the wear resistance for the aluminum products, a lining method with hard metal foils using shot peening was proposed. The hard metal foil was welded to the surface of the aluminum alloy workpiece due to plastic deformation generated by the hit of the shots. The weldability was examined from the experiment using a single shot. The hard metal foils were welded to the pure aluminum workpieces, whereas the welding to the aluminum alloy workpieces at room temperature was not accomplished. To improve the weldability of the aluminum alloys at room temperature, a pure aluminum foil was inserted between the hard metal foil and aluminum alloy workpiece. The present method using the shot peening is effective in improving the surface properties of the aluminum products.

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