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Cold Joining of Aluminium Sheets by Shot Peening

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The cold joining of aluminium sheets by shot peening was investigated. In shot peening, the substrate undergoes a large plastic deformation near its surface when hit by many shots. Consequently, the plastic flow areas formed by cold working may form the surface layer. When the metal sheets with the concavo-convex edge are connected, and then the contact area is shot-peened, the metal sheets can be joined. In this joining, the convex edges of the sheet are stacked on the other sheet. Namely, in the joining area, the two sheets are on top of each other. In this experiment, an air shot peening machine was used. Air pressure was 0.6 MPa and peening time was in the range of 30 - 240 s. The shot material used was made of high carbon cast steel. The sheets were commercial pure aluminium, pure titanium, low-carbon steel, stainless steel, pure copper and magnesium alloy. The effects of shot peening conditions on joinability were examined. The joinability was evaluated by tensile test. The joint strength increased with the amount of plastic flow. It was found that the present method was effective for cold joining of aluminium sheet and the dissimilar sheets.

Keywords: *Shot peening, Joining, Surface treatment, Plastic deformation, Joinability*

1. Introduction

In the parts of transfer machine such as automobile and aircraft, the joining techniques for the dissimilar metal sheets are very important. Recently, the use of aluminium and magnesium products is increasing because of an intensive demand for the decrease in weight of transfer machine. A number of the functional materials are already in commercial use. These products are characterized by a large ratio of the strength to the weight. Therefore, every year the development of the new materials is widely carried out. In case of magnesium alloy, the high-thermostability alloys were developed in Japan [1]. In titanium alloy, the functionality alloys are developed as a material of the aircraft. The effects of frictional wear characteristics and microstructural factors on fretting fatigue strength of titanium alloy annealed at various temperatures were reported [2]. Some of the newly developed alloys are designed to cater to a wide range of applications. However, new alloys and existing alloys cannot easily be joined by the usual methods of joining.

The authors have recently proposed new joining methods using shot peening [3, 4]. The shot peening process is one of the surface treatments. It is a process that is used very effectively to enhance fatigue life of materials [5], though these processes are not joining technique. Bombarding the surface with steel shot propelled at high velocity causes plastic deformation of surface. The process with the characteristic deformation was applied to joining process. Our approach has been applied to the butt joining of the dissimilar metal sheets [6, 7]. In this method, the edges of the two sheets are notched. Namely, in the butted section, the edge of two sheets has a shape of notch geometry like a nail. When the connection is shot-peened, the surface layer is deformed by the collision of the shot. In this method, both faces of the connection are peened. Thus, two sheets are joined without level difference. This process is similar to joining by caulking. In this method, however, the joint strength was lower than the flow stress of base metal. Since the upper and lower sides of the sheet were deformed by shot peening, only the joining was achieved near the surfaces of the sheet. To improve the joinability, the authors tried to modify the butt joining method.

In the present study, the cold joining of dissimilar metal sheets using a shot peening process was investigated to improve the joinability. The dissimilar sheets with the edge of the notch geometry are connected. We substituted a modified joining for butt joining. The effects of processing conditions on the joinability were examined. Tensile test was also examined to evaluate joint strength.

2. Experimental Procedure

2.1 Method of Cold Joining of Metal Sheets

The cold joining method of the metal sheets by shot peening are shown in Fig. 1. The edge shape of two sheets is a concavo-convex. The convex edges of the sheet are laid on top of the other sheet. Namely, the two sheets are superimposed in the joint area. When the connection is shot-peened, the material of the convex area undergoes large plastic deformation near the surface due to the collision of shots. In this process, particularly noteworthy is the plastic flow near surface layer. The convex edges of the sheet can be joined to the other sheet, thus two sheets are joined. The masking plate was also used in order to prevent a bend by shot peening, because the sheet used was very thin.

2.2 Shot Peening Equipment

The shot peening treatment was performed by using an air-type peening machine with an air-orifice diameter of 3 mm and an injection-nozzle diameter of 6 mm. The shot peening conditions were controlled in the experiment. The shots used were made of high carbon cast steel with an average diameter of 0.1 mm. Air pressure was 0.6 MPa and peening time was in the range of 30 - 150 s. The conditions used for the shot peening experiment are summarized in Table 1.

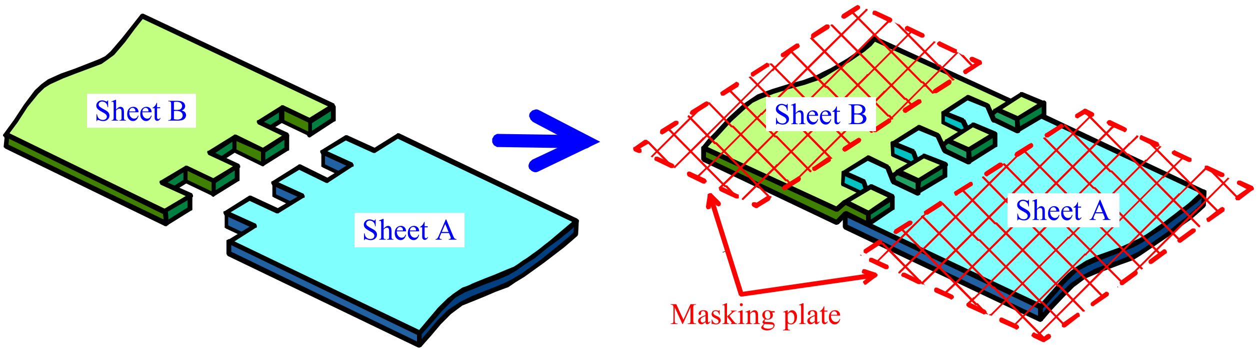

Fig. 1 Schematic illustration of cold joining method of metal sheets by shot peening

Table 1 Working conditions used for shot peening experiment

Equipment	Air peening machine
Shot material	High carbon cast steel, HV450
Shot diameter	0.10 mm
Air pressure	0.6 MPa
Peening time	30 - 150 s
Working temperature	Room temperature
Sheet t=0.5 mm	Pure aluminium A1050(HV43), Pure titanium TB340(HV141), Pure copper C1100(HV73), Magnesium alloy AZ31B(HV60), Low carbon steel SPCC(HV102), Stainless steel SUS304(HV194)
Atmosphere	Air

2.3 Materials

The sheets were commercial pure aluminium A1050, pure titanium TB340, pure copper C1100, magnesium alloy AZ31B, low-carbon steel SPCC and stainless steel SUS304. The dimensions of the sheets are 30 mm in width, 60 mm in length, and 0.5 mm thick. The edge was cut into the desired shape of 3 mm wide by 3 mm long. There are two types of sheets, sheet A and sheet B. The sheet A has four convex edges, while the sheet B has four concavo edges. The materials used for the experiment are also summarized in Table 1.

2.4 Evaluation of Joinability

When the dissimilar sheets were joined by peening, the joinability was evaluated. The joint strength between the joined sheets was measured by tensile test using a test machine INSTRON at a cross head speed of 2 mm/min. The joint strength was defined as the maximal load at joint failure.

3. Results and Discussions

3.1 Appearance of joined sheets

The appearances of the cold joined sheets by shot peening are shown in Fig. 2. The peening time was 60 s. The sheet B was pure aluminium A1050. The sheet A was the dissimilar sheet; these sheets are low carbon steel SPCC (a), stainless steel SUS304 (b), pure titanium TB340 (c), and pure copper C1100 (d). The convex edges at a contact area were deformed by shot peening. In all workpieces, the amount of plastic deformation of the sheet B (A1050) was larger than that of the sheets A. This is due to low flow stress. By using shot peening, the pure aluminium A1050 and the dissimilar metal sheets were successfully joined.

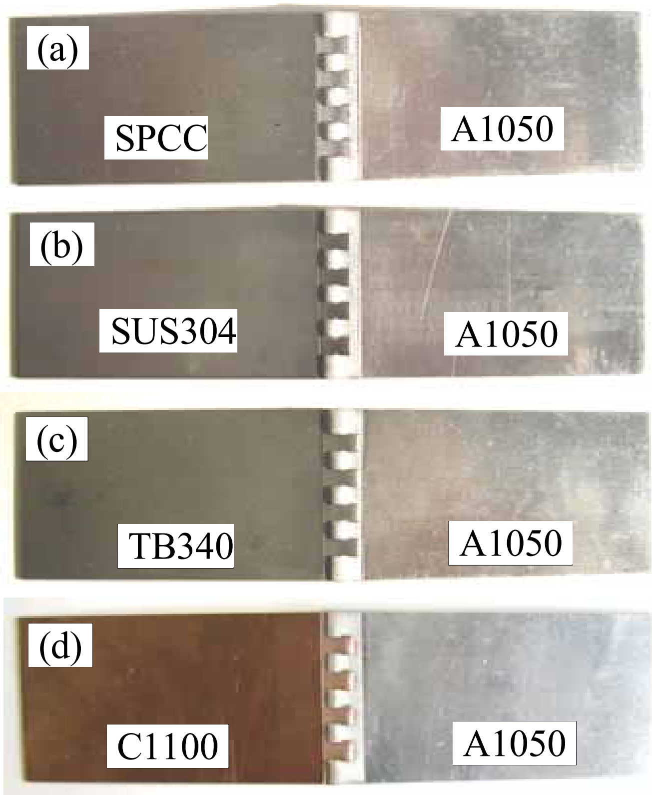

Fig. 2 Appearances of joined dissimilar metal (sheet A) / A1050 (sheet B) workpieces peened at 0.6 MPa for 60s
(a) SPCC (sheet A) / A1050 (sheet B), (b) SUS304 (sheet A) / A1050 (sheet B),
(c) TB340 (sheet A) / A1050 (sheet B), (d) C1100 (sheet A) / A1050 (sheet B)

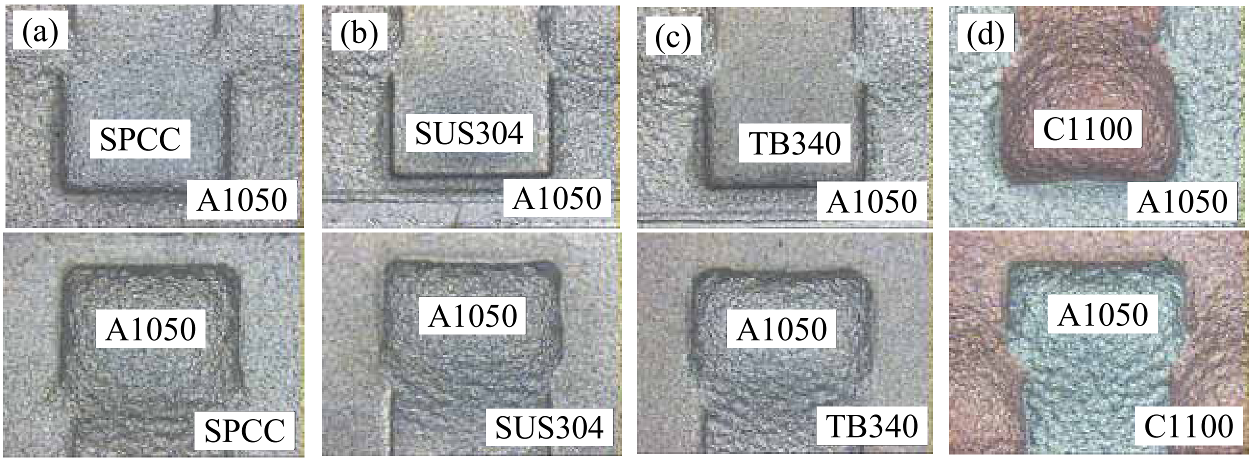

Fig. 3 Photomicrographs of the edges of the metal sheet (sheet A) / pure aluminium A1050 (sheet B) workpieces peened at 0.6 MPa for 60s
(a) SPCC (sheet A) / A1050 (sheet B), (b) SUS304 (sheet A) / A1050 (sheet B),
(c) TB340 (sheet A) / A1050 (sheet B), (d) C1100 (sheet A) / A1050 (sheet B)

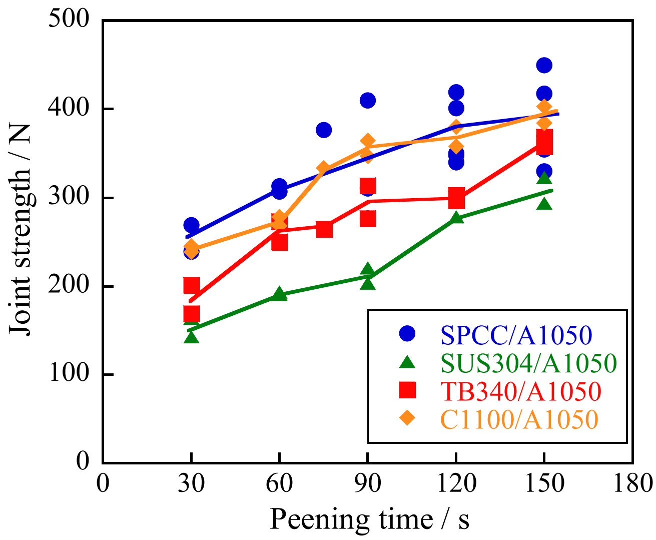

Fig. 4 Variation of joint strength with peening time for dissimilar metal / pure aluminium A1050 workpieces

The surface condition of the shot-peened workpiece was observed by microscope. The peened surfaces of the workpieces are given in Fig. 3. The workpieces were the metal sheet (sheet A) / pure aluminium A1050 (sheet B) workpieces peened at 0.6 MPa for 60 s. The convex edges were deformed by the repetitive collision of shots. The surface area of the convex edge was enlarged. Especially, the amount of plastic deformation of the sheet B (A1050) was larger. Since the flow stress of pure aluminium is low, the peen forming also occurs at the edge of the sheet. It was found that joining was accomplished by spreading convex edge.

3.2 Joint strength

The pure aluminium sheet and the dissimilar metal sheet were successfully joined (see Fig.2). To evaluate the joinability, the joint strength between the joined sheets was measured by tensile test. The variation of joint strength with peening time for the dissimilar metal (sheet A) / pure aluminium

A1050 (sheet B) workpieces is shown in Fig. 4. The sheet B was pure aluminium A1050. In all workpieces, the joint strength increases with peening time. This is because the surface layer is sufficiently formed by collision of media.

4. Conclusions

Shot peening are utilized extensively for machine components. Although joining applications are still considerably rare, the joining of the dissimilar sheets was performed. The butt joining method has been proposed to join the dissimilar metal sheets by using shot peening. The method is expected to be available. However, the joint strength was lower than the flow stress of base metal. In the present study, a modified joining method was designed to improve the joinability. The ability of shot peening to enhance cold joining of the dissimilar metal sheets was investigated. The dissimilar sheets with the concavo-convex edge were connected, and then the contact area was shot-peened. In the joining method, the convex edges of the sheet were laid on the other sheet. Namely, in the joining area, the two sheets were superimposed. Tensile strength was measured to examine the effect of peening time on the joinability. Although the joint strength was still lower than the flow stress of base metal, the joinability was somewhat improved. By further investigations, it is expected that improved joining method will be available. It was found that the present method was effective for cold joining of dissimilar metal sheets.

5. Acknowledgments

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