BUTT JOINING OF SHEET BY SHOT PEENING

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ABSTRACT
The ability of shot peening to enhance butt joining of the dissimilar sheets was investigated. In shot peening, the substrate undergoes a large plastic deformation near its surface when hit by many shots. When the machined part with the bore and the groove is excessively shot peened, the accuracy of the shape is lowered as the amount of plastic flow increases. This plastic flow is characterized by a shear droop at the edge of the substrate, i.e., the peened material overflows at the edge. When the dissimilar sheets with the notched edges are connected without a level difference and then the connection is shot peened, the sheets can be joined by the plastic flow generated by the large plastic deformation during shot peening. In this experiment, an air-type peening machine was used. The influences of processing conditions on the joinability were examined. Tensile tests were performed to evaluate joint strengths. The joint strength increased with air pressure, i.e., the amount of plastic flow. It was found that the present method can be used to enhance the butt joining of the dissimilar sheets.

KEY WORDS
Joining, Plastic flow, Joinability, Sheet

INTRODUCTION
In order to improve the productivity and the functionality of the machine parts, joining methods for dissimilar materials have been actively investigated (S. J. Muraski, 1990; K. A. Swanstrom, 1996). Different properties are important for functional purposes of the product. For common liquid-state joining processes, such as arc and resistance welding, the efficiency of joint for welding is higher than that for mechanical joining and adhesive joining. On the other hand, in solid state joining processes such as diffusion bonding and pressure welding, it is easy to control the reaction in the bonded interface. The processes are an important and necessary aspect of manufacturing operations.

Although the shot peening process is widely used to improve the performance of engineering components, its ability to improve surface properties has recently been studied. The dry coating techniques (Y. Kataoka, 2001) and cold splay (T. H. Van Steenkiste et al., 2002) are used for coating. The metal particles and the substrate can be joined by the adhesion or embedding of particles at high speed. Also, the authors have proposed a lining method by shot peening (Y. Harada et al., 1998). In shot peening, the material surface is collided repeatedly with many steel shots, making overlapping indentations on the surface. In the shot lining method, the pressure generated by many shots hitting is used for the lining of dissimilar foils. We also applied shot peening to the lining of the hard powders such as cemented carbide and ceramics to improve the wear resistance of aluminum and magnesium alloys (Y. Harada et al., 2002). The hard powders were successfully bonded over the surface. In addition, we have applied these processes to the joining of dissimilar materials (Y. Harada et al., 2006; Y. Harada and K. Fukaura, 2007).

In shot peening, the peening effects are characterized by the fact that the surface layer undergoes large plastic deformations due to the collision with the shot. When the machined part with the bore and the groove is excessively shot peened, the accuracy of the shape is lowered as the amount of plastic flow increases. Consequently, plastic flow characterized by shear droop occurs at the edge of the substrate due to shot peening. The plastic flow, or overflow material, makes the joining of the implant possible. When the dissimilar material is set in a hollow space on the surface of the substrate and then shot peened, it can be joined to the substrate by the overflow material generated by the large plastic deformations that occur during shot peening. This approach has been applied to the butt joining of thin sheets.

In the present study, the butt joining of the dissimilar material sheets using a shot peening process was carried out. The influences of peening time and shot material on joinability were examined. Joinability was evaluated by tensile testing.

EXPERIMENTAL PROCEDURE

The butt joining method of dissimilar sheets by shot peening shown in Figure 1 was used. In the butted area, the edges of the two sheets are notched. When the connection of the convex part is shot peened, the surface layer is deformed by the collision with the shot. The large plastic deformation that occurs on the surface layer generates overflow material in the edge of the sheet that fills the joint cavity between the two sheets. Thus, the sheets are joined without a level difference. This method is similar to joining by caulking. In this method, both faces of the connection are shot-peened primarily. The clearance was smaller than the diameter of the shots to prevent an insertion of shot media. A masking plate was used to prevent bend formation during peening.

The shot peening treatment was performed using an air-type peening machine (Sintobrator Ltd., MY-30B) with an air-orifice with a diameter of 3 mm and an injection-nozzle with a diameter of 6 mm. Air pressure and peening time were controlled in the experiment. The shots used were made of high carbon cast steel (700HV) and cemented carbide (1400HV) with an average diameter of 1.0 mm. The conditions used for the shot peening experiment are summarized in Table 1.

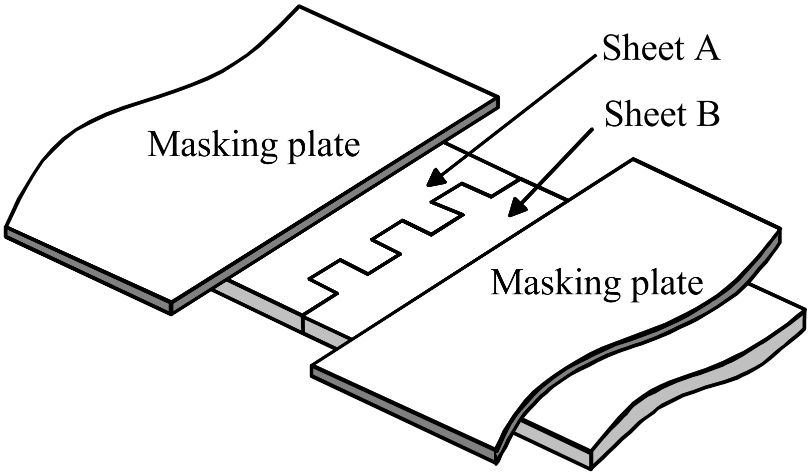


Figure 1 Schematic illustration of butt joining method of dissimilar sheets by shot peening

Table 1 Working conditions used for shot peening experiment

Equipment	Air peening type
Shot material	High carbon cast steel (700 HV), Cemented carbide (1400 HV)
Shot diameter	0.10 mm
Air pressure / p	0.4, 0.6, 0.8 MPa
Peening time / s	30 - 240 s
Working temp.	Room temperature
Workpiece (t=1.0 mm)	Low-carbon steel; SPCC / Stainless steel; SUS304, Low-carbon steel; SPCC / Magnesium alloy; AZ31B, Low-carbon steel; SPCC / Pure Al; A1050, Stainless steel; SUS304 / Pure Ti; TB340, Stainless steel; SUS304 / Pure Cu; C1100
Atmosphere	Air

The metal sheets were two ferrous sheets: commercial low-carbon steel SPCC, stainless steel SUS304 and four non-ferrous sheets: pure titanium TB340, pure copper C1100, pure aluminum A1050, and magnesium alloy AZ31B. A rectangular sheet was used that was 30 mm wide, 60 mm long, and 1.0 mm thick. The edge was cut into the desired shape of 3 mm wide by 3 mm long. The joint cavity between the two sheets was 0.05 mm. The materials used for the experiment are also summarized in Table 1.

The joint strength between the joined sheets was evaluated by tensile tests using a testng machine INSTRON-5582 at a cross head speed of 2 mm/min. The joint strength was defined as the ratio of the maximal load at joint failure to the total contact area; except for the area perpendicular to the direction of the tensile axis.

RESULTS AND DISCUSSIONS

Appearance of butt joined sheets

To examine the joinability of ferrous/ferrous and ferrous/non-ferrous workpieces, the joint strength of the joined workpieces was evaluated by tensile tests. The appearances of butt joined sheets by shot peening are shown in Figure 2. The ferrous/ferrous and ferrous/non-ferrous workpieces are the SPCC/SUS304 and the SUS304/Ti. The air pressure and peening time are p=0.6 MPa and s=60 s, respectively. In both workpieces, the clearance at a contact zone disappears due to particle bombardment, because shot peening causes large plastic deformation of surfaces. In addition, other workpieces were joined without the clearance.

The surface conditions of the sheet were observed by SEM after shot peening. The unpeened and peened surfaces for SPCC/SUS304 sheet are given in Figure 3. The air pressure and the peening time are p=0.6 MPa and s=60 s, respectively. After shot peening, the clearance at the joint part disappeared by the collision of the shots.

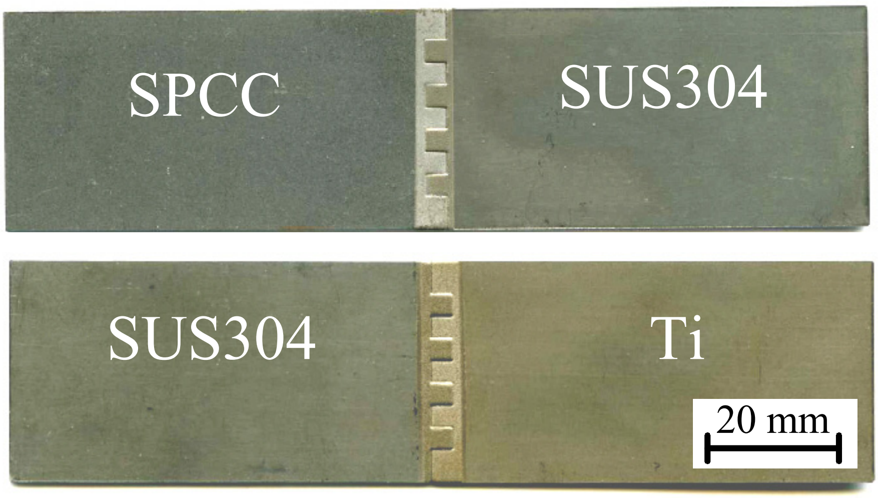
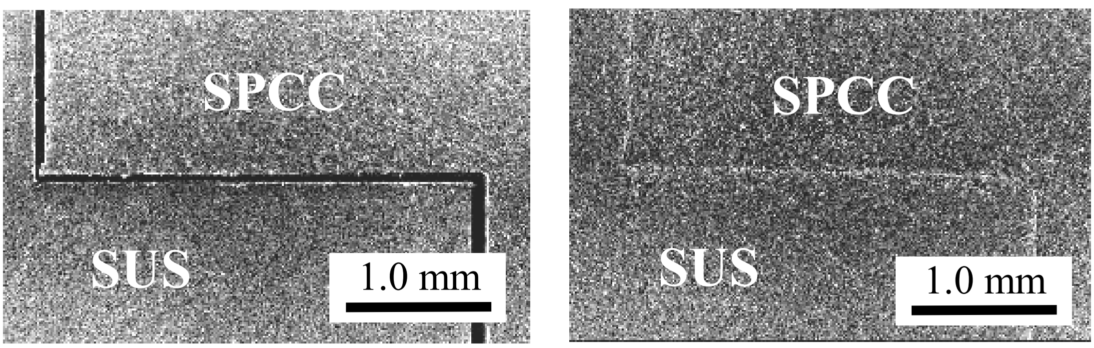


Figure 2 Appearances of butt joined sheets by shot peening (p =0.6 MPa, s =60 s)



(a) Unpeened (b) Peened

Figure 3 SEM photomicrographs of the surface of SPCC/SUS304 workpiece (p =0.6 MPa, s = 60 s)

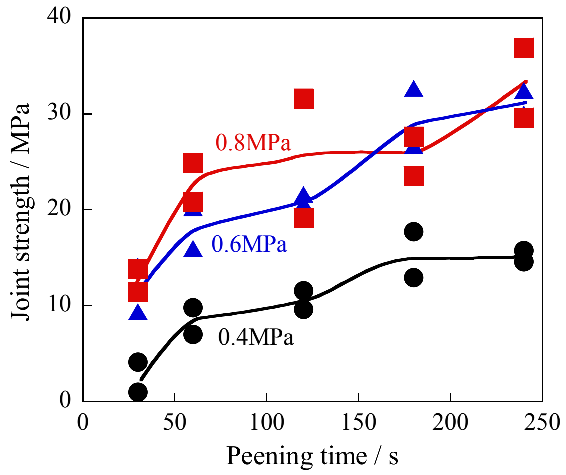


Figure 4 Effect of air pressure on the relation between joint strength and peening time for SPCC/SUS304 workpiece joined by shot peening

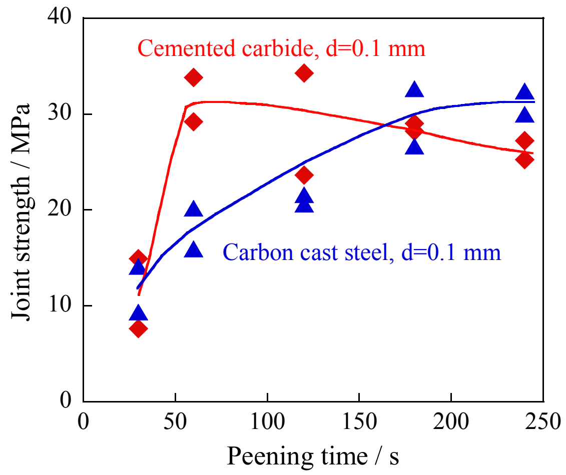


Figure 5 Effect of shot material on the relation between joint strength and peening time for SPCC/SUS304 workpiece joined by shot peening (p =0.6 MPa)

Joinability

The joint strength of the joined workpieces was evaluated by a tensile test. The effect of the air pressure on the relation between the joining strength and the peening time for SPCC/SUS304 workpiece joined by shot peening are shown in Figure 4. The joining strength increases with the peening pressure. The strength also rises with peening time due to the existence of space between the dissimilar metal sheets. Namely, the strength is not raised until the clearance near the surface is sufficiently filled with the deformed material. However, the joint strength is lower than the flow stress of base material.

To examine the effect of the shot material on the joining strength, the shot made of the cemented carbide (1400HV) was used. The effect of the shot material on the relation between the joining strength and the peening time for SPCC/SUS304 sheet joined by shot peening are shown in Figure 5. The joint strength of the workpiece peened by the cemented carbide media is higher than that by the cast steel media. Compared with the steel media, the cemented carbide media has higher kinetic energy at collision and this causes greater plastic deformation of the surfaces.

CONCLUSIONS

The shot peening process is characterized by large plastic deformations near the surface of material. In the present study, butt joining of dissimilar metal sheets was performed by means of shot peening. Tensile strength was measured to examine the influences of peening pressure and time as well as shot media on joinability. The dissimilar sheets can be successfully joined by shot peening. The use of cemented carbide media was very efficient in improving joinability. However, the joint strength is lower than the flow stress of base material. Although further investigations are needed to improve the joinability, we found that the present method can be used for butt joining of the dissimilar material sheets without melting.

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