Explosion Shock Waves and High Strain Rate Phenomena Materials Research Forum LLC
Materials Research Proceedings **13** (2019) 69-73 https://doi.org/10.21741/9781644900338-12

Joining of Dissimilar Metals Using Low Pressure Difference

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Keywords: Metal Bonding, Oblique Collision, Projectile Accelerator, Metal Jet

Abstract. In explosive welding, the velocity of flyer plate requisite for joining of two different kinds of metallic sheet is several hundred meters per second. We thought that the velocity would be accomplished easily without explosives. A lightweight projectile, which receives higher pressure on the rear side than front side, goes forward and is accelerated to extremely high velocity, even if the pressure difference is small. Joining should be achieved, when a thin metal sheet attached on the front of the projectile collides with another metal plate fixed on an oblique block. Oblique collisions between several kinds of metal were examined. Examinations of the joint interfaces of this resultant by both scanning electron and optical microscopes find no opening. Detachment at the joint interface did not occur, when tensile forces were applied. Therefore, we regard that the joint interface has sufficient strength.

Introduction

High-energy-rate processing has many excellent features that differ from static processing. For example, explosive welding, which is one of the methods for producing cladding materials, is applied to combinations in dissimilar metals and non-metals that are difficult to bond in diffusion bonding. Metal processing and material synthesis have been carried out with shock waves generated by explosives [1, 2]. The method that does not use explosives was originated, as experiments using explosives require qualifications to handle them and the cost of the experiment is high. The general methods of joining metals are mechanical bonding, metallurgical bonding, and chemical bonding. Each has advantages and disadvantages, and it is necessary to select a bonding method suitable for the material and bonding conditions to join metals efficiently. Explosive welding has the best features among these bonding methods. A simple projectile accelerator using a difference in air pressure has been produced. The equivalent qualifications to explosive welding will be succeeded, if the device were used. When this device is applied to sheet metal forming, good results than expected was obtained. Then I tried joining of dissimilar metals.

Experiment

In explosive welding, the flyer plate is arranged in parallel with an appropriate distance from the parent plate, and one end of the explosive placed on the flyer plate is detonated. In the proposed method, the flyer plate is accelerated by the air pressure difference substitute for the explosive. Since a high pressure difference is required to obtain a large acceleration, a vacuum collision chamber and a high-pressure chamber are made. Figure 1 is a photograph of the overall view of the projectile accelerator. A metal plate attached to the flyer plate is accelerated by the pressure

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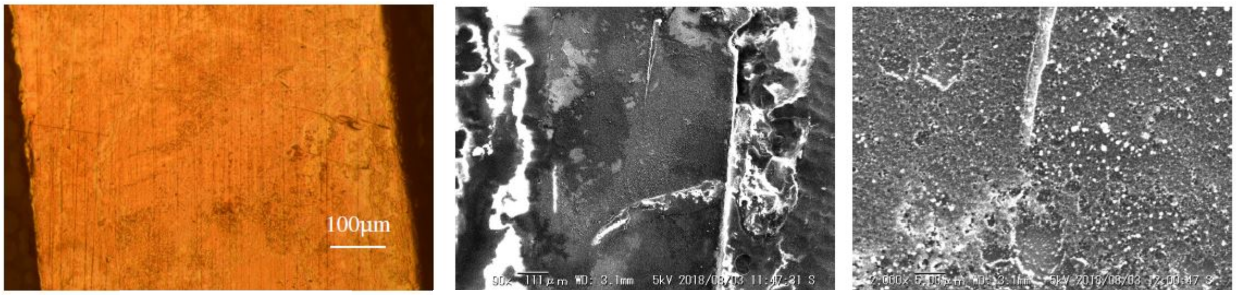
difference, and it collides with another metal plate at high speed obliquely. In order to achieve this, as the condition called weldability window [3] must be satisfied, it is necessary to adjust the collision velocity V_c and the collision angle β appropriately according to the combination between the material of flyer plate and that of parent plate.

Fig.1 Overall view of the projectile accelerator.

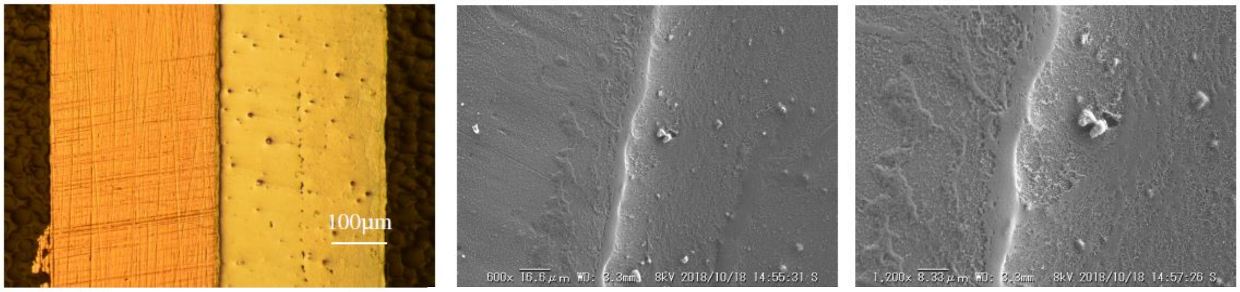
Results

Figures 2-5 indicate the results of observation of the bonding interface of the joined metal plates obtained in this experiment with an optical microscope and an electron microscope. Figure 2 shows the results in the case of joining copper to another copper. Figures 3-5 are in the cases of joining copper to aluminum, aluminum to stainless steel, and aluminum to cast iron, respectively. In all case, no clearance or crack was observed, and they were joined well.



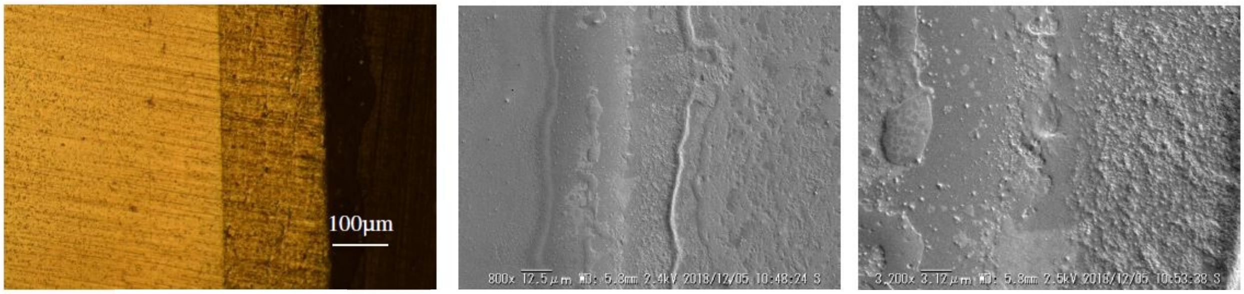
(a) Optical. (b) Low magnification SEM. (c) High magnification SEM.

Fig.2 Optical and SEM micrographs of bonding interface in the case of Cu and Cu.



(a) Optical. (b) Low magnification SEM. (c) High magnification SEM.

Fig.3 Optical and SEM micrographs of bonding interface in the case of Cu and Al.



(a) Optical. (b) Low magnification SEM. (c) High magnification SEM.

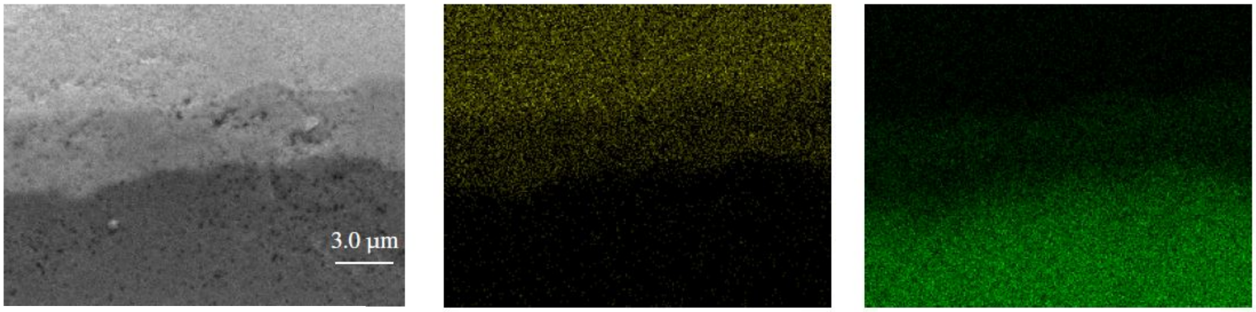
Fig.4 Optical and SEM micrographs of bonding interface in the case of Al and SUS304.

(a) Optical. (b) Low magnification SEM. (c) High magnification SEM.

Fig.5 Optical and SEM micrographs of bonding interface in the case of Al and cast iron.

Discussions

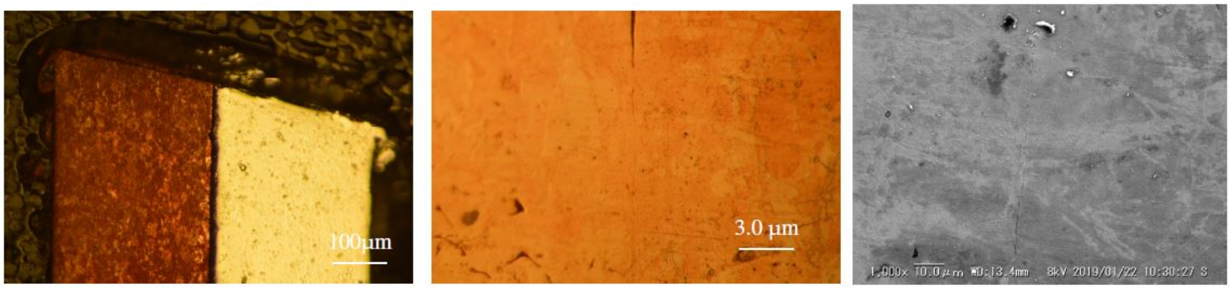
As the area between copper and aluminum in Fig.3(a) has different quality from two materials, intermetallic compounds may be formed by collision. Energy dispersive X-ray spectrometry (EDS) and X-ray diffraction analyzed (XRD) were operated. The central horizontal part with intermediate color in Fig.6(a) is the analysis target. Figures 6(b) and (C) indicate the molecular distribution map of copper and aluminum. The distribution of copper overlaps that of aluminum. Though the analysis of the crystal structure near the bonding interface was carried out by XRD, no peak for intermetallic compounds was observed.



(a) SEM of Al and Cu. (b) Distribution of Al. (c) Distribution of Cu.

Fig.6 Molecular distributions of boundary layer of Cu and Al observed with EDS.

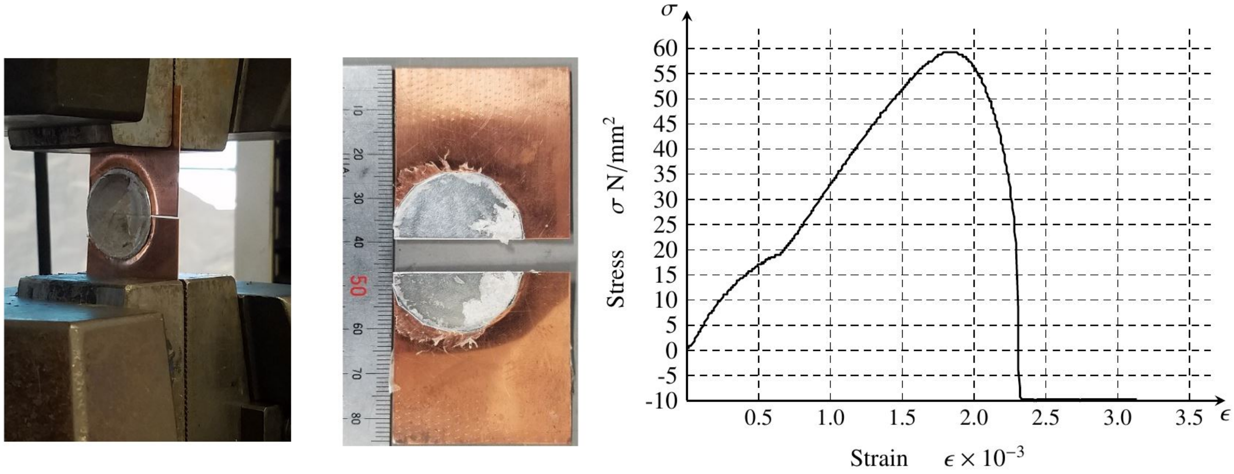
In order to observe the bonding interface in detail, the surface was corroded. A photomicrograph of the corroded interface between copper and aluminum is shown in Fig.7(a). Figures 7(b) and (c) are in the case of copper and copper. In each case, as the procedure of corrosion was not appropriate, the structure could not be clearly observed.



(a) Corrosion of Cu and Al. (b) Optical of corroded Cu. (c) SEM of corroded Cu.

Fig.7 Optical microscope and scanning electron microscope observation after corrosion.

A tensile test was carried out to check the bonding strength. Since a bonding material that can pull the bonding surface vertically cannot be manufactured, two plates with same size and material are aligned and another metal plate is bonded to the center of that. Figure 8(a) shows the test piece mounted on the tensile test instrument and (b) is the test piece after fractured. The stress σ is nominal stress that is obtained by dividing the maximum tensile load F at fracture point by the original cross-sectional area A, that is $\sigma = F/A = 59$ MPa. The result is slightly smaller than the tensile strength of aluminum 78 MPa. A slight gap between the two plates may cause a step on the flyer plate, which may affect the test results, and the bonding strength seems to be sufficient because it did not separate at the bonding interface as shown in Fig.8(b). Figure 8(c) is a curve plotted with nominal stress-nominal strain.



(a) Test piece mounted on the instrument. (b) Fractured test piece. (c) Stress-strain curve.

Fig.8 Tensile test.

Summary

In this study, we tried to join dissimilar metals using low-pressure difference.

- As in the observation at bonding interface by microscope, no clearance or crack was existed, bonding were success.

- Though in the observation by microscope, there was a different part in texture from original material, no peak for intermetallic compounds was observed in the analysis by XRD.
- The bonding strength is sufficient because it did not separate at the bonding interface in the tensile test.

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