

Magnetic Pulse Welding of Sheet Metals using Flat Three-Turn Coil

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Introduction

Magnetic pulse welding (MPW) is an impact welding process analogous to explosive welding. In MPW process a high speed collision of metal work-pieces creates a weld using electromagnetic forces. For a long time, MPW method has been used for welding tubular work-pieces [1-4]. Recently, this method is newly applied to flat work-pieces [5-11]. The mechanism and features of MPW are considerably well known.

In the case of flat work-pieces, the most common configurations consist of a lap joint of similar or dissimilar sheet metals. A very high current is discharged through a one-turn coil to produce intense electromagnetic forces. For example, an E-shaped flat one-turn coil is used [5-7]. It was necessary to apply discharge current of maximum 150-200kA to this coil for the welding [6]. About the improvement of the very high current, MPW of sheet metals has not been studied enough.

This paper describes a MPW technique of sheet metals using an E-shaped flat three-turn coil. In this case the maximum discharge current required for the welding was 50-60kA. The MPW technique using such a flat multi-turn coil was hardly reported until now.

Experimental procedures

Figure 1 is a sketch of the flat three-turn coil for MPW. The coil is comprised of three E-shaped insulated metal plates. The discharge current flows into the narrow central part of the upper plate upward and flows out from the two wide outside parts downward. The current which joined at the lower parts of the upper plate flows again into the central part of the middle plate. This current does three turns and comes back. Each central part of the plates is just piled up with the same width. A high-density magnetic flux (B) is generated around the central part of the coil. This coil can generate the magnetic flux of the same value by the current of about 1/3 in comparison with the one-turn coil.

The sheet metals (Al/Cu) for the welding are fixed on the three-turn coil like Fig. 2. The magnetic flux (B) is suddenly generated under the Al sheet and penetrates into the sheet. Eddy currents pass through the Al sheet to hinder its further penetration. As a result, strong electromagnetic forces f act on the Al sheet (Fig. 2) and it collides rapidly with the Cu sheet. The Al/Cu sheets are welded along the central part with the discharge current of about 1/3 in comparison with our conventional method.

Experimental apparatus and materials

The discharge system consisted of the capacitor bank, a discharge switch, the flat three-turn coil and others. The capacitor bank (capacitance $C=24\mu\text{F}$) consisted of four capacitors of $6\mu\text{F}$ in parallel. Generally, the capacitance for three-turn coil should be smaller than the case of the one-turn coil. The

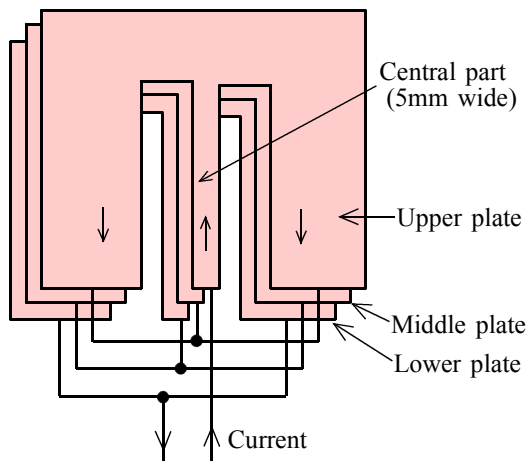


Fig.1 Sketch of flat three-turn coil.

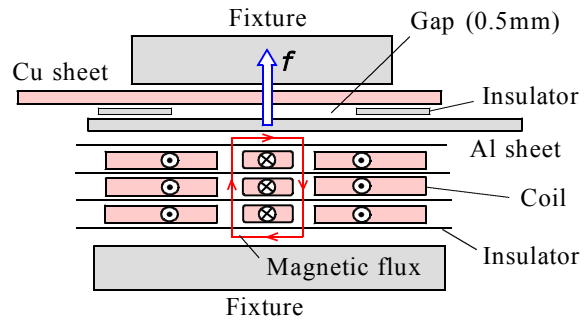


Fig.2 Fixation of coil and sheet metals, and electromagnetic force f which acts on Al sheet.

charged energy of the bank was 0.5-0.7kJ. The coil was mainly made by three E-shaped plates (1 mm thick) of Cu-Cr alloy. The narrow central part of each plate was 5mm wide and 100mm long. The cross sectional corners of the central part were rounded like Fig. 2 to protect thin insulators (0.1mm thick). Figure 3 shows the appearance of the coil consisting of the three plates which made gaps for photography. The inductance of the coil was about 0.34 μ H. A typical size of the sheets was 100mm long, 100mm wide and 0.3-0.4mm thick. Two sheets (Al/Cu) were overlapped 50mm in length with the gap of 0.5mm and fixed on the coil covering the thin insulator (Fig. 2). The discharge current signal and a collision time signal were measured by the same way as our previous paper [6].

Experimental results

Typical discharge current and collision time signals are shown in Fig. 4. The damping and oscillating current flows through the coil for duration of about 50 μ s. The maximum discharge current was about 50kA at the charged energy of 0.6kJ. The sheets collided in around the time for the maximum current and after 3.8 μ s from the start of the current. The collision speed when the sheets collided was calculated to be approximately 260m/s.

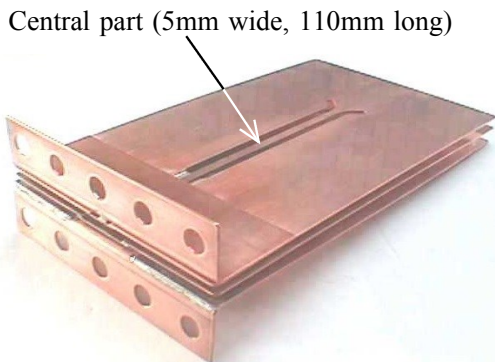


Fig.3 Appearance of flat three-turn coil.

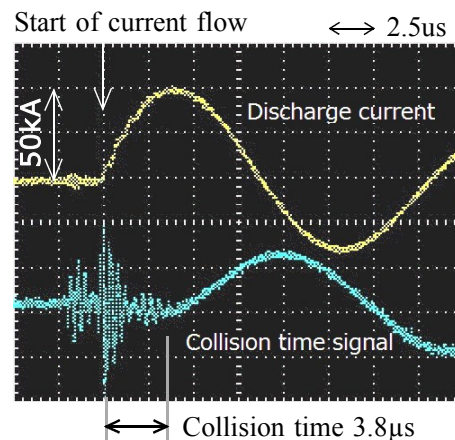


Fig.4 Current and collision time signals.

Figure 5 shows a typical appearance of seam welded sheets taken from the Al sheet side. A part of the Al sheet deformed toward the Cu sheet along the central part. The weld zones were in the deformed region which was 100mm in length to the longitudinal (or seam) direction and about 10mm in width direction.

Figure 6 shows a cross sectional appearance of weld interface at the deformed region. Two weld zones marked by arrows (↓) and a middle clearance (non-weld zone) were seen in Fig. 6. This result was similar when welded with the E-shaped flat one-turn coil [5]. Figure 7 is a typical optical micrograph of the interface at the one weld zone and Fig.8 a SEM micrograph in the same way. Wavy pattern morphology was seen in the weld interfaces as shown in Fig. 7 and 8. This morphology was also seen in the case of the one-turn coil [5].

Summary

This paper described the MPW technique of sheet metals using the E-shaped flat three-turn coil. The maximum discharge current required for this welding was 50-60kA. The welding results with this coil were similar with the case of the one turn-coil. The welded Al/Cu interface indicated wave interface morphology like the explosive welding.

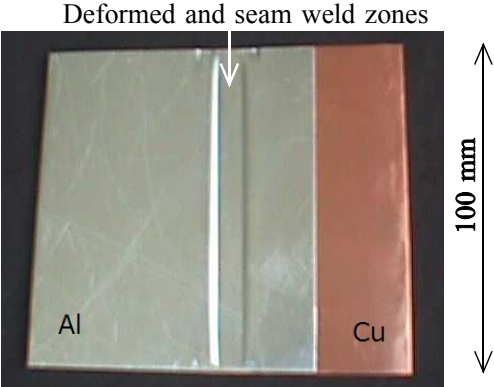


Fig.5 Appearance of welded Al/Cu sheets.

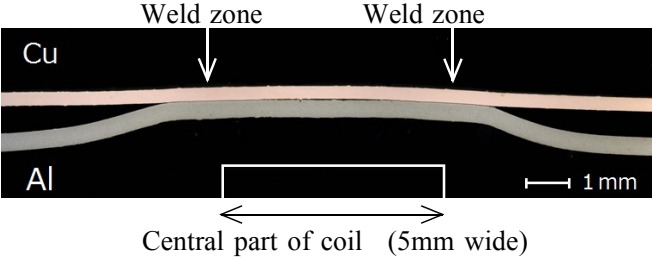


Fig.6 Cross section of welded Al/Cu sheets.



Fig.7 Optical micrograph of weld interface at one weld zone.

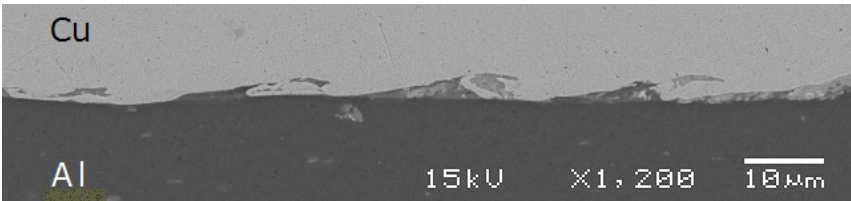


Fig.8 SEM micrograph of weld interface at one weld zone.

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