Application of Magnetic Pulse Welding for Dissimilar Aluminum-Copper Joints

D. Priem and S.K. Marya, Laboratoire Mécanique et Matériaux, Ecole Central Nantes
M. Marya, Colorado School of Mines

INTRODUCTION

Magnetic pulse welding (MPW) is a solid-state joining process, which is characterized by high collision velocities between the workpieces, thus short joining times. Also the absence of fusion makes this process most advantageous when welding dissimilar alloys together.

This paper describes magnetic pulse weld formation in the dissimilar joining of aluminum and copper. Particular attention is given to the metallurgical aspect of the MPW process.

TECHNICAL PROCEDURE

The welds were produced from aluminum tubes and commercially pure copper cones. The parts (with the aluminum around the copper) were placed inside a rigid solenoid. When a high alternating current was applied, the magnetic field around each coil created an Eddy current in the outer tubular aluminum part, which generated an opposing magnetic field. Repulsion between the two magnetic fields caused implosion of the aluminum tube toward the inner copper cone.

The inherently short process duration necessitates a LC circuit capable with two conflicting characteristics: a high capacitance for the high-energy release, and a low inductance for a fast bonding. Experiments were made using a 12 kJ magneto-forming machine which imposes severe restrictions. Discharged voltage was released by six 60-□F capacitors and only peaked at 7.9 kV. To improve weld formation, not only thickness of the aluminum alloy tube was 2 millimeters, but also the 6060 alloy was annealed to reduce its strength.

After welding, the test specimens were prepared for examination by optical microscopy, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), X-ray diffraction (XRD), and they were indented for micro-hardness.

RESULTS AND DISCUSSION

The MP welds were all characterized by wavy interfaces with amplitudes as high as 20 micrometers. In many welds, the interface exhibited a shiny transition region (Fig.1). Although frequently encountered between waves, this clearly distinct region was most apparent in proximity to the end part of the weld interface.

When analyzing the weld interfaces, XRD measurements were inconclusive because they did not identify the chemical and crystallographic nature of this region. Hardness indentations, however, indicated that this transition region was harder than the two parent materials and harder than any interfaces where the transition region was not observed. Because brittle intermetallic phases and well-localized strain hardening could explain these results, EDS analyses were conducted. Results by EDS showed that the transition region included elements from both materials. Chemical compositions were closely similar to that of the intermetallic compounds seen on the Al-Cu phase diagram (Fig 2).

Due to the short bonding time and the finite rates of solid-state phase transformations, a strong possibility exists that a thin layer on the low-melting point material fused and alloyed with the more refractory copper. Because melting and rapid solidification explain the formation of intermetallic phases well, existing analytical models will also be reviewed and used to estimate the temperature rise due to Eddy current heating and impact energy heating when the bond was established.

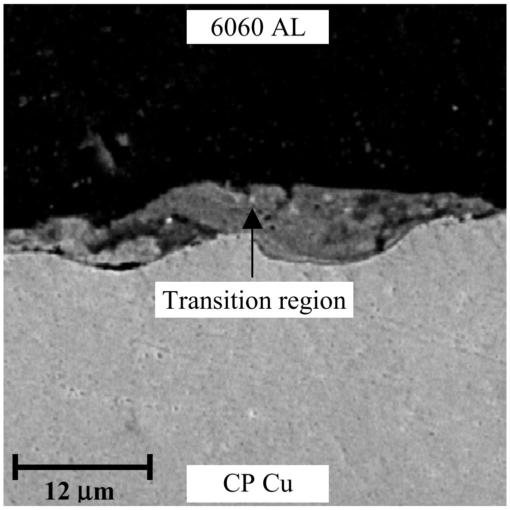

Fig 1 - Secondary electron image for the interface between aluminum and copper.

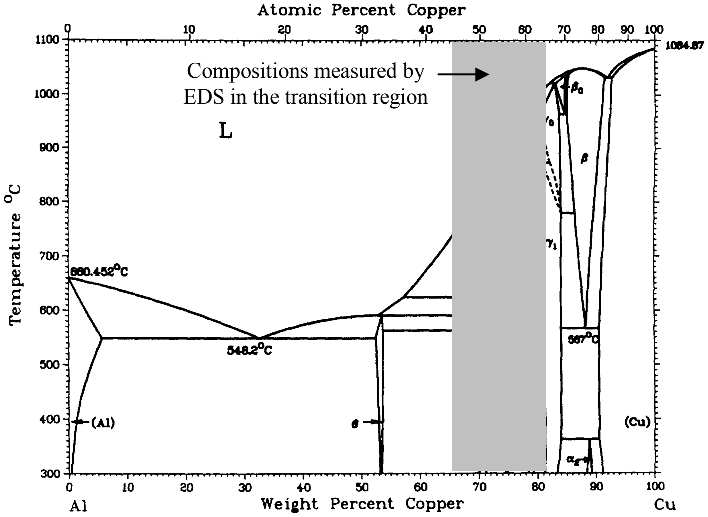

Fig 2 – Aluminum-copper phase diagram.

CONCLUSIONS

During the MPW of aluminum and copper enough heat can be generated at the interface to promote sufficient mass transport for the precipitation of intermetallic phases. However, the relative amounts of these phases (still not clearly put into evidence) remained small compared to fusion welding processes because the observed transition region was narrow and discontinuous.