

**Mitsuhiro Watanabe, Assistant Professor,
Department of Organic and Polymeric Materials**

1. Main Research Results

1) Simulation and experimental analysis of metal jet emission in impact welding

Metal jet emission in impact welding was investigated for similar- and dissimilar-metal lap joints. Numerical simulation of oblique collision between metal plates was performed using smoothed particle hydrodynamics (SPH) method for various plate thicknesses, collision velocities, and collision angles. Metal jet emission and formation of the characteristic wavy welding interface in impact welding were reproduced successfully. The composition of the metal jet was governed by the degree of relative density difference between two metals. When the density difference was large, such as Al/Cu and Al/Ni lap joints, the metal jet was mainly composed of the metal component with lower density, Al. On the other hand, when the density difference was small or zero, such as Cu/Ni and Al/Al lap joints, the metal jet was composed of both metal components. Several types of lap joints were fabricated by magnetic pulse welding. Metal jets emitted from Al/Cu and Cu/Al lap joints were collected, and their components were analyzed by X-ray diffraction. The microstructure of the welding interface was also examined. The experimental results were in good agreement with the simulation results.

2) Growth manner of intermetallic compound layer produced at friction stir spot welded aluminum/steel interface

Lap joining of a pure aluminum plate and a low carbon steel plate was performed using friction stir spot welding. The aluminum plate was placed over the steel plate, a rotating welding tool was inserted into the aluminum plate, and the tip of the tool was dwelled above the aluminum/steel interface. Dwell time was controlled in the range of 0 to 120 seconds. The microstructure of the welding interface was examined by optical microscopy and scanning electron microscopy. Chemical composition analysis was carried out by energy dispersive X-ray spectroscopy. Welding was achieved for all dwell times. Refined grains were formed by plastic flow in the aluminum matrix close to the welding interface. Intermetallic compound layer was produced along the welding interface. Precise backscattered electron image observation and energy dispersive X-ray spectroscopy analysis revealed that the intermetallic compound layer consisted of an $\text{Al}_{13}\text{Fe}_4$ phase layer and an Al_5Fe_2 phase layer. The thickness of the layers increased in proportion to the square root of the dwell time. The parabolic coefficient K was 1.30×10^{-14} and $6.06 \times 10^{-13} \text{ m}^2/\text{s}$ for the $\text{Al}_{13}\text{Fe}_4$ layer and the Al_5Fe_2 layer, respectively.

2. List of Publications

Original Papers

- 1) Mitsuhiro Watanabe, Hiroshi Matsumoto, Keyan Feng, Yoshio Nakamura and Shinji Kumai: "Effect of tool shape on interfacial microstructure of friction stir spot welded aluminum/steel lap joint", *Proceedings of the 8th International Symposium of Friction Stir Welding*, CD-ROM, (2010).

- 2) Mitsuhiro Watanabe and Shinji Kumai: "Welding interface in magnetic pulse welded joints", *Materials Science Forum*, 654-656, 755-758, (2010).
- 3) Shinji Kumai, Mitsuhiro Watanabe and Keyan Feng: "Microstructure and joint strength of similar- and dissimilar lap joints fabricated by several advanced solid-state welding methods", *Materials Science Forum*, 654-656, 596-601, (2010).
- 4) Keyan Feng, Mitsuhiro Watanabe and Shinji Kumai: "Joint interface morphology of friction stir spot welded aluminum alloy sheets and plated steel sheets", *Materials Science Forum*, 654-656, 970-973, (2010).
- 5) Mitsuhiro Watanabe, Keyan Feng, Yoshio Nakamura and Shinji Kumai: "Growth Manner of Intermetallic Compound Layer Produced at Friction Stir Spot Welded Al/Steel Lap Joint", *Proceedings of the 12th International Conference of Aluminum Alloys (ICAA12)*, 984-987, (2010).
- 6) Shinji Kumai, Keisuke Hayashida and Mitsuhiro Watanabe: "High-speed Solid-state Welding of 2xxx Aluminum Alloy Studs to 5xxx Aluminum Alloy Plates", *Proceedings of the 12th International Conference of Aluminum Alloys (ICAA12)*, 940-944, (2010).
- 7) Shougo Kakizaki, Mitsuhiro Watanabe and Shinji Kumai: "Metal Jet Emission and Wavy Interface Formation in High-speed Impact Welding", *Proceedings of the 12th International Conference of Aluminum Alloys (ICAA12)*, 945-949, (2010).
- 8) Feng Keyan, Mitsuhiro Watanabe and Shinji Kumai: "Microstructure and Joint Strength of Friction Stir Spot Welded Aluminum Alloy Sheet and Plated Steel Sheets", *Proceedings of the 12th International Conference of Aluminum Alloys (ICAA12)*, 1806-1810, (2010).

3. Conferences

International

- 1) Shinji Kumai, Mitsuhiro Watanabe and Keyan Feng: "Microstructure and joint strength of similar- and dissimilar lap joints fabricated by several advanced solid-state welding methods", The 7th Pacific Rim International Conference on Advanced Materials and Processing (PRICM7), Cairns, Australia, August 3, 2010. (Keynote lecture)
- 2) Mitsuhiro Watanabe, Hiroshi Matsumoto, Keyan Feng, Yoshio Nakamura and Shinji Kumai: "Effect of tool shape on interfacial microstructure of friction stir spot welded aluminum/steel lap joint", The 8th International Symposium of Friction Stir Welding, Timmendorfer Strand, Germany, May 20, 2010. (Oral presentation)
- 3) Mitsuhiro Watanabe and Shinji Kumai: "Welding interface in magnetic pulse welded joints", The 7th Pacific Rim International Conference on Advanced Materials and Processing (PRICM7), Cairns, Australia, August 3, 2010. (Oral presentation)
- 4) Keyan Feng, Mitsuhiro Watanabe and Shinji Kumai: "Joint interface morphology of friction stir spot welded aluminum alloy sheets and plated steel sheets", The 7th Pacific Rim International Conference on Advanced Materials and Processing (PRICM7), Cairns, Australia, August 3, 2010. (Oral presentation)
- 5) Mitsuhiro Watanabe, Keyan Feng, Yoshio Nakamura and Shinji Kumai: "Growth Manner of Intermetallic Compound Layer Produced at Friction Stir Spot Welded Al/Steel Lap Joint", The 12th International Conference on Aluminium Alloys (ICAA12), Yokohama, Japan, September 8, 2010. (Oral presentation)

- 6) Shinji Kumai, Keisuke Hayashida and Mitsuhiro Watanabe: “High-speed Solid-state Welding of 2xxx Aluminum Alloy Studs to 5xxx Aluminum Alloy Plates”, The 12th International Conference on Aluminium Alloys (ICAA12), Yokohama, Japan, September 8, 2010. (Oral presentation)
- 7) Shougo Kakizaki, Mitsuhiro Watanabe and Shinji Kumai: “Metal Jet Emission and Wavy Interface Formation in High-speed Impact Welding”, The 12th International Conference on Aluminium Alloys (ICAA12), Yokohama, Japan, September 8, 2010. (Oral presentation)
- 8) Keyan Feng, Mitsuhiro Watanabe and Shinji Kumai: “Microstructure and Joint Strength of Friction Stir Spot Welded Aluminum Alloy Sheet and Plated Steel Sheets”, The 12th International Conference on Aluminium Alloys (ICAA12), Yokohama, Japan, September 7, 2010. (Poster presentation)
- 9) Keyan Feng, Mitsuhiro Watanabe and Shinji Kumai: “Joining of aluminum alloy sheet to plated steel sheet by friction stir spot welding”, 2010 Asia Forum on Light Metals, Guilin, China, October 27, 2010. (Poster presentation)

Domestic Conferences

- 1) Shinji Kumai, Keisuke Hayashida, Mitsuhiro Watanabe: “Relationship between fracture manner and joint interface morphology of stud-welded aluminum alloy joint”, The 118th Spring Meeting of The Japan Institute of Light Metals, Osaka, Japan, 2010. 5. (Oral presentation)
- 2) Shougo Kakizaki, Mitsuhiro Watanabe, Shinji Kumai: “Metal jet emission in high-speed impact welding of Al similar- and dissimilar-plates”, The 118th Spring Meeting of The Japan Institute of Light Metals, Osaka, Japan, 2010. 5. (Oral presentation)
- 3) Tomokatsu Aizawa, Keigo Okagawa, Shinji Kumai, Mitsuhiro Watanabe: “Magnetic Pulse Welding Interface of Various Sheet Metals”, The 41th Japanese Spring Conference for the Technology of Plasticity, Tokyo, Japan, 2010. 5. (Oral presentation)
- 4) Keyan Feng, Mitsuhiro Watanabe, Shinji Kumai: “Effects of welding time on microstructure and strength of friction stir spot welded aluminum alloy sheets and plated steel sheets”, The 119th Fall Meeting of The Japan Institute of Light Metals, Niigata, Japan, 2010. 11. (Oral presentation)