RESEARCH ARTICLE

Modelling and Controlling Interfacial Reaction in Dissimilar Metal Welding

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Multi-material structures are required to best exploit light metals, allowing different alloys with optimized properties to be used for different components. Such structures require joining, and solid-state welding methods such as friction stir welding and ultrasonic welding are attractive candidate processes. Experimental studies carried out within LATEST2 Theme 1 have investigated the feasibility of using these methods to perform dissimilar metal joining between a range of aluminium, magnesium and titanium alloys as well as joining of these metals to steels.

The experimental work has revealed that the key to improving the mechanical properties (and in particular the toughness) of dissimilar metal joints is controlling the formation of brittle intermetallic phases that are produced by the reaction between the dissimilar metals at the interface. It has been revealed that the thickness of the reaction layer on process conditions, but also depends on the base alloy composition. This suggests there is potential not only to optimize process conditions to control reaction, but also to design alloys specifically tailored for dissimilar metal joining.

To understand the effect of processing and alloy chemistry on intermetallic formation during dissimilar metal welding and to enable rapid assessment of potential solutions to control interface reaction, an integrated modelling approach is being developed. This work is a collaboration between Cambridge University Engineering Department, who are providing expertise on modelling of solid state welding processes, and LATEST2 who are developing the interface reaction and property models.

The process model takes the weld geometry and process conditions as inputs and outputs information such as the thermal and strain rate history for any region of the weld. These outputs are used as inputs to the interface reaction model, which itself consists of several components to model all of the physical processes that occur during welding. Figure 1 shows the steps considered in the model for ultrasonic welding; together these control the final thickness of the intermetallic layer. The necessary material data for such models are derived from multicomponent calculations (using Pandat and JMatPro software) to account for the complex chemistries encountered in real industrial alloys.

Figure 2 shows example outputs from the model for ultrasonic welding applied to the dissimilar joining of an aluminium and magnesium alloy. The model predict each step in the process, and gives a final prediction of intermetallic layer thickness that agrees well with that determined experimentally.

Ongoing work is developing similar models for friction stir welding, and applying such models to design alloy compositions or interlayers to retard interfacial reaction and hence produce a step change improvement in dissimilar weld properties.

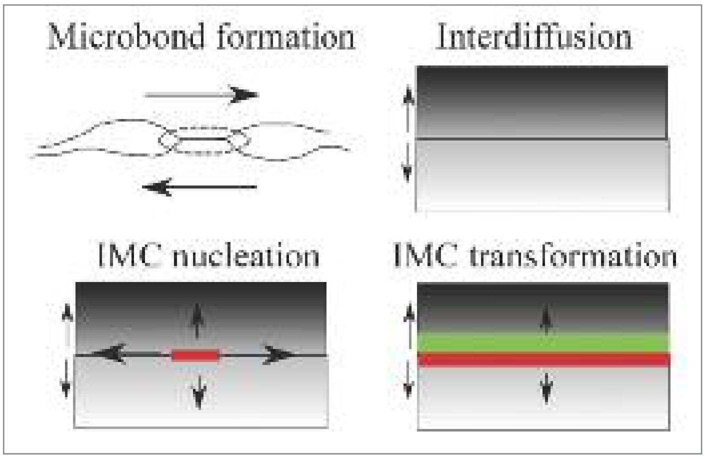

Fig. 1 Sequence of events that occur during intermetallic compound (IMC) formation during dissimilar metal ultrasonic

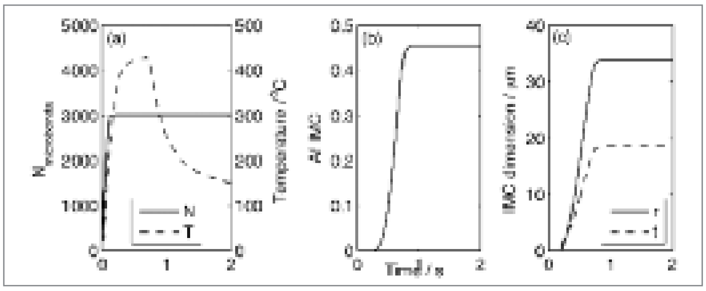

Fig. 2 Example model outputs for a 1s weld. (a) Temperature evolution and number of microbonds. (b) Area fraction of interface covered by intermetallic. (c) Size and thickness of intermetallic regions.

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