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Simulation of Ultrasonic welding of fibre elements in metal matrices

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Abstract

Metal-matrix structures are used in applications where structure is required to withstand the hostile environments and meet safety regulations. In most of the metal-matrix composites processing, high temperature and pressure is used which results in damage to the fibres. Ultrasonic consolidation is a novel rapid manufacturing technique which occurs at relatively low temperature and it is capable of inducing high plastic flow in the matrix material. Both of these characteristics can be used in embedding sensitive fibres or sensors inside the metal structure without the risk of damage. The success of the process of embedding of the fibres in metal matrix using the ultrasounic power is dependent on the strength of the bonds between the foils and the full coverage of the fibre through sufficient plastic flow of the metal matrix which leaves no cavity between the fibre and surrounding metal.

In this work a computational approach using finite element methods has been proposed to successfully simulate the embedding process. The main elements of the approach include an appropriate constitutive material model which realistically represents the effect of superimposed high frequency ultrasonic vibration, applied load and temperature. Also, the contact and friction at the interfaces of the sonotrode, foils and fibre are important in transferring the applied load and imposed vibration throughout the specimen; therefore it is crucial to implement a suitable friction model which is able to indicate the friction behaviour at the interfaces of sonotrode, foil and fibre. By incorporating the derived material model and developed friction model thermomechanical analyses of embedding of fibre in metal structure has been

performed. The research here has especially focused on the quality of the developed weld which could be evaluated by the friction work and the coverage of the fibre which is estimated by the plastic flow around the fibre.

Comparison between the computed friction work from thermomechanical analyses performed in this study has been made with experimental peeling load. It is found that there is very small increase in friction work with increasing load. Similar trend of peeling load have been found during experiments.

Deformation profile of the fibre embedded aluminium alloy shows that the highest plastic deformation occurs near the foil/sonotrode interface, similar trend of deformation are found during experiments. The currently developed model indicates the full closure of voids around the fibre which is confirmed by the experimental observations.