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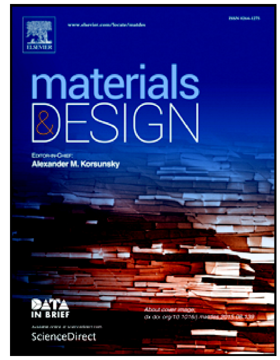

Finite element analysis of heat generation in dissimilar alloy ultrasonic welding

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Finite element analysis of heat generation in dissimilar alloy ultrasonic welding

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Abstract
This paper presents a computationally efficient finite element analysis of the heat generation in ultrasonic welding (USW). The temperature field is predicted from a continuous thermal model, with the heat generation rate being calculated intermittently, using a deformation model for single cycles of oscillation. The model was applied to USW of Al 6111 to itself, and to DC04 steel and Ti6Al4V, with plastic deformation only occurring in the Al alloy. Ultrasonic softening was allowed for empirically in the constitutive plastic response of the Al alloy. The predicted heat generation rate for all three material combinations was consistent with that inferred from thermocouple data and the thermal model. Material deformation maps were developed as a means of illustrating the dominant deformation regime of temperature and strain-rate. The thermal and deformation models were then fully coupled, as a proof of concept, to demonstrate that the power and temperature histories can be predicted directly from the constitutive data for the alloy and a kinematic description of the process.

Keywords
Ultrasonic welding; aluminium alloys; titanium alloys; carbon steels; process modelling; finite element analysis.

Declarations of interest: none

1. Introduction

Ultrasonic welding (USW) in metals is a solid-state joining process for making lap welds, in which high-frequency vibrations are applied parallel to the weld interface under a static clamping pressure. As a solid state joining method, USW avoids many of the undesirable phenomena observed in fusion welding of metals, such as solidification cracking, grain boundary liquation cracking, porosity and micro-segregation, while enabling the control of the formation of brittle intermetallic phases in dissimilar metal welding [1-4]. The process has become applicable to sheet metal up to a few mm thick, thanks to the availability of higher power welding systems. These are capable of joining many alloys, including dissimilar combinations provided: (i) at least one of the alloys is sufficiently soft; (ii) detrimental interface reactions can be avoided. Its range of application has therefore extended beyond electronics to automotive alloys, as part of the development of lighter vehicles. In this context, USW can compete with alternative fusion-based processes, such as resistance spot welding (RSW), as it is comparably fast (potentially less than 0.5s).

A number of authors have studied metallic USW experimentally, measuring weld temperatures and the influence of welding parameters, such as tool design and weld time, on the resulting microstructures and joint properties. The welds modelled in this paper were produced in a collaborative research project with Manchester University Materials Science Centre. The key results from this work are summarised first, as they provide the experimental basis for the model. Other relevant experimental work is then discussed below, alongside the review of modelling of USW.