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Modeling of resistance spot welding of multiple stacks of steel sheets

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ABSTRACT

Weld quality is a major challenge for resistance spot welding of multiple stacks of steel sheets. Because of the differences in mechanical and physical properties of steel sheets and the sheet gage variation, the contact state between sheets and welding current flow throughout the stack joint is complicated. As a result, discrepant weld sizes at the faying interfaces become an issue. In this study, a coupled thermal–mechanical/thermal–electrical incremental model has been developed to reasonably predict the weld nugget formation process of resistance spot welding of a sheet stack made of 0.6 mm thick galvanized SAE1004+1.8 mm thick galvanized SAE1004+1.4 mm thick galvanized dual-phase (DP600) steel using published thermal, electrical, and mechanical properties. It was found that the weld nugget on the faying interface of DP600 forms earlier than that on the other interface, which agrees well with the experimental results. Based on the coupled model, the effects of the sheet gage combination and steel grade combination were examined. The results show that, for a multiple stacks of steel sheets SAE1004 + SAE1004 + DP600, the critical ratio of sheet thickness between the top and bottom sheets is approximately 1:3. The model could provide an important guidance in the selection of the welding variables, sheet gage and steel grade to meet the weld quality of steel component.

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1. Introduction

With the demand of lightweight vehicle structures, resistance spot welding (RSW) of multiple stacks of similar and dissimilar work pieces is increasingly applied in some complex structures such as front longitudinal rails, A-, B-, and C-pillars, and the bulkhead to inner wing. However, due to the complexity of the multiple stacks of the structures with various sheet gages and grades, the weld nugget quality has become a major concern. Under a given welding schedule, weld nuggets are not always properly formed at the faying interfaces in the RSW process. Consequently, additional welds are often added to the body structures and repair procedures are required in the assembly lines. These result in excessive energy consumption and manufacturing time and cost.

The RSW process includes coupled interactions of electrical, thermal, mechanical and metallurgical phenomena. Because of this complexity, it is difficult to obtain insightful information on the welding process through experiments alone. Fortunately, numerical modeling provides an alternative way to study these interactions [1–4]. Recently, a lot of research works have been carried out on the numerical simulation of RSW [5–15]. Nied [5] has developed a simplified finite element model to investigate the effect of the electrode geometry on the deformation and stresses as a function of temperature. Furthermore, sophisticated FEM models which considered temperature dependent material properties, contact status, phase transformation, and coupled field effects into the simulation of RSW have also been reported in the literature [6–10]. Most recently the iterative method was employed to model the interaction between the coupled electrical, thermal, and mechanical fields [11–15]. Although many studies have been reported, the information on the RSW of multiple stacks of steel sheets is still lacking.

In this study, we focus our attention on developing a model for RSW of multiple stacks of steel sheets. A typical automotive multiple stacks of steel sheets is presented in Fig. 1 as the modeling object. The experimental procedures including sample fabrication and weld nugget and penetration measurements are followed by the modeling results. Specifically, the predicted weld nugget sizes were compared with the metallographic test results to verify the accuracy of the model. Then, the model was employed to assess the effects of sheet thickness and steel grade combinations on the weld nugget size and penetration in multiple stacks of steel sheets.

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