MULTIPHYSICS MODELING OF RESISTANCE SPOT WELDING PROCESS AND JOINT STRENGTH

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ABSTRACT

Advanced high-strength steels (AHSS) have been widely used in automotive industries for light-weighting and crash resistance applications. Resistance spot welding (RSW) is one of the main joining technologies for assembling vehicle structural components. The rapid heating and cooling thermal cycle during RSW can significantly alter the base metal microstructure, resulting in formation of several sub-regions in the heat-affected zone (HAZ). Particularly, highly non-uniform temperature gradient experienced by the sheet metal leads to the formation of coarse-grained heat affected zone (CGHAZ) and subcritical heat affected zone (SCHAZ), two regions prone to “premature” failure.

A multiphysics modelling framework is developed to describe the RSW process and the resulting joint strength for AHSS. In particular, the RSW process modelling is based on the numerical solution of coupled thermal-electrical-stress equations. It takes into account Joules heating (both bulk and interfacial) and mechanical contact between steel sheets themselves and that between steel sheet and electrode. Contact resistance at those interfaces is defined as a function of contact pressure and material yield strength at temperature. The computed thermal cycle is inputted into a metallurgical model to predict the location and size of the various sub-regions in the HAZ. Finally, the

microstructure information is subsequently mapped into a stress model to predict the joint strength in a conventional lap-shear testing and a specially-designed wedge testing configuration. This stress model considers the microstructure-specific mechanical properties measured experimentally.

The modelling framework is applied to RSW of Usibor® 1500, a hot-stamped boron steel. Spot welds are fabricated in a 2T stack-up of the steel with a gauge thickness of 1.5 mm. The predicted hardness distribution in the HAZ is compared to that measured on the actual spot weld. In the wedge testing, a half weld sample is used, allowing the direct measurement of local plastic deformation and failure initiation on the exposed transverse section using the digital image correlation (DIC) method. The importance of considering microstructure-specific mechanical properties is discussed by comparing the calculated deformation results with those measured experimentally.