Mechanical Engineering Doctoral Defense

Improving electric vehicle and battery pack assembly through predictive modeling of resistance spot welding and distortion reduction in thin-gauge metal sheets

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Abstract

An approach for modeling resistance spot welding of thin-gauge, dissimilar metal sheets with high electrical conductivity is presented in this work. In this scenario, the electrical and thermal contact resistances play a dominant role in heat generation and temperature evolution within the workpieces; these interactions ultimately control the weld geometry. Existing models are limited in modeling these interactions, especially for dissimilar and thin--gauge metal sheets, and at higher temperatures when the multiphysics becomes increasingly interdependent. The approach presented here uses resistivity measurements, combined with thermal modeling and known bulk resistance relationships to infer the relationship between electrical contact resistance and temperature for each of the different material interfaces in the welding process. Corresponding thermal contact resistance models are developed using the Wiedemann-Franz law combined with a scaling factor to account for nonmetallic behavior. Experimental and simulation voltage histories and final weld diameter were used to validate this model for a Cu/Al/Cu and a Cu/Al/Cu/Al/Cu stack-ups. This model was then used to study the effect of Ni-P coating on resistance spot welding of Cu and Al sheets in terms of weld formation, mechanical deformation, and contact resistance. Contact resistance and current density distribution are highly dependent on contact pressure and temperature distribution at the Cu/Al interface in the presence of alumina. The Ni-P coating helps evolve a partially bonded donut-shaped weld into a fully bonded hourglass-shaped weld by decreasing the dependence of contact resistance and current density distribution on contact pressure and temperature distribution at the Cu/Al interface. This work also provides an approach to minimize distortion due to offset rolling in thin aluminum sheets by optimizing the stiffening feature geometry. The distortion is minimized using particle swarm optimization. The objective function is a function of distortion and smallest radius of curvature in the geometry. Doubling the minimum allowable radius of curvature nearly doubles the reduction in distortion from the stadium shape for a quarter model. Reduction in distortion in the quarter model extends to the full-scale model with the best design performing 5.3% and 27% better than the corresponding nominal design for a quarter and full-scale model, respectively.

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Zoom Link: https://asu.zoom.us/j/8648910870