Computationally efficient simulation methodology for railway repair welding: cyclic plasticity, phase transformations and multi-phase homogenization

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Abstract

The in-situ railway repair welding process consists of multiple weld passes, which makes it significantly different from other rail welding processes. In this study, finite element simulations of repair welding are performed to predict the resulting microstructure and residual stresses. To accurately simulate the material behaviour, the modelling includes phase transformation kinetics, cyclic hardening plasticity, transformation induced plasticity, and multi-phase homogenization. More specifically, four different homogenization methods are investigated: isostrain, isostress, self-consistent and linear mixture rule. The performance of the material modelling is demonstrated by simulating multiple weld passes using a classical three-bar welding experiment. Based on the results, the self-consistent method and linear mixture rule are used in a 3D full-scale railhead repair weld simulation, in which the former generates a more realistic mechanical response. The immense computational cost associated with 3D full-scale, full-detail multi-pass welding simulations is addressed by exploring different model reduction schemes. From this study, a 2D generalized plane strain model, extended with out-of-plane axial and bending stiffness, is found to replicate the full-scale model at a mere fraction of the computational cost. Finally, the longitudinal residual stress distribution obtained from the reduced model is shown to correlate well with experimental measurements.

Keywords: Railway repair, Weld simulation, Multi-phase steel, Phase transformation, Homogenization, Residual stress

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