An Integrated Computational Modeling of Deformation, Microstructure Evolution and Phase Transformation: Application to Multi-Pass Hot Rolling and Quenching

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Conventionally, numerical methods for predicting multi-pass hot rolling with quenching and self-tempering (QST) process in steel H-beam manufacturing has been conducted separately for its complexity in both shape and multidisciplinary modeling process. In the present work, a full integration of both parts is established using the finite element method (FEM) coupled with deformation microstructure, and phase transformation. The highly distorted FE meshes during large plastic deformation of hot rolling is resolved by the applied steady-state condition for each roll pass. Subsequently, the accumulated plastic deformation and temperature are transferred to the cellular automata (CA) model for the prediction of recrystallization phenomenon. The information of final microstructure distribution is utilized to estimate the prior austenite grain size, alongside the temperature distribution in the consecutive phase transformation kinetics model used for the QST process. The proposed fully integrated approach provides predictive results on recrystallized microstructure distribution, distribution of transformed phase fractions, hardness profiles, and flow stresses. The model correlated to the electron backscatter diffraction (EBSD), X-ray diffraction, and indentation results of a low carbon steel H-beam. The developed model is of significance in industrial application as it is extendable to predicting strength, residual stress, and shape distortion after the thermo-mechanical-metallurgical process in the stage of process optimization.

Keywords: Cellular Automata, Finite Element, H-Beam, Phase Transformation, Recrystallization

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