Validation of Thermomechanical and Microstructural Process Simulator (TMProSim)

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The PETRA project aims to optimize the carbon footprint of steel by developing a digital twin for the hot rolling process, enabling the prediction and optimization of material microstructural properties. The digital twin, named TMProSim (Thermomechanical and Microstructural Process Simulator), integrates coupled multi-stage models. The thermomechanical rolling model uses finite element methods to solve nonlinear coupled thermomechanical equations, while the microstructural model, RSProSim (Rolling Schedule Process Simulator), employs physically based models to simulate microstructural evolution in steels during thermomechanical treatment.

TMProSim predicts temperature, strain, and strain rate through the thickness of the steel during hot rolling. These parameters are fed into the microstructural module to calculate grain size and distribution for each rolling pass. The model was validated using austenitic stainless steel, due to easier microstructure evaluation. The steel was processed through ingots, reheated, cast into slabs, and hot rolled in a heavy plate rolling mill. Intensive simulations determined optimal rolling scenarios, setting the furnace temperature to 1250 °C, the slab thickness at beginning of finishing phase at 190 mm, and incorporating intermittent waiting between rolling passes to enhance recrystallization, leading to finer grain distribution.

Validation occurred in several stages, starting with thermomechanical condition simulations before rolling, followed by microstructure development simulations for the chosen rolling path. The results were compared with actual grain size analyses from the test-rolled plate, showing good agreement with TMProSim predictions. The model also simulated post-rolling heat treatment, with results closely matching test outcomes. Consequently, TMProSim is deemed ready for industrial application, as demonstrated by the successful testing on the rolled piece.

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