Efficient models for the off-line computer system for design of the hot rolling and laminar cooling technology for AHSS strips

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Design of manufacturing processes often involves time consuming computations, in particular when multi iteration optimization techniques are applied. Hot strip rolling is an example of such manufacturing process, in which particular operations (rolling, laminar cooling, coiling) are controlled by a number of the design variables. The objective of this work was development of the computer system, which will allow designing of the arbitrary rolling line and performing numerical simulations using high efficiency hardware architectures. Selection of the mechanical, thermal and phase transformation models, which will allow decreasing the computing costs while the accuracy of simulations is maintained on the reasonable level, was the particular objective of the paper. Thus, metamodel was applied in the mechanical part and a simple finite element (FE) approach was used in the thermal part of the hot rolling model. Modified Avrami model was used in simulation of phase transformations during the laminar cooling.

The system was designed in the client server architecture, in which client's part is in the form of the graphical interface. This interface allows to make the design of the rolling line. The server part is composed of three layers: controllers which prepare computing tasks, middleware layer responsible for launching and monitoring of the computing tasks and the layer of numerical computations. Deal.II library dedicated to solve partial differential equations was used for the time step adaptations. All these parts lead to very short computing times and additionally to queuing sensitivity analysis tasks and to parallel solution of the optimization tasks.

Material models describing flow stress, microstructure evolution and phase transformation were identified on the basis of experimental tests, and were implemented in the FE thermal code using multiscale modeling approach. These models are kept in the data base of the system. The system was tested for the industrial process of hot rolling and laminar cooling for DP steel strips. Simulations of the thermal-mechanical-microstructural phenomena were performed for various variants of the rolling-cooling sequence and the results were validated by comparison with laboratory physical simulations and with industrial trials.