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Numerical Modelling of the Thermo-Mechanical Material Response of Heavy Plates during Accelerated Cooling in the Steel Industry

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Heavy plates are essential construction components for the energy business and heavy machinery. The production process includes reheating of steel slabs, reversed rolling followed by accelerated cooling and levelling.

Accelerated cooling is a decisive process step since it enables the precise adjustment of mechanical material properties such as yield strength and fracture toughness. At the same time, by applying optimized cooling strategies, plates with minimized distortion are obtained at the end of the cooling step. Modelling accelerated cooling involves dealing with complex material phenomena which are a source of significant nonlinearities. Above all, the phase transformation from the austenitic parent phase to the bainitic product phase has to be taken into account [1]. It causes not only release of latent heat but also a significant change of the physical material properties [2]. Moreover, transformation induced plasticity occurs.

All models developed in this project are part of a comprehensive modelling approach which covers several important production steps including rolling and levelling. Therefore, all thermo-mechanical material data are continuously monitored. This concept proves to be beneficial for the simulation of accelerated cooling since the plastic predeformation generated during thermo-mechanical rolling has a detectable influence on the phase transformation kinetics during accelerated cooling.

Competitive models of the accelerated cooling step are expected to make sufficiently fast, nevertheless precise predictions about the thermo-mechanical material behaviour. On the global level developing fast strategies entails a reduction of the number of degrees of freedom (DOFs), however without sacrificing too much accuracy. Starting with a comprehensive 3D model build-up in the commercial FEM package ABAQUS [3] a fast autonomous FEM-algorithm is devised consisting of one single element with 3 DOFs only [4]. The fast algorithm enables the prediction of warpage as well as through thickness stress and strain distributions. On the integration point level the constitutive laws have to be implemented in a plane stress formulation. Finally the fast algorithm enables a reduction of the computation time by several orders of magnitude thus enabling parametric studies and a virtual process design.

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