Modelling Hot Levelling Processes by utilising Arbitrary Lagrangian Eulerian (ALE) concepts

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ABSTRACT

During production of heavy plate, hot levelling is representing the final process step and hence the last opportunity to influence geometrical tolerances and material characteristics. The ability of simulating the production process including the influence of process parameters on product properties, such as plate flatness and yield stress, enables the tracking, guiding and control of crucial product properties, which is highly advantageous and indispensable for modern production lines. The developed system of mathematical modelling components constitutes the basis for overcoming existing shortcomings by a new generation of off-line process models. Subsequent on-line automation systems shall incorporate the relations between process parameters and geometrical as well as mechanical-technological properties of the final products and allow for a dynamic adaptation of the process parameters throughout the production process.

Eliminating curvature and warping of flat products such as metal plate and metal sheet respectively, caused by preceding production steps is the main purpose of all levelling technologies like hot levelling as well as tension levelling and is achieved through back and forth bending of plates and sheets respectively around multiple levelling rolls. Beneficial side-effects of this treatment consist in minimising residual stresses and selective control of yield stress.

To identify and fully understand the underlying physical effects and correlations, the commercial FEM package *Abaqus/Explicit*™ was employed for modelling and analysing the hot levelling process. Automated generation of 2D plane strain models using *Python*® scripts proved convenient for effective operation of parametric studies that require a multitude of similar models. Comparing simulation results to process data as well as implementing a torque controlled single drive concept using *Abaqus* User Subroutines led to a realistic FEM model of the hot levelling machine. Gained referential data from an extensive parametric study form an initial point of a hierarchical modelling approach to derive a self-developed customized software prototype by model reduction techniques that overcomes the high computational costs of FEM simulation models due to the requirement of large numbers of degrees of freedom in combination with the highly non-linear characteristics of contact, material and geometry.

Customized 2D plane strain models of different granularity based on the principle of virtual work and a specialised steady-state “Arbitrary Lagrangian-Eulerian” (ALE) formalism in conjunction with “Parametric Shape Functions” (PSF) describing both curvature and strain distribution of the deformed plate are derived from a hierarchical modelling approach. These models yield all key results like the bending line, stress and strain distribution fields, reaction forces at the levelling rolls and power requirements of the drives. The input parameters include plate thickness, geometrical setup of the machinery, roll adjustments as well as elastic and inelastic material properties. The constitutive material law applied to the elastic-plastic, path-dependent streamline stress update takes into account work hardening as well as the (cyclic) kinematic hardening effect.

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