Analysis of Camber Formation, Suppression and Control in Hot Rolling of Wedge-Shaped Slabs by utilizing FEM and Analytical Concepts

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ABSTRACT

In hot rolling of steel the suppression and control of camber formation resulting from wedge-shaped slabs is of utmost interest. Reducing wedge without generating camber is still a big challenge for today's process automation systems for hot strip mills. Therefore, adequate numerical models of different hierarchical order and granularity are essential to understand the relevant technical and physical details of the underlying forming processes. This knowledge enables the accurate prediction, tracking, guidance and control of product properties in such production mills and is a vital precondition for the development of highly sophisticated control algorithms for manufacturing high quality products satisfying even the most challenging tolerance demands.

Detailed transient 3D-models of the underlying severely asymmetric flat hot rolling processes were developed by using the commercial FEM-package ©Abaqus Explicit. The strip material is described elasto-viscoplastically, whereas the roll stack, side-guides and edger-rolls are assumed to be rigid. By utilizing suitably positioned edging rolls, the corresponding lateral force acting on the strip induces a lateral material flow inside the roll gap, leading to stress-redistributions such that the outgoing camber-curvature is drastically reduced. Special emphasis was put on the accurate determination of the evolution of strip wedge and camber and the detection of well pronounced steady state scenarios. Systematic parameter studies performed so far revealed the dependence of the lateral edging force and the resulting strip camber-curvature on characteristic rolling parameters, such as slab aspect ratios (width over thickness), thickness reduction, initial wedge and material properties (e.g. yield stress and work hardening). Such sets of characteristic curves, which were validated against real process data from an industrial production mill, are an essential pre-requisite for subsequent online control strategies.

An automation scheme is outlined that enables significant wedge reduction without generating camber. Roll tilting in the roughing mill stand and a suitably positioned edger inducing lateral forces onto the strip or slab serve as actuators to control wedge and camber in the rolling process.

To understand the underlying highly non-linear elasto-viscoplastic forming processes inside the strip or slab in more detail, and to develop fast simulation-tools, semi-analytical model reduction approaches were developed. This enables a quantitative analysis of the induced lateral material flow and the occurring stress-redistributions inside the roll bite. By introducing a lateral material transfer parameter directly correlated to the camber-curvature, an analytical relation could be derived for the bending moment (and external work) that has to be applied to eliminate the camber of the strip or slab. These analytical predictions, although based on rough simplifications, correspond quite satisfactorily with those attained by 3D-FEM simulations.

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