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SIMULATION CONCEPTS FOR ROUGHNESS TRANSFER IN TEMPER AND SKIN-PASS ROLLING

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ABSTRACT

Temper rolling represents the final stage in the production chain of cold rolled flat steel products. During temper rolling, material and surface properties as well as flatness of cold rolled strip are tailored and customised. To generate the desired surface structure on uncoated or zinc-coated steel strip, textured work rolls are utilized. Based on the knowledge resulting from extensive temper rolling tests [1], FEM-simulations [2, 3] have been established as an important tool for the quantitative description of such rolling and stamping processes.

For the accurate and reliable simulation of temper rolling processes, special emphasis has to be put on typical characteristics, such as a small contact length between work roll and strip as well as pronounced elastic roll flattening resulting in a non-circular arc roll contour. The FEM-models presented recently in [4] and also in this context were developed by utilizing the commercial FEM-package Abaqus [5] and take into account both uncoated and zinc-coated elasto-plastic steel strip and elastic work rolls. Highly sophisticated submodelling techniques are applied, in order to reach reasonable calculation time and storage capacities for 3D models. Submodelling techniques divide the whole process simulation into two parts. The first calculation step is a coarse large scale analysis of the rolling process e.g. with a smooth work roll surface and takes into consideration elastic work roll flattening. Currently, a regularised Coulomb friction law is incorporated to account for the global effects of the roughness transfer. Based on the results of the coarse global analysis, the subsequent simulation step performs a detailed local analysis on the length scale of the roughness structures. In this simulation step, only a small cut-out of work roll and strip with detailed modelling of the roughness structures is analysed.

Due to the inherent neglect of the feedback of the submodelling behaviour onto the global model, consistence between global and submodel is of utmost importance to ensure precise results. This requires an adjustment of the parameters of the global

model, which is based on the use of effective regularized parameters describing roughness transfer and Coulomb friction of the global model. However, systematic numerical studies point out that for surface structures with pronounced roughness (e.g. in terms of magnitude and steepness), no adequate description within the (for cold and temper rolling widely-used) frame of the Coulomb friction law is possible. The deviations from such an empirical frictional law can be understood most easily by taking into account two physical phenomena, namely the pronounced change of fractional area of contact near the roll-gap entry side, and the massive local plastic deformations of the strip-surface inside the roll bite. The first effect leads to severe alterations of the elastic work roll flattening, and therefore the effective roll gap length increases significantly compared to a smooth work roll. It should be emphasized that the large local deformations of the surface layer, in particular penetration, reverse extrusion and toothing effects, result in pronounced inhomogeneous plastic flow in the bulk material domain as well. Besides, the locally stored elastic energy, resulting from toothing effects of roughness structures stamped onto the strip surface inside the roll gap, also contributes to the non-applicability of the Coulomb friction law.

Therefore, more general tribological concepts have to be applied in future simulations, incorporating in particular the ratio of bearing contact area to total area as essential influence value. To accomplish this task, different approaches have been assessed, especially with regard to the application in a finite element temper rolling model. The main purpose of such investigations is to study the limits of the applicability of the Coulomb friction law, and to derive guidelines for geometrically simple supplemental roughness structures as well as to find a suitable integral/overall description of roughness transfer effects for the global model.

The different tribological approaches have been evaluated by FEM-simulations of the pure stamping process with rigid tools, which enables the precise analysis of the roughness transfer forming process, detached from the characteristics of temper rolling. The approaches evaluated in such a way are also applied to temper rolling models and compared systematically. This should finally lead to a more thorough understanding of the underlying tribological and roughness transfer process details.

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