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An Extended Heat and Mass Transfer Slice Model for Continuous Casting of Steel

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Abstract

Continuous casting (CC) [1] is currently the most common process for production of steel. The process can be accompanied by a range of quality problems such as shape defects, cracking, inclusions, segregation, porosities, etc. Respectively, there is a very big demand for related process modelling, which is used in the design of casters, proper setting of process parameters, and on-line control of the casters. The models [2] range from very simple, usually used in the on-line mode in the regulation of the plant, to very sophisticated multi-scale and multi-physics approaches that run off-line for several days and tackle the specific aspects of the process like melt - casting powder interaction, inclusions dynamics, oscillation mark formation, etc. The focus in this paper is the so called slice model concept. This concept neglects all interactions in the direction of the casting, and takes into account only the interactions perpendicular to the casting in form of a traveling slice. Respectively, a quasi-three dimensional picture of the strand status can be obtained much faster than when solving a complete 3D configuration. However, the model could of course not predict any realistic turbulent fluid flow effects. Several important solidification parameters, such as the shell thickness along the casting direction, the metallurgical length and the temperature of the strand surface can be calculated satisfactory accurate by the thermal slice model. This model has been upgraded with the solution of the grain structure [3], and very recently to grain structure and macrosegregation [4]. The model predicts surprisingly well the quantitative features of the temperature, macrosegregation and grain structure patterns for billets. It is the purpose of the present paper to upgrade the slice concept framework with the deformation and the porosity formation modules. The deformation module is particularly important in new continuous casting technologies where the cross-section of the strand is intelligently and intentionally forced to change to the desired shape. On the other hand, the inclusion of the porosity formation module represents additional measure of quality. We are aware that the quantitative picture, obtained from such a simple model, might be too crude, however, on the other hand, such a simple model can be used in the on-line mode and give the plant operators a quick insight into the quality changes and trends in the strand as a function of the process parameter changes. It can also serve as an estimator of the strand quality [5]. The basic features of the discussed comprehensive multiscale and multiphysics model are as follows: The heat and species transfer models are based on the mixture continuum assumptions with Lever solidification rule and enhanced thermal and solutal diffusivities for heuristic accounting of fluid flow effects. The deformation module is based on the plane strain assumption [6]. The grain structure model is based on the Gaussian

nucleation, and KGT growth model, coupled to the macroscopic heat and species transfer models [7]. The shrinkage porosity model is obtained by assuming transversal Stokes-Darcy flow in the mush [8]. The heat, species and deformation models are solved by using strong formulation and meshless local collocation with augmented radial basis functions [9]. Elliptic node generation is used for re-positioning of the nodes of the deformed transversal shape of the strand. The grain structure model is solved by the point automata technique, a novel meshless variant of the cellular automata method. The current capabilities and future refinements of the model with respect to additional physical mechanisms are discussed.

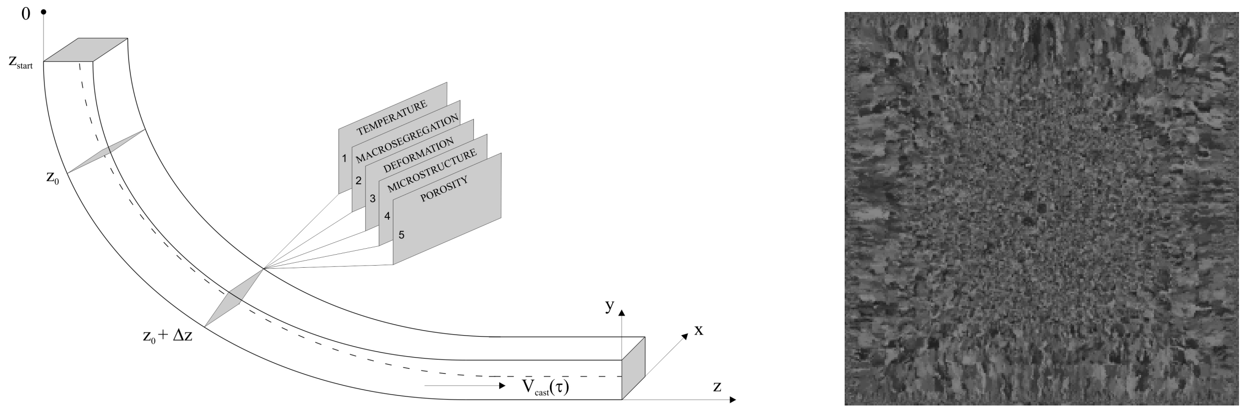

Figure 1: Left: slice traveling schematics in the strand with 5 different models. Right: results of the microstructure model.

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