A Study of the Initial Mould Filling during Up-hill Ingot Casting

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Abstract

The fluid flow in the mould during up-hill teeming is of great importance for the quality of the cast ingot and thereby the quality of the final steel products. At the early stage of the filling of an up-hill teeming mould, liquid steel flows with a high velocity from the runner into the mould. The resulting turbulence on the meniscus can lead to entrainment of mould flux. The entrained mould flux might subsequently end up as defects in the final product. It is therefore very important to get a less turbulent and more stable inlet flow in the entrance region of the mould, to minimize the interactions between the steel and the mould flux. It has been acknowledged recently that a swirling motion, induced using a helix shaped swirl blade in the submerged entry nozzle, is remarkably effective to control the fluid flow pattern in both the slab and billet type continuous casting moulds. The focus in this thesis is the effect of a swirling flow, generated through a helix shaped swirl blade inserted into the runner system of the up-hill casting system, as a new method of reducing the deformation of the rising surface and the unevenness of the flow during filling of the up-hill teeming mould. The study covers a theoretical part, including mathematical modelling and water modelling experiments. Moreover, a part with some novel plant trials to test the swirling technology at the steel plants of Ovako bar in Hofors and Scana steel in Björneborg. The swirl blade has two features: (1) to generate a swirling flow in the entrance nozzle and (2) to suppress the uneven flow developed after flowing through a bend. Water modelling was used to assert the effect of the swirl blade on rectifying of tangential and axial velocities in the filling tube for the up-hill teeming and also to verify the results from the numerical calculations. The effect of swirl in combination with a diverged nozzle was also investigated in a similar way, i.e. with water model trials and numerical calculations. The earlier studies, using water as a fluid, have shown that the placement of a swirl blade in the vertical part of the runner channel, at the entrance to the mould, will be beneficial for a calm initial filling of the ingot during casting. Later, the plant trials were carried out to test if it would be possible to place a ceramic swirl blade in the runner channel during filling of ingots and to investigate the effect of a widening of the entry nozzle. Because of constrains of the current design of the runner systems at the steel plants it was not possible to place the swirl blade at the entrance. Instead, the swirl blade was placed in the horizontal part of the runner system. The initial experiments with swirl blade in the runner showed that no production disturbances were found. More specifically, no problems with unusual refractory wear or cracks in the refractory were found. Also, the mould powder consumption was found to decrease when using the swirl blade in combination with an inlet with a 6° diverged nozzle. Thus, it was concluded that the use of swirl blade has a potential in the future to be used to influence the initial filling conditions in a positive way. In addition to the plant trials
with swirl blade, separate trials of changing the inlet angle from 1.7° to 6° or 10° showed that the widened inlet area resulted in a decrease in mould powder consumption. However, the decrease was not to the same extent as for the case with swirl blade.

Keywords
swirling flow, up-hill teeming, nozzle, casting, fluid flow, modelling, CFD, LDA, swirl, ingot casting, filling, red eye