Study of Submerged Shroud Designs to Reduce Potential Stickers in a Slab Caster




Tundish-to-mold shrouds, which include the submerged-entry nozzle (SEN), monotubes and submerged-entry shrouds, play a crucial role in transferring liquid steel to the mold. Most products are designed to work well within an ideal operating window. When operating under wide mold widths and slow casting speeds, the steel streams exiting the nozzle have low momentum and do not reach the narrow faces effectively. This can lead to suboptimal flow and temperature distribution within the mold. Sticker alarms were experienced at the Cleveland-Cliffs Burns Harbor caster under certain conditions. A comprehensive study was undertaken to evaluate the flow under these conditions using both computational and physical modeling techniques. The effect of several design features of the SEN on the flow in the SEN and eventually the mold is investigated and presented. Implementation of design features to achieve better flow distribution in the mold and reducing the potential for stickers are presented.

Authors

Pavan K. Shivaram (top left), Head of Flow Control US & Canada, RHI Magnesita, York, Pa., USA
pavan.shivaram@rhimagnesita.com

Lidia Yakovleva (top right), Process Coordinator Operations, Steel Producing, Cleveland-Cliffs Burns Harbor, Burns Harbor, Ind., USA
lidia.yakovleva@clevelandcliffs.com

Gernot Hackl (bottom left), Head of Global Simulation, RHI Magnesita, Leoben, Austria
gernot.hackl@rhimagnesita.com

Wolfgang Fellner, Simulation Professional, RHI Magnesita, Leoben, Austria
wolfgang.fellner@rhimagnesita.com

Yong Tang (bottom right), Simulation Expert, RHI Magnesita, Leoben, Austria
yong.tang@rhimagnesita.com

During the continuous casting process, liquid steel is transferred from the ladle to the tundish and proceeds to be introduced into a mold, wherein the steel eventually solidifies. The shape, size and configuration of the mold is different depending on the type of caster and the product being produced. However, regardless of the configuration, in casting, this transfer into the mold is arguably the most critical part of the process, as a failure to maintain appropriate conditions and flow patterns can lead to major issues. These may include quality downgrades or loss of containment due to insufficient shell thickness. The role of tundish-to-mold (T2M) shrouds, which help transfer the liquid steel from the tundish to the mold, then becomes critical in maintaining the steel flow and temperature within the mold.[1]

The bore of the tube, the port size, port shape, port angles, immersion depth of the nozzle in the mold, and the existence of a sump at the bottom of the bore are all active variables that influence the flow patterns within the mold as a result of the T2M shrouds.[2–5] In this study, the authors have aimed to resolve a particular issue that was observed during the use of a specific shroud design. In the process, an attempt has been made to understand the influence that many of the design variables have on the flow within the mold and mitigate any potential quality concerns resulting from undesirable flow features.

Note that in this article the authors collectively refer to the various types of refractories used to transfer the steel from the tundish to the mold as T2M shrouds. These can include submerged-entry nozzles (SEN), submerged-entry shrouds (SES) and monotubes (MTs). The design discussed in this study is an interchangeable tube which is employed with a slidegate system, generally referred to as a monotube. However, the more generic term — submerged-entry nozzle — is used to describe the nozzle for the rest of this article, to maintain generality.

Discussion

Background

The Burns Harbor division of Cleveland-Cliffs Inc. is a premier steel-producing plant with two slab