Design and Implementation of High-Performance Submerged-Entry Nozzle Designs for Thin-Slab Casters

Thin-slab casters, first introduced by SMS group as Compact Strip Production (CSP), have specific requirements for a submerged-entry nozzle (SEN). These casters are often characterized by relatively thin cross-sections, a funnel shape, high casting speeds and a curved mold. Modern steel shops are constantly pushing the envelope to achieve long production times on an SEN. As such the designs, material combinations and the associated production of SENs play a critical role in achieving the performance demanded by such casters. This article details the development and implementation of such designs through material development and study of designs using modeling techniques. Particular references are provided to the successful implementation of one such SEN at Nucor Steel–Indiana.

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Introduction

Thin-slab casting is a specialized continuous casting process in which molten steel is transferred into relatively thin mold sections (less than 110 mm thick) to be solidified and converted to slabs. This allows for the slabs to be directly fed through rolling mills, which reduces an additional step of reheating slabs, making this process more efficient than traditional slab casting. The technology was first implemented by SMS group at Nucor Steel–Indiana in 1989. Ever since, the technology has evolved and more challenging product mixes have been attempted through this process.[1,2] A nice review of 30 years of history and potential future prospects is provided by Shui-Ze et al.[3]

The transfer of steel between the tundish and the mold is accomplished by specially designed refractory nozzles called submerged-entry nozzles (SEN). Due to the relatively thin cross-sections of the mold, the flow channel of the SEN changes from a round or near-round shape to being narrow and flat on the one side. To accommodate for the flowrate, the nozzle needs to flare out in the other direction. Thus, the most common SEN designs used in thin-slab casting appear similar to and are called beaver tail designs. These are complex pieces of refractory to manufacture, requiring specialized tooling and high level of precision. The role of the SEN in minimizing unfavorable turbulent patterns, improving productivity without compromising on steel quality and the various considerations for the design of these SEN are discussed in several articles.[4,5]

Steel manufacturers have been taking great strides in stringing together long sequences of grades to be cast. As such, the life expectation of the SENs is quite demanding. To meet these expectations, there are several requirements that the SEN designs have to meet, which include complex designs, high corrosion resistance of the slag band and good mechanical integrity. This article will discuss in some detail each of these challenges and the approach taken to address each of these challenges.

Discussion

Materials Selection and Development

When the SEN limits sequence lengths, this is usually from the wear at the slag band from corrosion, which renders the refractory wall too thin to safely continue operation. If continued, this