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Application of PHOENICS Fluid Dynamics Software for the Redesign of SEN tube for Continuous Casting of Steel – A. K. Sinha, U. S. Steel

The SEN (submerged entry nozzle) tube in continuous casting delivers liquid steel from a reservoir (Tundish) to the mold for final solidification into slabs. At United States Steel Corporation ("U. S. Steel"), the SEN tube has two port openings from which the steel enters the mold from the tundish. The ports have a down angle to direct the flow down inside the mold and the ports are located slightly above the bottom plane of the SEN, so that there is an internal recess or cup height. Recently, use was made of PHOENICS fluid dynamics software to mathematically model the flow of liquid steel in the mold.

The work involved increasing the useful life of the SEN tube being used at a U. S. Steel plant. Since the tube life was dictated primarily by mold flux attack on the tube refractory at the liquid interface, increased thickness of the SEN refractory wall by reducing the inner bore diameter of the tube, would help to increase the life of the tube. However, when the plants initially reduced the inner bore diameter from 90 to 80mm, the flow speeded up and changed significantly near the liquid surface, such that mold flux powder on the steel surface was being entrapped into the steel, thus reducing steel cleanliness and quality. That is when mathematical modeling of the flow in the mold was performed to solve this problem.

Using PHOENICS, the flow profile in the mold was computed for the existing SEN design, the unsuccessful reduced bore design and some new proposed designs incorporating the reduced bore technology. The velocity and turbulence values at a plane near the liquid surface were recorded for all the cases. The objective was to match the velocity and turbulence values generated by the proposed reduced bore design as close as possible to that generated by the existing big bore SEN design near the top surface of the liquid, which is the region where the mold flux powder was being entrapped. To model the free surface at the top, the IPSA algorithm was employed. The KE model was used to model the turbulence and a fixed volumetric flow rate condition was imposed at the inlet.

The steel flow pattern at t=25seconds for the current big bore tube is shown in Figure 1 while Table 1 is a partial list of the different SEN designs that were investigated. Version K is the big bore tube, version A is the unsuccessful reduced bore design and version X is a new reduced bore design.

Table 1: Description of all the different SEN tube designs investigated

Tube Type	Version Index	Description
Current J Tube	K	Bore 90, Port 70x90, Angle 15, CupHt 66
SmallBore ModifiedPort	X	Bore 80, Port 70x80, Angle 20, CupHt 55
Experimental L Tube	A	Bore 80, Port 70x80, Angle 15, CupHt 66

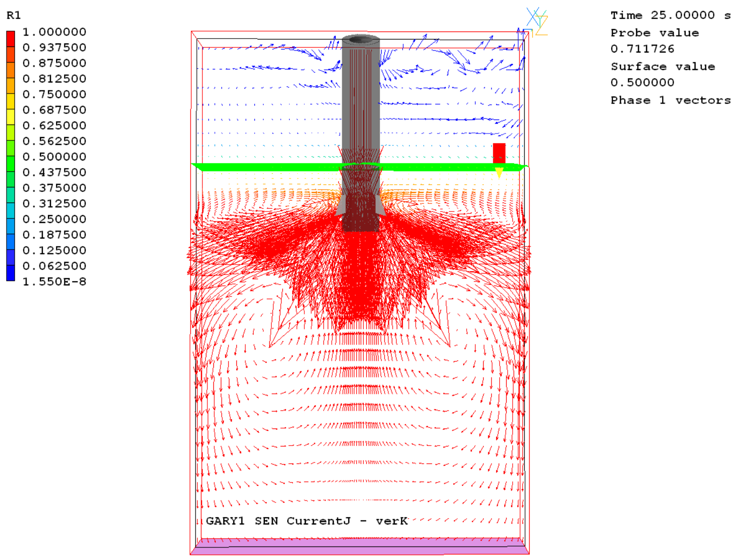

Figure 1: Schematic of the liquid steel flow in the mold from the two-ported SEN.

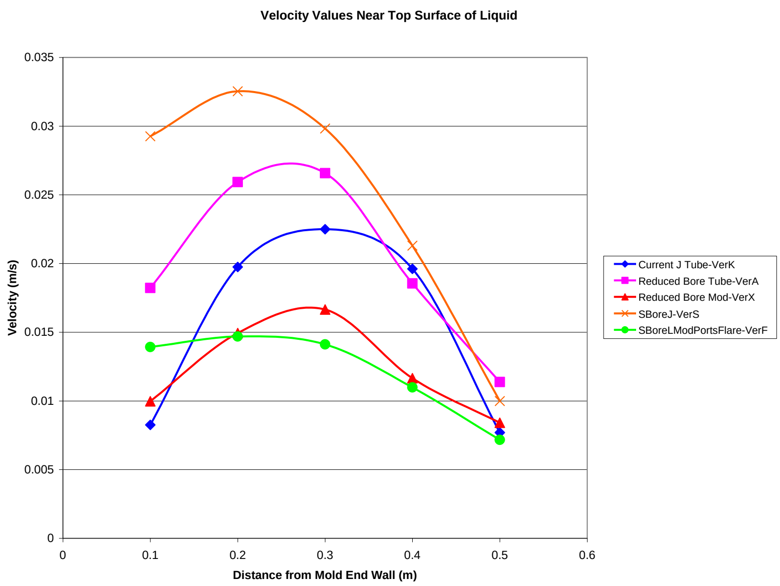

Figure 2: velocity values near top surface of liquid for different SEN designs.

Figure 2 shows the velocity values along a line near the top surface of the liquid in the mold, extending from one end of the mold to the other along the centerline. As seen in Figure 2 of all the different designs investigated, version X (red line) has the closest match to version K (blue line) the current big bore tube. Version A (pink line), the unsuccessful tube shows higher velocity over most of the surface compared to version K and caused the mold flux entrapment. Thus version X design was trialed in the plant and the tube life index improved from a value of 0.68 to 1.0 i.e. almost 50% improvement and this design has been currently adopted for use at the plant leading to cost savings.

CHAM Ltd, Bakery House, 40 High Street, Wimbledon Village, London SW19 5AU, UK
Tel: +44 (0)20 8947 7651 Fax: +44 (0)20 8879 3497 Email: phoenics@cham.co.uk
Web: http://www.cham.co.uk