THERMAL ANALYSIS OF A CONTINUOUS CASTING TUNDISH BY AN INTEGRATED FEM CODE

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***Abstract*— This work describes a computational model named TEMREP, which determines the thermal states of a tundish and the liquid steel temperature during continuous casting, as a function of steel ladle teeming temperature evolution, heat losses to tundish refractory lining, and insulating coating during transient and steady states of the operating process. Solution of the thermal equations is performed via the finite element method. TEMREP predicted numerical values were compared with in plant experimental measurements, with good accordance between them. On average, steel tundish temperature difference was of about ±4ºC. The model can be used as a design tool, by performing parametric studies to detect the relevant process variables. Since the computing time is much smaller than that of real process, the model is suitable of being implemented in an on-line system for tracking the steel temperature for automation control during the casting sequence.**

***Keywords*— numerical simulation, heat transfer, steel temperature, continuous casting tundish.**

I. INTRODUCTION

The quality of steel casting products is associated to the knowledge of numerous variables and operation parameters strongly interrelated. The phenomena that take place in the steel ladle directly affect those occurring in the tundish; later, what goes on in the continuous casting mold and downstream will be reflected in the intermediate and semi-finished cast products quality (slabs, blooms, billets).

The knowledge of the temperature of steel poured from the ladle is relevant to obtain high quality products. High superheat above liquids temperature in the tundish will increase central segregation, affect grain size and even produce breakouts owing to local solidified shell thinning of cast products, interrupting the continuous casting sequence. On the other hand, low superheat in the tundish will promote clogging of tundish nozzles, macro inclusions entrapment and will affect flux powder melting increasing the probability of mold sticker formation.

After tapping from the LD converter, the liquid steel held in the ladle is transferred to the Ladle Furnace and Trimming Stations, for final grade composition and temperature adjustment. Then, the ladle is delivered to the continuous caster and no further temperature correction is possible. Thus, the forecast of steel temperature to be poured in the tundish depends upon many operating parameters such as the thermal history and wear of the ladle refractory lining, precise knowledge of refractory thermal properties and transfer coefficients, the use of ladle top covers and insulating slag layers, the time each operating stage lasts, argon stirring practice and waiting period before teeming which lead to different ladle stratification grades, teeming rate, etc.

Computational modeling has become a powerful tool for the analysis of heat losses of liquid steel along the continuous casting process. A literature review mainly classifies published models in two groups. To the first group belong the models that predict bulk temperature of the melt in the ladle and in the tundish (Fredman *et al.*, 1999; Gastón and Medina, 1996; Petegnief *et al.*, 1989; Tomazin *et al.*, 1986; Linka *et al.,* 1986; Morrow and Russell, 1985; Pfeiefer *et al.,* 1984). This kind of models is particularly appropriate for on-line implementation for steel temperature control and tracking of the thermal state of casting ladles and tundishes (Castillejos *et al.*, 1997; Gupta and Chandra, 2004a, 2004b; Zoryk and Reid, 1993). The other group corresponds to CFD studies of the stratification phenomena developed in the ladle during holding and teeming and its impact on the tundish temperature flow (Chakraborthy and Sahai, 1992a, 1992b). Most of them were carried out using commercial packages like PHOENICS and CFX (Austin *et al.*, 1992; Grip *et al*., 2000; Xia and Ahokainen, 2001; Pan *et al.*, 2003).

Numerical fluid dynamics has also been intensively applied to analyze the characteristics of the fluid flow in the tundish for design optimization. Physical modeling of transport phenomena has also assisted in the understanding of fluid flow in steel casting vessels in general.

The model described in this work belongs to the first group. It is a specific code that predicts the mean steel tundish temperature and the tundish thermal state during continuous casting as function of heat losses through the tundish shell, insulation of the steel bath and temperature of the outlet steel melt drained from the ladle.