METABK METABK 56(3-4) 291-293 (2017)
UDC – UDK 669.186:518.1:531.3=111

METHODOLOGY OF INCLUSIONS REMOVING FROM STEEL FLOWING THROUGH THE TUNDISH

Received – Prispjelo: 2016-12-12
Accepted – Prihvaćeno: 2017-03-25
Original Scientific Paper – Izvorni znanstveni rad

Obtaining high quality steels mainly depends on the quantity of non-metallic inclusions contained into it and this, in turn, to a large extent on the structure of the flow in the tundish. Optimization of the flow of liquid steel through the tundish makes it possible to control the trajectory of inclusions and thereby to improve the conditions of their outflow into the slag layer. The following article presents an analysis of research opportunities of the inclusions distribution and removing process from the steel flowing through the tundish, resulting in reconstruction of the own research facility.

Key words: tundish, continuous casting, physical and numerical modeling, inclusions

INTRODUCTION

One of the basic device in the process of continuous casting of steel is a tundish. Its main tasks include the uniform distribution of liquid steel to individual moulds, maintaining a constant casting speed and protection against excessive heat loss. From a certain period of time tundish is classified as a device that can significantly contribute to the removal of part of the non-metallic inclusions. Conducting research in the tundish in industrial conditions is very limited due to the physical conditions of the process it self (the size of the tundish, high temperature of the process). These limitations can be overcome by moving research from the real device to the physical and mathematical models. Physical models also known as water models due to the use of water to render the liquid steel, are generally performed with a reduced scale. An indispensable condition for proving the correctness of the study is the geometric and hydrodynamic similarity in relation to the real object. Research done on physical models often are supported by numerical models that use numerical algorithms for solving differential equations of transport of mass, momentum and energy. During the development of the mathematical model it is necessary to take into account a number of parameters which result from the investigated metallurgical technology [1-3].

This paper presents the possibilities of research undertaken by the authors to determine the phenomena such as: distribution of solid particles (non-metallic inclusions) in the workspace of flow device, which is the tundish and the separation of these particles from the liquid. Laboratory studies included experimental measurements carried out on the model of the device in a reduced scale. Mathematical modeling included numerical simulations of analyzed process, carried out using commercial code ANSYS Fluent.

CHARACTERISTICS OF WATER MODEL AND MATHEMATICAL MODEL

Model tests were carried out with the use of hydraulic physical model of tundish device for continuous casting of steel.

In the measuring unit, next to the modeled tundish a mould is present acting as a cooperating device. Other elements of measurement equipment act as auxiliaries segments to allow maintenance within the required experimental conditions. Auxiliary segments include: hy-

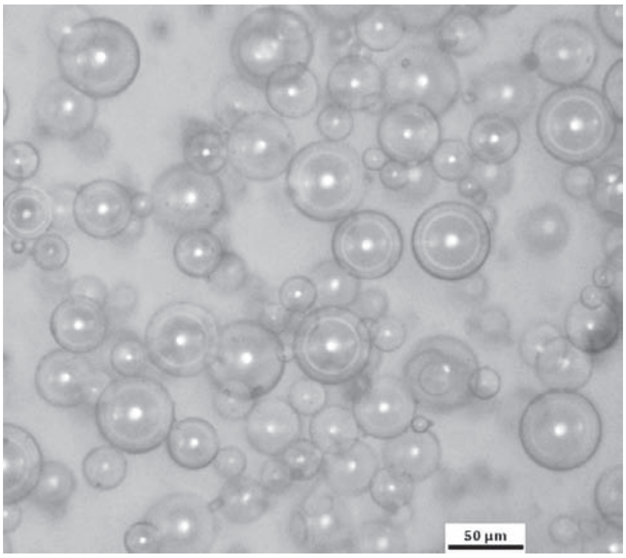

Figure 1 View of the particles used in the model study

M. Warzecha, A. M. Hutny, P. Warzecha, B. Jedrysiak: Department of Metals Extraction and Recirculation, Czestochowa University of Technology, Czestochowa, Poland
T. Merder: Silesian University of Technology, Institute of Metals Technology, Katowice, Poland

draulic infrastructure, tanks for collecting liquid model performing in addition a certain extent role as steel ladle models, the system of automatic control, measurement systems, flow control systems for modeled liquid, etc.

Included particles have a spherical shape (Figure 1) and were composed of glass beads with the density of 0,12 g×cm^{-3}.

TEST DESCRIPTION

For each particle fraction a measured dose of microparticles has been prepared and mixed with water in an amount of 4 300 ml. The capacity of the tank allows the introduction of the microparticles mixture into modeled ladle continuously throughout the duration time of the experiment.

Every time a portion of the microparticles was approximately 0,5 g. A small amount of soap (2 drops) was introduced into prepared mixture in order to change the surface tension of water. The mixture was intensively mixed for a few minutes in order to achieve good water-particle homogenization (Figure 2). The mixture has been mixing for the duration of the measurement, which provided the same level of mixture homogenization.

The mixture was fed through a specially made hydraulic system that allowed the introduction of its axis stream flowing into the tundish. Schematic view of the measurement system is shown in Figure 3.

Figure 2 View of a mechanical particles stirrer together with the water tank

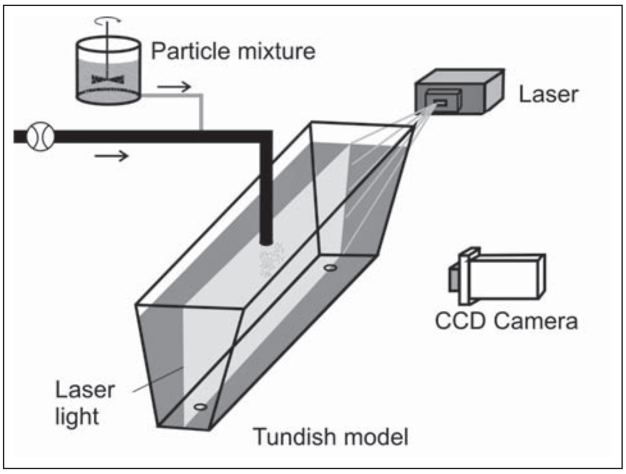

Figure 3 Schematic view of the measurement device to track the behavior of microparticles in the water model of tundish

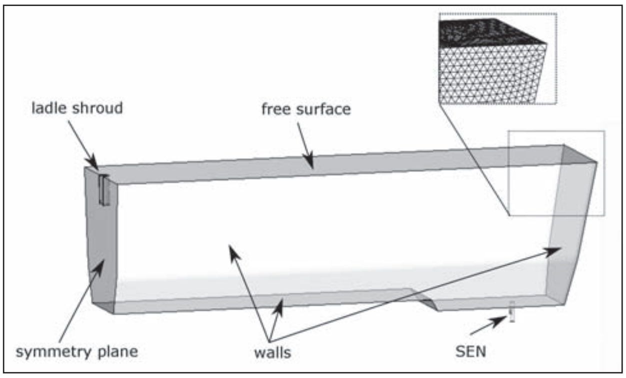

Figure 4 View of numerical model of the tundish with boundary conditions

The mathematical model of the flow of non-metallic inclusions in the tundish is based on the Euler - Lagrange method, in which the system of differential Navier-Stokes equations and turbulence method (k - ε model) for the given boundary conditions are solved. The boundary conditions correspond to a real object. For calculations a virtual object of investigated tundish has been created, which as a result of discretization presents a computational grid (Figore 4). Calculations were carried out using a commercial code ANSYS Fluent with transitional mode.

THE RESULTS OF INVESTIGATION

Distribution of flowing particles in the water model of tundish has been observed in the laser light on selected sections of the object. Figure 5 shows the particle distribution of the longitudinal section of the tundish after the time 10, 25 and 110 seconds after particles introduction into the tundish. Brighter areas of the liquid indicate an increased content of the microparticles.

Numerical simulations of particle motion in the water for a modeled object allowed to obtain the following characteristics: velocity vector fields and fields of turbulence intensity (Figure 6) for the selected section

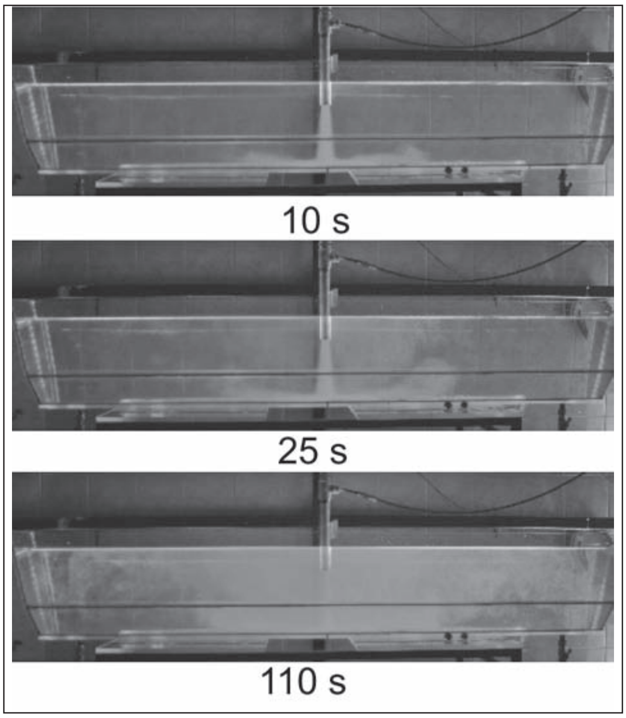

Figure 5 Particle distribution visualization obtained for water model

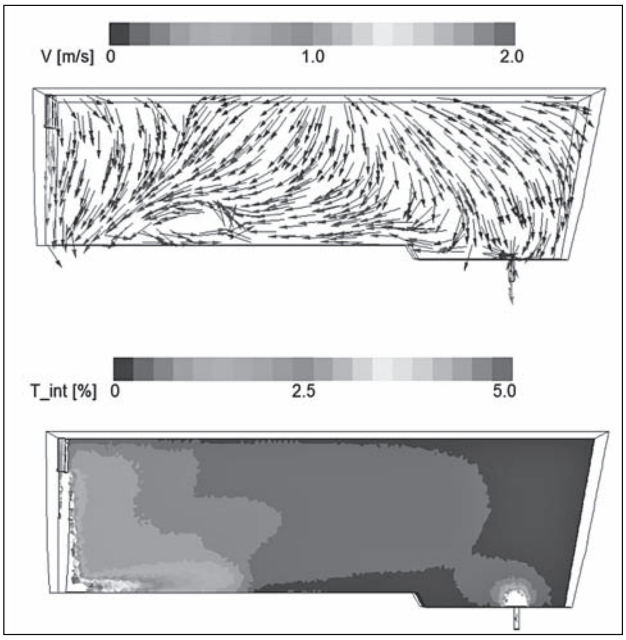

Figure 6 Velocity vectors and turbulence intensity of the fluid (CFD model)

planes and particle trajectories inside the tundish. Figure 7 shows the distribution of particles in water model for measurement (Experiment), which corresponds to the conditions of numerical simulation, for which results as a non-metallic inclusions trajectories are reported in this Figure.

CONCLUSIONS

The evaluation of the behavior of non-metallic inclusions flowing through the tundish can be achieved

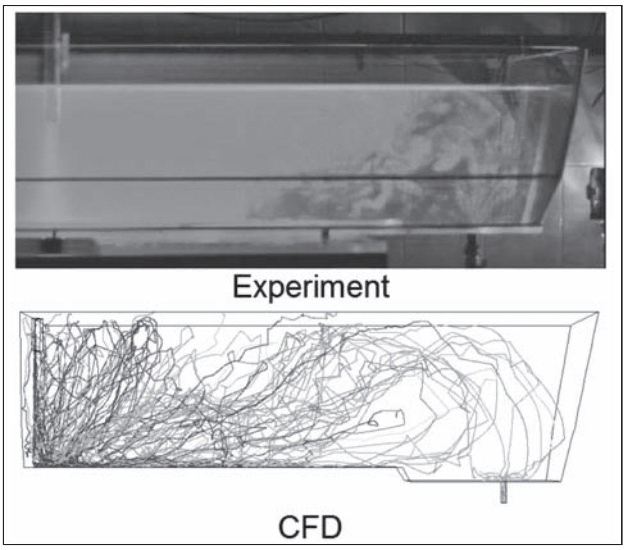

Figure 7 Particle distribution visualization obtained for water model and CFD model

by using a water model test using glass beads for microparticles. Water model should meet the criteria for geometric and hydrodynamic similarity of real object. Results of particles distribution in water indicate the complexity of the flow inside the modeled tundish, which is a representation of an industrial facility. It reflects an intense stream of particles entrained to the surface just next to the tundish inlet, and then move in the advancing liquid front in the direction of the nozzle. This is confirmed by the results of computer simulations, evidenced by comparing the results in Figure 7.

To summarize, it is clear that the simultaneous use of physical modeling and numerical modeling is a good tool for assessing the distribution of non-metallic inclusions in the industrial tundish.

A special assessment of refining steel non-metallic inclusions can be present after further research.

Clearly, the trajectories of particles (after reaching the region of outflow) are very similar, which proves that the numerical model successfully reproduces the movement of particles in the investigated object.

Acknowledgements

Acknowledgements to the National Science Centre: project No 2013/09/B/ST8/00143.

REFERENCES

[1] Y. Sahai, T. Emi, Tundish Technology for clean stell production, New Jersey, World Scientific, 2008.
[2] Modeling of Continuous Casting of Steel, Monograph under Sc. Editor J. Falkus, (in Polish), Publishers of Naukowe Instytutu Technologii Eksploatacji – Państwowy Instytut Badawczy, 2012.
[3] A. Cwudziński, Steel Res. Int. 85 (2014), 902-917.

Note: The responsible translator for English language is B. M. Wolna, Poland