THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 1 - 2023, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2023.1.03

IMPORTANCE OF SIMULATING THE STEEL FLOW PROCESS IN THE TUNDISH, ON THE QUALITY OF CONTINUOUSLY CAST SLABS

Beatrice Daniela TUDOR, Ali Jawad Jaber MATROOD
“Dunarea de Jos” University of Galati, Romania
e-mail: beatrice.tudor@ugal.ro

ABSTRACT

The benefits of using mathematical modeling of the flow are obvious, the final objective being the elimination of as many inclusions as possible during the flow of steel through the tundish, and thus, obtaining steel with superior quality.

In this work, a simulation of the movement of the liquid alloy in the tundish was carried out, in order to highlight the erosion of its refractory lining. For this, we used SolidWorks, RealFlow, and ABAQUS programs.

Using these simulation programs, the filling method of the tundish, the contact area of the alloy jet with the tundish wall, and the "dead" areas are highlighted, as well as the turbulences that can appear during the flow, which have a negative impact on the quality of the steel.

KEYWORDS: tundish, simulation, mathematical modeling, steel quality

1. Introduction

The benefits of using mathematical modeling are obvious, and modeling has become much more accessible with the continuous evolution and availability of more powerful and faster computers.

Many quality problems that occur during continuous casting can be attributed to the control of fluid flow conditions.

The importance of the flow of liquid alloy starts from the manufacture of steel and from the refining operations, including in the pot.

The flow and filling of the tundish has as its objective, a chemical composition and a temperature as uniform and homogeneous as possible of the alloy, and the inclusions to be, as much as possible, removed in the slag layer. [1, 3].

The final objective remains the elimination of as many inclusions as possible, during the flow through the tundish, thus obtaining steel with superior quality.

The flow system must transport the molten steel, at the desired flow rate, from the pot to the tundish. The flow conditions should minimize contact with the atmosphere, avoid entrainment of slag or other exogenous inclusions, and help lift the inclusions in the slag. Achieving these objectives requires a study that takes into account all these phenomena that can influence the quality of the finished product, and requires a simulation of the flow, in order to reduce or eliminate them.

The tundish ensures a continuous flow of metal from the pot to the continuous casting machine. The flow in the tundish must ensure uniformity and the elimination of inclusions, while avoiding problems related to flow, such as turbulence, interruption, “dead” zones, etc. [2].

The flow can produce turbulence and can lead to the phenomenon of reoxidation, the entrainment of slag, and the time for the inclusions to be floated being insufficient. "Dead" zones are stagnant, colder regions that inhibit the removal of inclusions, and can contaminate the steel flowing through the tundish. If the liquid level is too low, high-velocity asymmetric flow can produce eddies, which can entrain surface slag [5].

The flow behavior in the tundish is influenced mainly by the size and shape of the tundish and by the location of flow control devices, such as dams. The flow pattern is also affected by the steel flow and its temperature distribution. Hotter steel tends to rise, having a lower density, while cooler steel tends to flow down the distributor walls. A temperature difference of only a few degrees is enough to completely reverse the flow direction.

The generation of inclusions and the impact on quality are the problems that arise during this operation of changing the casting pots. During this operation, there is a period of temperature fluctuation and of the equilibrium state, which can lead to the reoxidation of the melt, the reactions with the casting slag, and the deposition of masonry particles from the pots. These aspects cause a negative impact on the steel quality in the tundish [4, 6].

2. Simulation of the liquid steel flow process in the tundish

The design of the distributor focused more on steady-state operation than on non-stationary state. Most new steel casting facilities use casting patterns and optimized flow control to improve inclusion removal. These larger tundishs provide the opportunity for an increased stationary time of the steel, and to pick up the inclusions into the slag, when using optimized flow control.

In order to better study and understand the processes that take place during the stationary and flow of the liquid alloy through the tundish, a simulation was made of the movement of the liquid alloy in the tundish, to highlight the erosion of its refractory lining [8].

It started from the creation of the 3D drawing of the tundish, beginning from the 2D drawing, which contains the real dimensions of the tundish. The drawing was made with the program SolidWorks, version 2016 Premium [7, 9].

The drawing has been exported in STL file format. The purpose of the STL file format was to convert the SolidWorks file.

The STL file was imported into MeshLab version 2022, in a 3D object file. The 3D object file was then opened in the RealFlow2015 software version. In Figure 1 you can see what the final drawing of the tundish looks like in the RealFlow software, starting from its drawing.

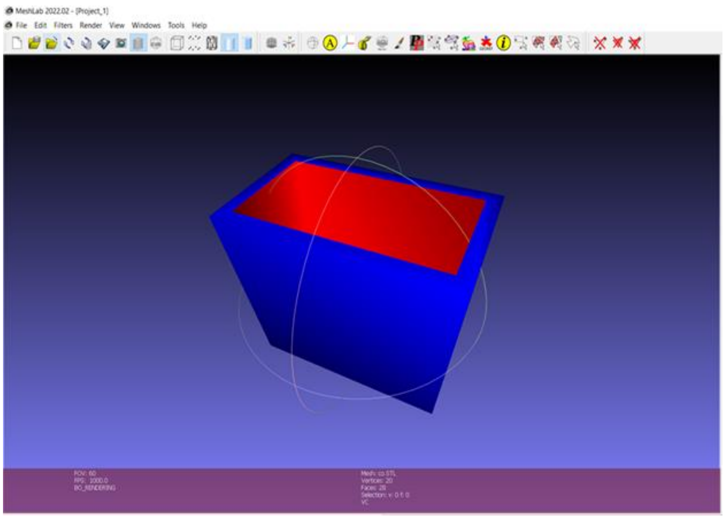

Fig. 1. *The drawing of the distributor from the continuous casting machine made in the Meshlab program*

The simulation of the flow of the liquid alloy in the tundish was done using the RealFlow program. RealFlow is a tool for simulating fluids in a dynamic system. The drawing made in Meshlab was converted into (a 3D object) format in the Realflow software (Fig. 2).

Through this simulation, it is possible to observe the filling mode of the tundish, with the first contact zone of the jet, with the wall of the tundish, with the "dead" areas, and the turbulences that may appear (Fig. 3).

The simulation of the flow of steel in the tundish, using this application (Realflow), has the purpose to highlight the flow of liquid steel, starting from the first impact of the jet with the wall made of ceramic material, until its complete filling. It is very clear, both the way of filling with the turbulences and "dead" areas, as well as the contact with the shotcrete wall. The movement and speed of the jet can tear the ceramic wall, degrading the liquid alloy, and can drive the inclusions inside the melt. The application of this simulation can help understand and combat these phenomena.

THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
Nº. 1 - 2023, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2023.1.03

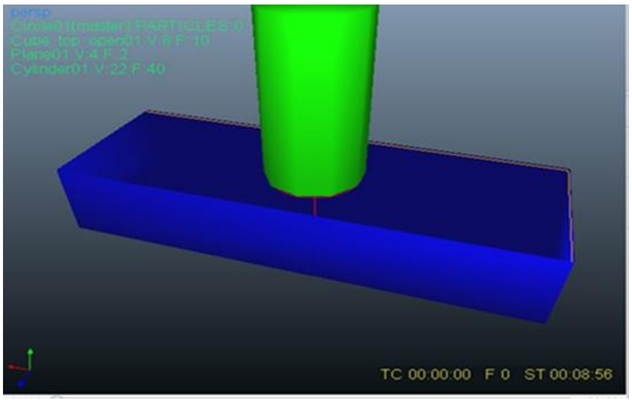

Fig. 2. *The drawing of the tundish, from the continuous casting machine, made in the Realflow program*

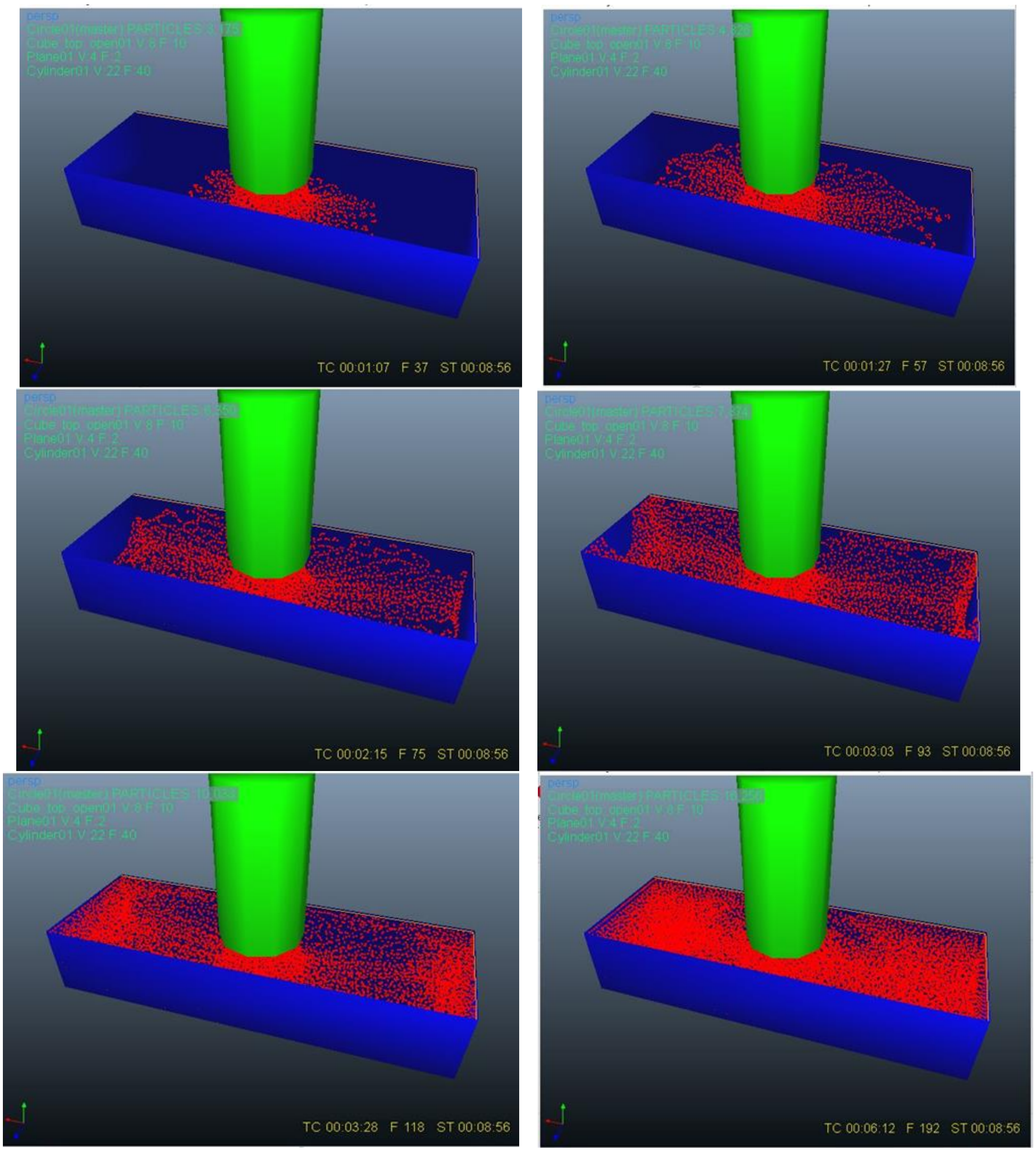

Fig. 3. *Captures from the development of the steel flow simulation program in the tundish*

THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 1 - 2023, ISSN 2668-4748; e-ISSN 2668-4756
Article DOI: https://doi.org/10.35219/mms.2023.1.03

3. Simulating the compression resistance of the tundish walls

In order to better observe how the forces created by the liquid alloy act on the refractory lining of the tundish, the compression was simulated using the Solidworks and ABAQUS programs.

ABAQUS is a software suite for finite element analysis and computer-aided engineering of various materials subjected to mechanical tests [10, 11].

To study the compressive strength of the refractory concrete used to line the tundish, the ABAQUS program was applied, and a simulation was made of the compressive strength during filling with liquid alloy, on the walls of the tundish, made of refractory concrete. According to the data provided by the program, the force that develops on these walls, during filling, is 20 N. This is an important factor, which leads to the wear of the refractory lining (Fig. 4).

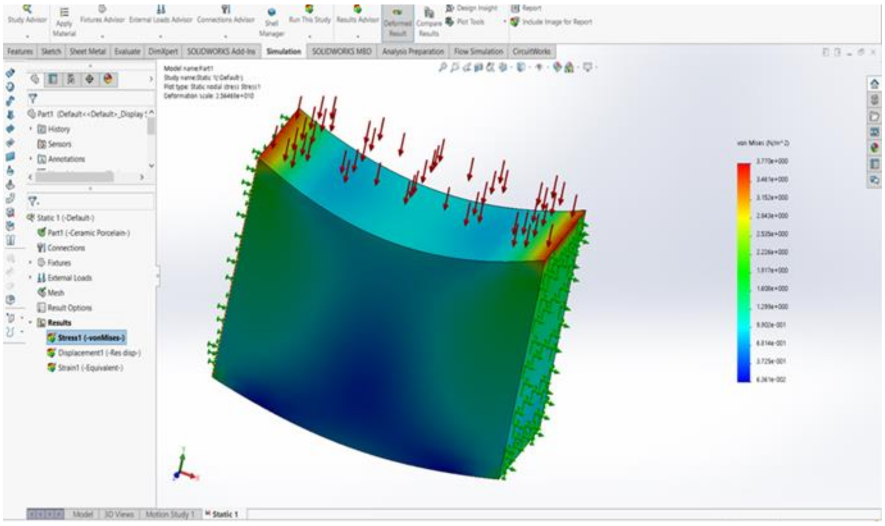

Fig. 4. *Simulating the compression forces on the walls of the tundish by applying the ABAQUS program*

The program also allows the creation of samples, on which the compression resistance is simulated.

The specimen is drawn in 3D, in the form of a cylinder with dimensions 150 mm X 375 mm with a fixed end, and the material used is concrete.

After applying pressure, from the upper part of the cylinder, a tension force is generated, which leads to the generation of cracks. Through this concrete compression test, we can find out the pressure value that the material at hand can withstand (Fig. 5).

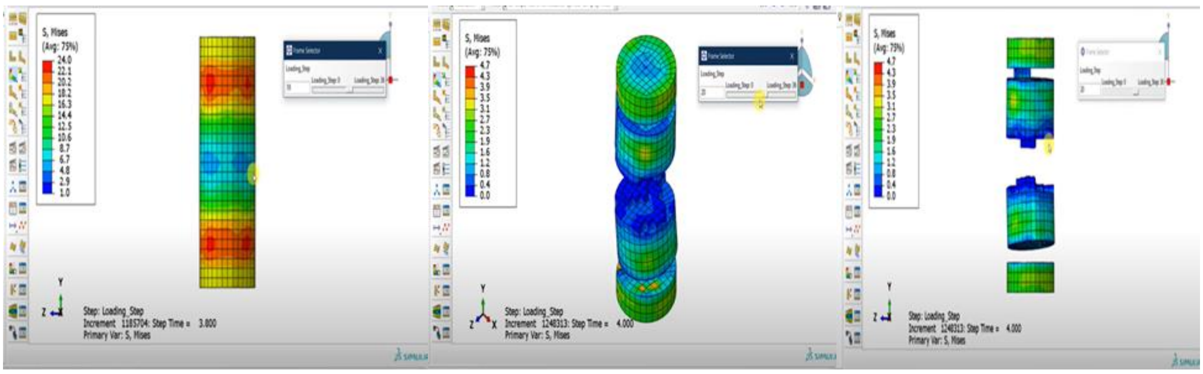

Fig. 5. *Sequences, of the application of the SolidWorks and ABAQUS programs, for determining the compressive strength of the refractory concrete, from the lining of the tundish*

The compression forces, which act on the walls of the tundish, developed by the liquid alloy, combined with the temperature differences, and with the friction, which occurs at the interface of the alloy with the shotcrete layer, represent an important factor that can influence the quality of the steel, through liner wear of the tundish.

4. Conclusions

The topological optimization of the tundish would represent a solution for increasing the quality of continuous cast steel.

The simulation of the movement of the liquid alloy in the tundish highlights the erosion of its refractory lining.

The RealFlow program is a tool for simulating fluids in a dynamic system, with the help of which you can observe the filling mode of the tundish, highlighting the first contact area of the jet with the tundish wall, and the "dead" areas, as well as the turbulences. These can appear during the flow and can have a negative impact on the quality of the steel in the tundish.

During the operation of changing the casting pots, inclusions are generated because there is a period of temperature fluctuation and of the equilibrium state, which can lead to the reoxidation of the melt, to reactions with the casting slag, and to the deposition of masonry particles to the casting pot.

References

[1]. McLean A., *The Turbulent Tundish-Contaminator or Refiner*, Proc. Steelmaking Conf., Iron and Steel Society, 71, p. 3-23, 1988.

[2]. Van der Stel J., *et al.*, *Tundish Metallurgy: A Solution or a Limitation to Clean Steel*, Development in Ladle Steelmaking and Continuous Casting, edited by G. D. Lawson (Montreal: The Canadian Institute of Mining and Metallurgy, p. 218-223, 1990.

[3]. Lowry M. L., Sahai Y., *Thermal Effects on the Flow of Liquid Steel in Continuous Casting Tundishes*, Iron and Steelmaker, 19:3, p. 81-88, J. Schade. Lecture Notes, ISS Short Course on Ladle and Tundish Metallurgy for Clean Steels, p, 314-321, Oct. 10, 1997.

[4]. Sahai Y., Chakraborty S., *Importance of Thermal Modeling in Continuous Casting Tundishes*, Proc. Process Technology Division Conf., 10, p. 161-176, 1992.

[5]. Graves A. M., *et al.*, *Design of Consumable Tundish Refractories for Production of UltraLow-Carbon Steel*, Proc. Steelmaking Conf., 75, p. 333-335, 1992.

[6]. Daussan A., Martin J., Roziere J., Steel Purity in Continuous Casting Tundishes, Proc. Steelmaking Conf., 78, p. 471-477, 1995.

[7]. Dorricott J. D., Heaslip L. J., Hoagland P. J., *Asymmetric Tundish Design and Flow Control Principles in Multistrand Billet and Bloom Casters*, Proc. Electric Furnace Conf., Iron and Steel Society, 48, p. 119-124, 1990.

[8]. Hiraki S., *et al.*, *Influence of Tundish Operations on the Quality of Hot Coils During HighSpeed Continuous Casting*, Iron & Steelmaker, 26:3, p. 47-52, 1999.

[9]. Suzuki I., *et al.*, *Development of Tundish Induction Heater for High Quality Continuously Cast Blooms*, Tundish Metallurgy, vol. 1, edited by A. McLean (Warrendale, Pa.: Iron and Steel Society), p. 201-207, 1990.

[10]. Melville S. D., Brinkmeyer L., *Evaluating Steelmaking and Casting Practices Which Affect Quality*, Proc. Steelmaking Conf., 78, p. 563-569, 1995.

[11]. McPherson N. A., McLean A., *Tundish to Mold Transfer Operations*, Continuous Casting, vol. 6 (Warrendale, Pa.: Iron and Steel Society), p. 11-15, 1992.