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NUMERICAL SIMULATION OF CASTING SYSTEM CONFIGURATION FOR LOW-DENSITY TWIP-STEEL

The production of Fe-Mn-Al-C steel does not require exotic procedures or special equipment, even though it is highly alloyed steel. The main goal in producing Fe-Mn-Al-C steel is to achieve maximum purity and optimal properties [1]. In the study [2], it was noted that Fe-Mn-Al-C steels are mainly produced using existing steelmaking equipment with minor modifications to standard melting practices. Austenitic Fe-Mn-Al-C steels are produced in both open induction furnaces and vacuum furnaces [1-3]. For open-air induction furnaces, MgO-based refractory linings are widely used. Alumina and silica refractories should not be used because they exchange oxygen with liquid steel due to the high Al content in the melt, which degrades the furnace lining and increases the inclusion content in the steel. Casting materials use olivine sand molds or preheated casting molds to minimize reactivity. Steel melted in open-air furnaces requires a strong argon gas flow to minimize atmospheric reactivity. The high Al content is beneficial for the melt, as it eliminates the need for a deoxidizer before slag removal and tapping. In both open-air and vacuum furnaces, the oxygen content is usually less than 6 ppm.

The production of castings from TWIP steels with high aluminum content remains a challenging task due to the tendency to form liquation in castings and molds. During the preparation of the melt and its pouring into the mold and subsequent distribution within it, aluminum is not absorbed in most cases. One effective technological method to mitigate this phenomenon may be to overheat the melt, but this simultaneously leads to an increase in slag content and changes in the chemical composition of the alloy. Another effective technological approach to increase the uniform distribution of aluminum in the melt inside the casting mold may be forced mixing due to the configuration of the casting system. The paper presents the results of numerical modeling of low-density TWIP steel casting and solidification.

In this study transient-state, incompressible, Navier-Stokes equations with SST k- ω model have been solved in the commercial computational fluid dynamics

(CFD) package program, ANSYS FLUENT, to simulate the turbulent flow and solidification. The interface tracking of the free surface between gas and liquid was performed by the Volume of Fluid (VOF) model using an algebraic approach [4]. The surface tension effects were taken into account.

A constant steel mass flow rate of 1.5 kg/s corresponding to the real mold teeming time was chosen as the inlet of the geometry model. A pressure outlet boundary with zero-gauge pressure was used at the outlet of the mold. Moreover, a no-slip condition was applied to all the walls. The physical properties of air and steel used in the current calculations are shown in Table 1. A computational grid consisting of an average of 300,000 polyhedral elements was prepared using FLUENT MESH software (Figure 1).

Table 1 – The physical properties of air and low-density steel

Density of air, kg/m ³	1.225
Density of molten steel, kg/m ³	6250
Casting temperature, °C	1500
Dynamic viscosity of air, Pa·s	1.7894×10^{-5}
Dynamic viscosity of molten steel, Pa·s	0.006
Surface tension between molten steel and air, N/m	1.6

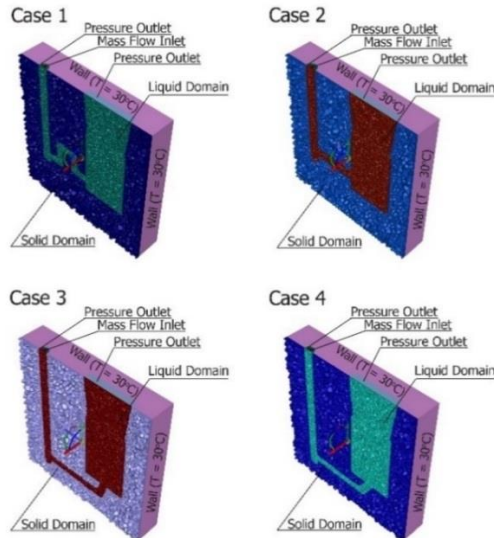


Figure 1 – Mesh of the computational domain.

Moreover, the PRESTO discretization method was adopted to discretize the pressure. The PISO scheme was used to solve pressure-velocity coupling. Second order upwind schemes were applied to the momentum, turbulent kinetic energy, and turbulent dissipation rate. In addition, the Geo-reconstruct was used to spatially discretize the volume fraction. Also, the courant number of VOF was fixed at 0.25. The time step for the simulation was 0.001 s, mold filling time – 2.5 s, solidification time – 40 s.

The paper studies the hydrodynamic features of metal flow movement and solidification. Four cases of mold filling were considered, which differed in the configuration of the mold feeder casting (Figure 1).

The results of the metal flow velocity in the mold volume are shown in Figure 2. In Case 2 the melt flow velocity is more evenly distributed over the volume of the form as in Cases 1, 3 and 4.

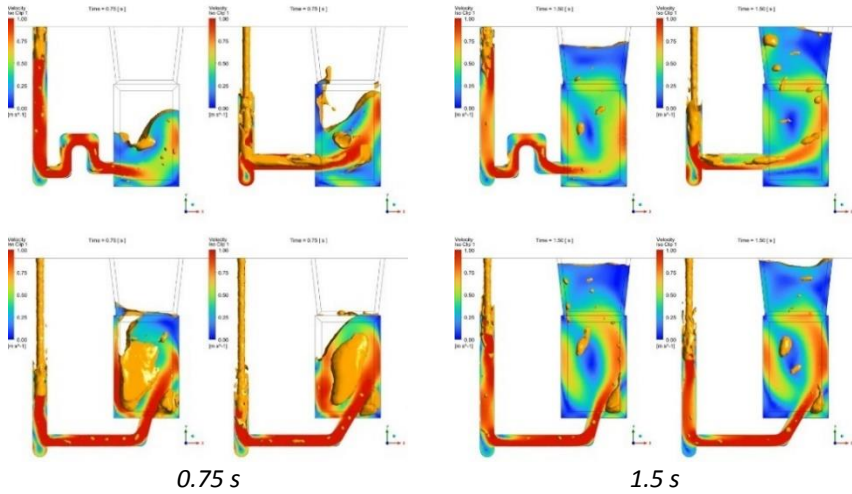


Figure 2 – Contours of metal flow velocities in the mold volume.

Temperature distribution in the mold (Fig. 3) shows that in case 2, the profit does not freeze. Therefore, in this case, feeding the mold with molten metal will occur until the solidus temperature is reached. Accordingly, taking into account the propensity of this class of steels to the formation of gas shrinkage defects, case 2 can be considered optimal.

The results of mathematical modeling showed that during the casting process of the low-density steel experience not only the influence of temperature stresses, but also additional effect from the circulating fluid flows. In this case, the greatest

impact, expressed in maximum values of temperature, is observed in the corners of the mold and persists until the metal level reaches the surplus.

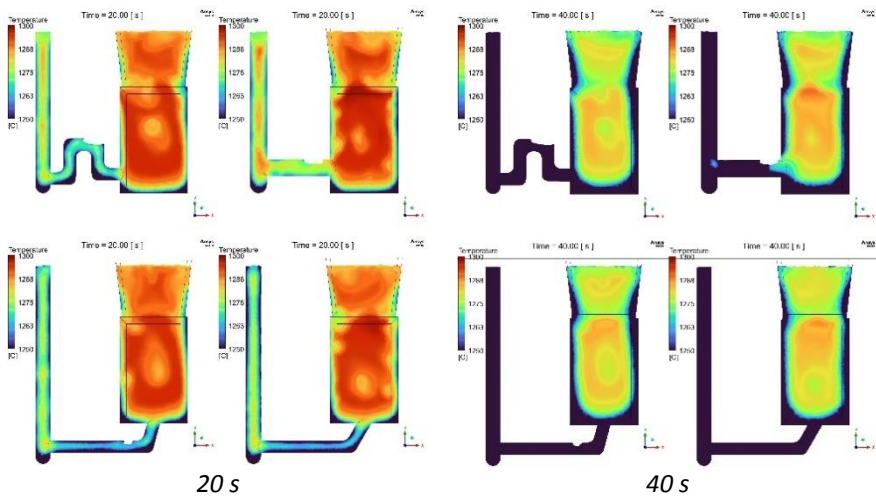


Figure 3 – Temperature distribution in the mold.

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