Numerical Simulation of MHD Stirrer for 12 Ton Metallurgical Aggregate

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***Abstract*—Paper presents results of numerical simulation of the induction stirrer for 12-ton metallurgical aggregate for liquid aluminum. A comparison between several designs of stirrer was made. Influence of stirrer position relative to metal was considered. In addition, a study of the effect of adding special high temperature magnetodielectric inserts to the lining was made. Based on the results obtained, the most energy effective design of the induction stirrer.**

***Keywords*—MHD; stirrer; electromagnetic; composit; lining;**

I. INTRODUCTION

Sverdlovsk region there are more than 70 metallurgical enterprises that produce up to 30% of volume of ferrous metallurgy and more than 20% of volume of non-ferrous metallurgy in Russia. With this scale of production, need to apply most advanced energy efficiency technologies.

One of such technologies is electromagnetic influence on liquid metal, which has proved itself in various technological processes: melt transportation [1, 2], stirring in mixers for doping [3, 4] and stirring with continuous casting [5].

At the same time, despite high efficiency, metallurgical plants of Sverdlovsk region have low amount units with electromagnetic influence on liquid metal. However, constant increase in requirements for quantity, quality and cost of products produced led to need to equip existing metallurgical units.

The paper considers modernization of a 12-ton mixer for aluminum. This mixer is used for thermostating of melt before pouring. Process is due to free convection between hot upper and cold lower layers of melt. For heating upper layer, gas burners are used. All this leads that this method has a high energy and time cost.

Proposed to place a magnetohydrodynamic (MHD) stirrer under mixer to create forced convection of melt. For maximum effectiveness of it is work, a study was conducted, consisting of two stages:

- At the first stage a comparison was made between the efficiency of equalizing the melt temperature in the mixer without and with using MHD stirrer.
- At the second stage of study, a comparison was made between efficiency of equalizing temperature of melt in unit with a standard stirrer from the first part of work and with a modernized stirrer in the design of which there are inserts from HMD composite.

II. MODEL DESCRIPTION

For the first part of the study, a two-dimensional model was built, the general form of which is shown in Fig. 1. For the second part, HMD composite inserts have been added to the initial model. The result is shown in Fig. 2. The main parameters of both models are shown in Table 1.

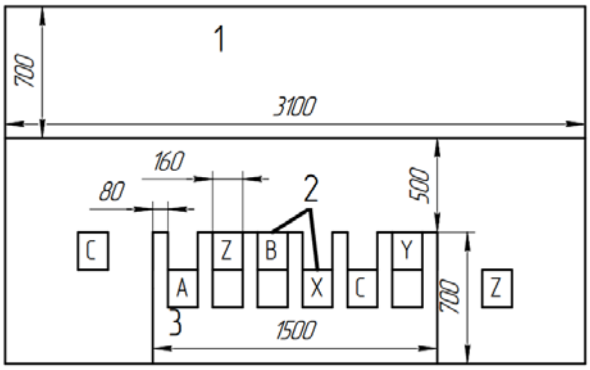

Fig. 1. Schematic representation of mixer with MHD stirrer: 1 - molten metal, 2 - coils, 3 – magnetic core.

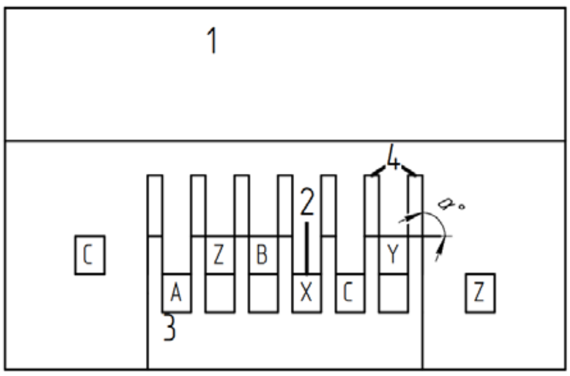

Fig. 2. Schematic representation of mixer with MHD stirrer with HMD inserts: 1 - molten metal, 2 - coils, 3 – magnetic core, 4 – HMD inserts.

TABLE I. BASIC PARAMETERS OF MHD STIRRERS

Physical parameters		
	Standard stirrer	***Modernized stirrer***
Molten metal conductivity, S/m	$3.5*10^6$	$3.5*10^6$
Relative permeability of iron core	1200	1200
Molten metal density kg/m^3		
Molten metal viscosity, Pa·s	0.002	0.002
Relative permeability of inserts	-	9.6
Inserts conductivity, S/m	-	$5*10^{-4}$
Inclination angle of inserts (α), °	-	90-30

At both stages of the study, computer modeling of three connected problems was carried out: electromagnetic, hydrodynamic and heat transfer.

A. Electromagnetic Part

Frequency of the inductor supply current is greater than F = 2 Hz, the problem was solved in a quasi-stationary formulation. It is result is a time-averaged electromagnetic force, which is then transferred to hydrodynamic part. Electromagnetic properties do not depend on temperature.

B. Hydrodynamic Part

The Reynolds number for this model is Re = $5 \cdot 10^6$, therefore for it is description k–ω SST model of turbulence was chosen. The properties of the melt are temperature independent. The free surface was not taken into account

C. Heat Transfer Part

Temperature gradient from 650°C to 700°C was given along the Z axis with same temperature values in horizontal plane at each level. At the same time, the upper part of the molten metal was heated. Stirring efficiency was estimated by time, which the temperature gradient in the melt volume would be $\Delta T = 0.5$°C, provided that the minimum temperature is T_{min} = 690°C.

All evaluations was made by means of computer simulation in program COMSOL Multiphysics.

III. RESALTS

The most convenient is to divided results into separate groups, like in model description.

A. Electromagnetic Part

Figure 3 shows distribution of induction field in the magnetic core and inserts for the three versions of stirrer. It is clear to see, that the induction does not exceed B_S=1.9 T, which means that the magnetic core and inserts do not go into saturation.

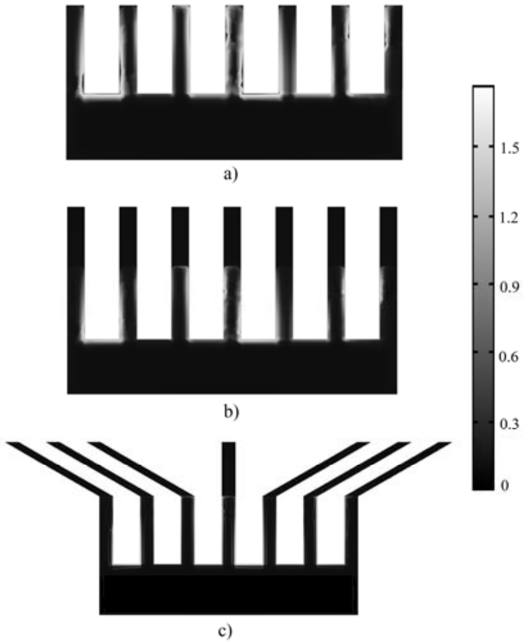

Fig. 3. Distribution of induction field for three stirrers: a – standard, b – modernized α = 90°, c – modernized α = 30°.

B. Hydrodynamic Part

Figure 4 shows distribution of time average velocity field in the molten metal for the three versions of stirrer.

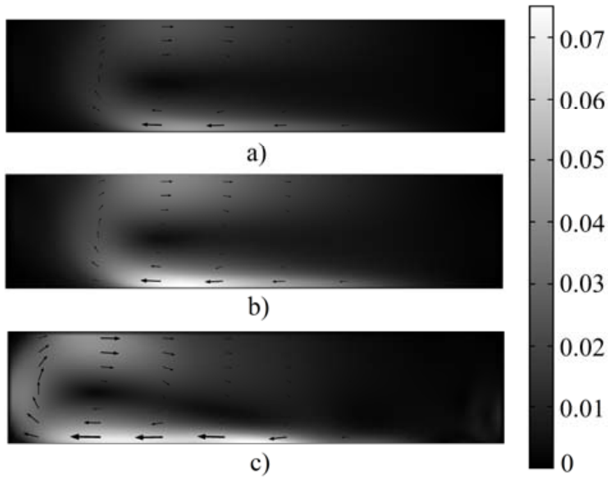

Fig. 4. Distribution of time average velocity field for three stirrers: a – standard, b – modernized α = 90°, c – modernized α = 30°.

C. *Heat Transfer Part*

Figure 5 shows dependence graph of total temperature equalization time versus inclination angle of HMD composite inserts, as well as the results for the standard stirrer.

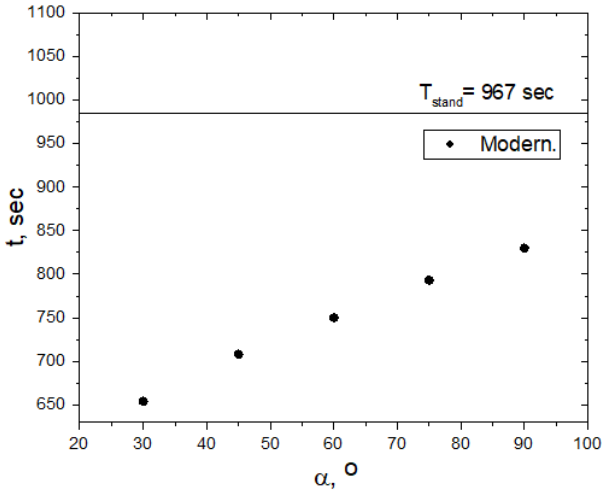

Fig. 5. Graph of total temperature equalization time.

IV. CONCLUSIONS

Using of an electromagnetic stirrer allowed increasing efficiency of mixer in 3 times. In addition, use of HMD composite inserts at different angles, also showed perspectivetes, it allowed to increase its efficiency by 4.2 times with an angle of inclination of 30 degrees.

In the future, it is planned to study in more detail influence inserts form on mixer energyefficiency.

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