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$$SI = \frac{60{,}000 \cdot \sqrt{\frac{kW \cdot D}{SG \cdot \rho \cdot f}}}{A}$$

kW is the p [redacted]
f – operatin [redacted]
D – diamete [redacted]
SG – specif [redacted]
– resistivi [redacted]

A is the area of the cross-section perpendicular to the vertical axis of the crucible, m^2.

Thus, according to the calculations based on formula (1), it has been determined that the stirring index in the crucible of the laboratory furnace will correspond to flow velocities in the transparent low-temperature model of the crucible at a liquid flow rate that pumped through the pump at $5.83 \cdot 10^{-4}$ m^3/s.

In order to determine the optimal position for introducing alloying agents and ferroalloys into the crucible of the induction furnace, a series of tests was planned with variations in the introduction place both radially and in height within the crucible. The experimental conditions included introducing materials onto the surface of the melt near the crucible wall, at a distance of 1/4, 1/2, and 3/4 radius from the crucible wall, and directly on the vertical axis of the crucible. To determine the optimal height for introducing ferroalloys, experiments were conducted with the forced immersion of the test sample on the bottom of the crucible, at 1/4, 1/2, and 3/4 of the crucible height from the bottom, and on the surface of the melt. Studies on the influence of the depth of ferroalloy introduction were based on the most effective variant of radial introduction into the crucible. The dissolution process in the simulation model was accompanied by video recording, allowing for the determination of the hydrodynamic conditions of the process (predominant trajectories of ferroalloy lump movement in the melt volume under the influence of hydrodynamic flows), the time of model ferroalloy lump dissolution, and the time of homogenization of the melt model in the crucible.

Moreover, the influence of melt movement velocity in the induction furnace crucible on the efficiency of ferroalloy dissolution processes and melt homogenization in the crucible was investigated. This was based on the best introduction variant identified in the previous research stage. The research methods and monitored parameters were similar to those of the previous case.

Each experiment was repeated three times. In addition to visual observations of the ferroalloy fragment, the criteria for the complete dissolution of the fragment and the complete homogenization of the metal bath was the absence of a gradient in the intensity of the liquid color (determined based on the video recording).

RESULTS AND DISCUSSION

Determination of the rational place for introducing the ferroalloy/deoxidizer by the radius of the induction furnace crucible and its height. In the first stage, the efficiency of dissolving a fragment of ferroalloy in the melt in the middle of the crucible of an induction furnace was investigated. In particular, consider the behaviour of a piece of ice imitating a ferroalloy at different places of its introduction into the model. Figure 2 shows characteristic trajectories of the movement of the ice piece and its dissolution, for example, when introduced near the wall (A), at a distance of 1/2 the radius (B) and in the centre of the model (C). The images for a distance of 3/4 of the radius were similar to those for 1/2 of the radius and at 1/4 of the radius were similar to those obtained when introduced near the wall, so that they are not shown.

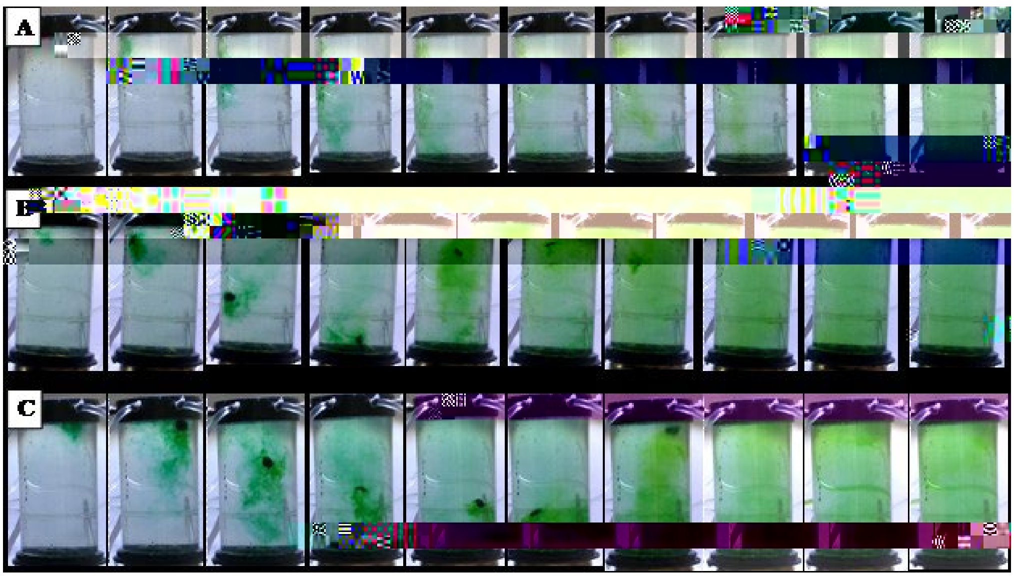

Fig.2 - Images of the trajectory of the ice piece simulating the ferroalloy and its gradual dissolution when placed: A – near the wall, B – at a distance of 1/2 of the model radius and C – at the center.

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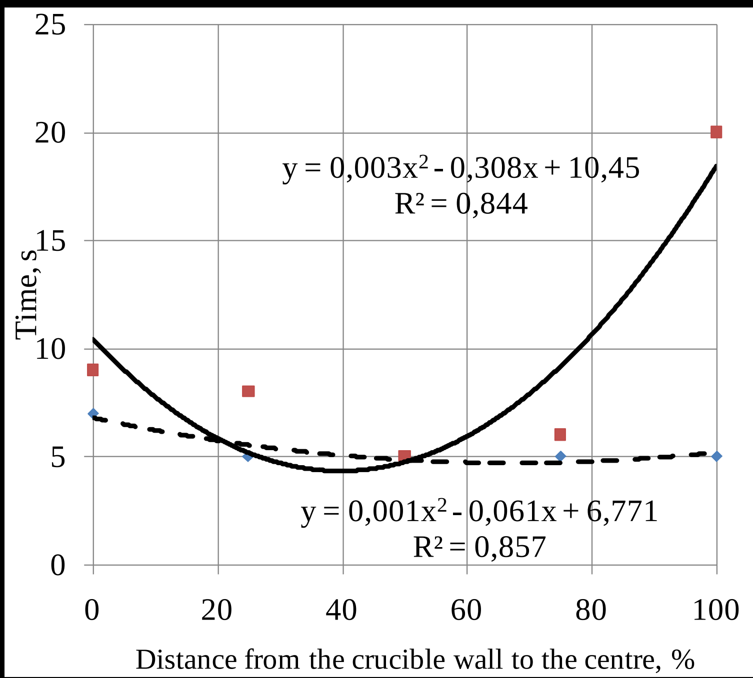

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Fig.3 - D[redacted]
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[18]. Based on this, the required holding time of the metal in the crucible of the laboratory induction furnace with a capacity of 10 kg is at least 5 minutes, and for production conditions (crucible capacity up to 150 kg), it is 10-15 minutes.

Considering the features of the affinity of alloying elements for oxygen (Fig. 7) and the essential for guaranteed removal of non-metallic inclusions formed in the melt, the following scheme of deoxidation and alloying is proposed.

Fig.7 - Features of the affinity of alloying elements for oxygen [18].

The first stage is the introduction of aluminium or silicon into the melt for deep deoxidation. Afterward, the introduction of elements with low affinity for oxygen (nickel, copper, tungsten, and molybdenum). Further, at the next stage is manganese and chromium. Then is carbon (during deoxidation, gaseous products are formed, which additionally remove non-metallic inclusions from the melt). The last stage is the introduction of rare earth materials for the final modification of the structure of both the finished steel and non-metallic inclusions.

CONCLUSION

Based on the results obtained from the low-temperature modelling of the interactions between ferroalloys and the molten bath of an induction furnace, exemplified by the interaction of colored ice fragments with water, it should be concluded that the most rational place for the introduction of ferroalloys into the crucible of an induction furnace is the area of the molten bath located at a distance of 1/2 the radius from the centre of the crucible, with better results being obtained by avoiding the central area. At the same time, due to the features of hydrodynamic flows formed in the furnace crucible, the effect of holding a ferroalloy fragment in the volume of the metal melt during the time of complete dissolution is observed.

Concerning the depth of introduction of the ferroalloy into the volume of the crucible, there is a tendency for the dissolution time to decrease with increasing depth of introduction into the melt. However, in real production conditions, it is very difficult to obtain the introduction of deoxidizers and alloying agents into the volume of the molten metal; therefore, their addition is carried out on the surface of the melt. Consequently, there is a reason for holding the melt when introducing a ferroalloy.