STUDY OF METAL HOMOGENIZATION IN TEEMING LADLES WITH USE OF VARIOUS BOTTOM BLOWING DEVICES FOR OXIDATIVE BLOWING

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Ultra Low Carbon (ULC) steels have good formability and a superior surface quality. These advantages provide their use as automobile panels since the latter half of the 1980s. This automobile panel material is normally produced by cold rolling and annealing after hot rolling, in which hot rolling is usually finished in the austenite region at the elevated temperature [1].

There are 3 technological routes for the production of ULC steel: 1) smelting of crude steel in an EAF followed by refining in AOD converter; 2) smelting of crude steel in BOF or LBE-converter followed by processing in RH-OB, VOD or VD-OB and 3) LWS-process [2-4]. The third route is not used outside of France [5]. Both technological routes significantly increase the cost of steel through application of additional units for deep decarburization of steel below a critical concentration of 0.03%. A cheaper alternative to the above-mentioned technologies is smelting of crude steel in BOF to carbon content of 0.03%, followed by oxidative blowing in a teeming ladle with oxygen-argon mixture [6].

Important indicators for the implementation of the proposed technology are the durability of the blowing devices and the mixing time of the metal in the ladle. The high durability of blowing devices can be achieved by a rational blowing mode and gases flow rates. The mixing time depends of many factors, including the design of the blowing devices, their location, the blowing mode, etc. [6].

It has been carried out number of studies aimed to determine the optimal location of the blowing devices and blowing modes [7-13]. But the effect of pores location and type of porosity in the blowing devices on the averaging mixing time still remains unexplored.

The aim of the study is to determine the effect of pores location in the blowing devices on the mixing time.

Estimation of mixing time during physical modeling on water models is possible in three ways: temperature, optical, and chemical (conductive) [15]. Since the temperature method has a high inertness, and the results obtained with the conductive method can differ depending on the location of the electrodes in the ladle model, an optical method has been chosen to estimate the mixing time, which has a sufficiently high accuracy and visibility.

The object of the study was a unit cell mixing of the teeming ladle of 250 t capacity, in which the distribution of the additive occurs. According to the principles of similarity theory, the gas flow rate can be described by the dimensionless volumetric flow rate [13] and the mixing time by the modified homochromous number [6]

$$Q = \frac{q}{\sqrt{g \cdot d^5}}, \quad (1)$$

$$Ho' = \frac{g \cdot \tau^2}{d}, \quad (2)$$

where q – gas flow rate; g – acceleration of gravity; d –diameter of porous plug; τ – mixing time.

For the experiment, an experimental facility was assembled on a 1:8 scale. As a tracer imitating chemical heterogeneity of the melt, we used a 30% aqueous solution of $KMnO_4$, in an amount of 100 ml. A tracer was poured at the top of the model. The completion of melt homogenization was judged by approximating the color intensity of the solution to the color of a 3.5% $KMnO_4$ aqueous solution installed in a transparent container on the other side of the transparent model.

Using the video, the time was estimated for which the entire volume of liquid reached a uniform color, the same as the color of the control sample. Figure shows a comparison of the average tracer mixing time in water. As can be seen from the comparison, blowing devices with non-directional porosity provide the shortest mixing time. This is probably due to the larger total specific area of the bubbles that form on the surface of the blowing device with non-oriented porosity.

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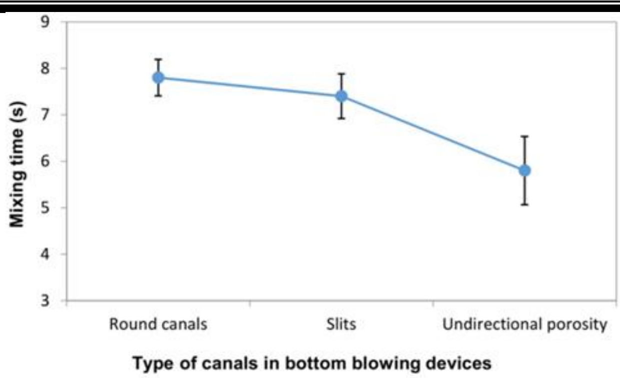

Figure 3 – Comparison of mixing time when using porous devices of various designs

At the same time, plugs with non-oriented porosity have two significant disadvantages [16]. The first is the rapid wear of the working part of the blowing devices in contact with the metal. The second disadvantage is their low throughput. The last one is eliminated when using plugs with slot porosity. However, when using such plugs, there is a risk of deep infiltration of liquid metal into the slots during an uneven argon supply.

The aim of further research is the development of the design of the mixing chamber of the blowing device, in which oxygen and argon are pre-mixed before being blown into the liquid metal.

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