ASSESSMENT OF BATH MOVEMENT INTENSITY ON PHYSICAL MODEL

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Abstract

Physical simulation of complicated phenomena in fluid mechanics is still widely used. Together with mathematical modeling it provides the necessary knowledge and information about the studied problems and thus significantly contributes to solving of design- engineering tasks. This paper is related to efforts to increase the intensity of energy, mass and momentum transfer in the metal and the slag melt bath or homogenisation and agitation improvement in steelmaking furnaces (ladles).

This can be achieved by argon blowing by suitably located (bottom) blowing blocks, which blow gas under bath level, or lances (nozzles) that guide the flow of flowing gas on the surface of the melt. Measurements and experiments on a physical models provides valuable information for the realization of this intention. Physical model equipped by measuring and evaluation system allows to analyze the properties of the flow fields generated in the model melt. From the results obtained from the model measurement it is possible to deduce the behavior of the melt in the process of argon blowing by different types of tuyeres and also in time of combined argon and refining oxygen blowing in the real situation.

Keywords: physical simulation, gas blowing, homogenisation, tuyeres

1. INTRODUCTION

Perfect bath homogenization (of liquid steel) is a technologically very important factor that has , especially in the aggregates for the metals production, affect on the quality of the produced material. For the purpose of the melt homogenization so called tuyere blocks are used which are built-in into the refractory lining layer and are located primarily in the bottom of the hearth steel furnaces and ladles. Except tuyere blocks for example the homogenizing nozzles are used for the purpose of the steel homogenizing. This nozzles are inserted into the liquid bath from above. They are mainly used in cases when it isn't for example from technological reasons possible to blow through bottom of the aggregate, in case where high work security is required and as backup device in case of failure of the buttom blowing device.

Information about quality of the homogenization can be obtained in addition to the numerical modeling [2], [3] also from experiment on a physical model of the aggregate. Experimental research of bath homogenization on hearth physical models has task to determine the optimal operation method for homogenization , the number of tuyere blocks, number of jets , the number of nozzles and their placement in the hearth of the furnace. In this context it is necessary to design and make a model of the hearth , blowing system including models of tuyeres themselves or nozzles [1].

2. EXPERIMENTAL MEASUREMENT

In work focused on the physical modeling invariants of physical similarity must be determined. They are based on relevant criteria equations - incomplete physical resemblance. On the basis of this physical similarity model of the furnace hearth including blowing elements is constructed.

Drinking water was in isothermal models used as the liquid simulated melt. Compressed air was used as blowing media. Compressed air supply system was designed in such a way that it allows pressure regulation of the air flow flowing to blowing elements (nozzles).

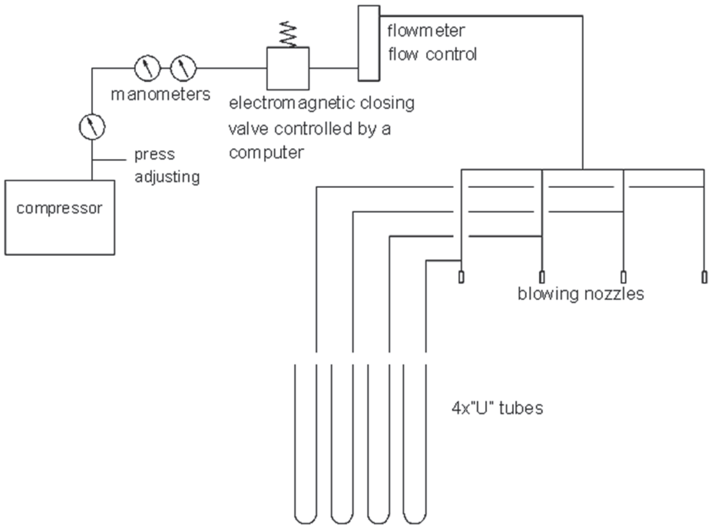

Fig. 1 Scheme of compressed air supply to model burners

When assessing the effects of the argon stream to steel melt it is based on the criteria given by the ratio of the total momentum of the argon stream to counterforce acting at given depth of the melt in the nozzle outlet cross section of the blowing element $\pi = H_p/P$ (ratio of current flow momentum and counterforce in the outlet cross section of the nozzle) [1].

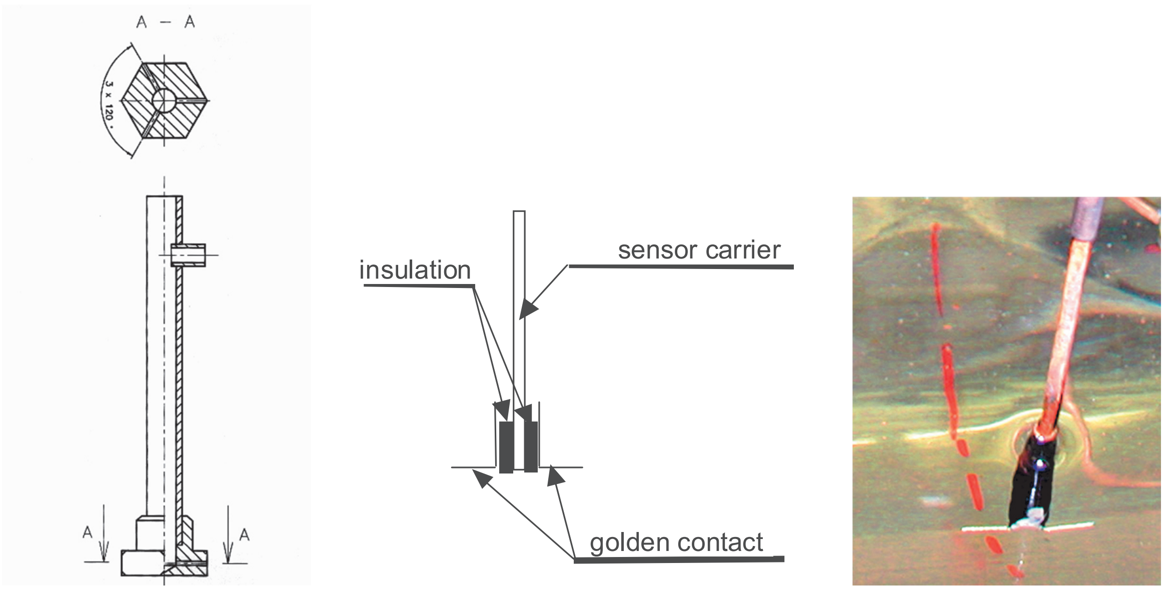

Fig. 1 Example of three-hole nozzle design on the model - on the left
Design of the measuring probes (sensors) and design detail - in the middle and on the right

To determine this criterion it is therefore necessary to determine the parameters of the argon outlet stream from a single nozzle (at the tuyere, which contains more nozzles). Functional relationships between physical quantities valid for one-dimensional isentropic flow of an ideal gas are used to determine these characteristics [4],[5].

$$\frac{p}{\rho} = f(R,T)\,; \qquad Q_m = f(S,\rho,v)\,; \qquad \frac{p_0}{p} = f(\kappa,M)\,; \qquad \rho = f(\kappa,\rho_0,M)\,;$$

$$v_{kr} = f(\kappa,R,T_0)\,; \qquad v = f(\kappa,p_0,\rho_0,p)\,; \qquad \frac{p_0}{p_{kr}} = f(\kappa)\,; \qquad H_p = f(S,\rho,v)\,; \quad P = f(S,p)\,.$$

κ	isentropic exponent	[1]
R	individual gas constant	$[J.kg^{-1}.K^{-1}]$
S	flow area	$[m^2]$
p	pressure	[Pa], [MPa]
T	static temperature	[K]
ρ	density	$[kg.m^{-3}]$
Q_m	mass quantities flowing through the nozzle	$[kg.s^{-1}]$
v	flow speed	$[m.s^{-1}]$
M	Mach number	[1]
H_p	low momentum	[N]
P	counterforce in the outlet of the nozzle	[N]

meaning of subscripts:

kr	value corresponding to the critical state of flow
0	static value

Required air flow for a given number of nozzles in the tuyere head is determined to create the value of specified criteria which is given by a ratio of current flow momentum and counterforce in the outlet cross section of the nozzle - $\pi = H_p / P$.

Example of model jets downloaded into the melt from above construction design is shown in **Fig. 2**.

The whole measuring line consists of the blown media distribution and measuring apparatus. The measuring device itself includes several probes and evaluation computer for processing data from the probes.

The measurement is performed by measuring probes (sensors) which are located in the model hearth (melt) with some regularity in exposed places - where it is necessary to measure the intensity of the melt movement. Schematic probe structure is shown in **Fig. 2** [1].

Probes, calibration measurements of which showed that to the flow velocity (water between contacts) $6mm.s^{-1}$ is a deadzone and from the speed of $20mm.s^{-1}$ is the saturation zone, are used for measurement.

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Signals from individual probes are recorded in a period of 0.5 seconds.

For better and clearer possibility of comparison of the particular measurement the measured data are transformed to the form as documented in **Fig. 3**.

When evaluating the quality of heart content mixing the following data are compared :

- • signal speed increase
- • maximum voltage level achieved,
- • speed with which there was a voltage decrease on the probes after finishing of blowing.

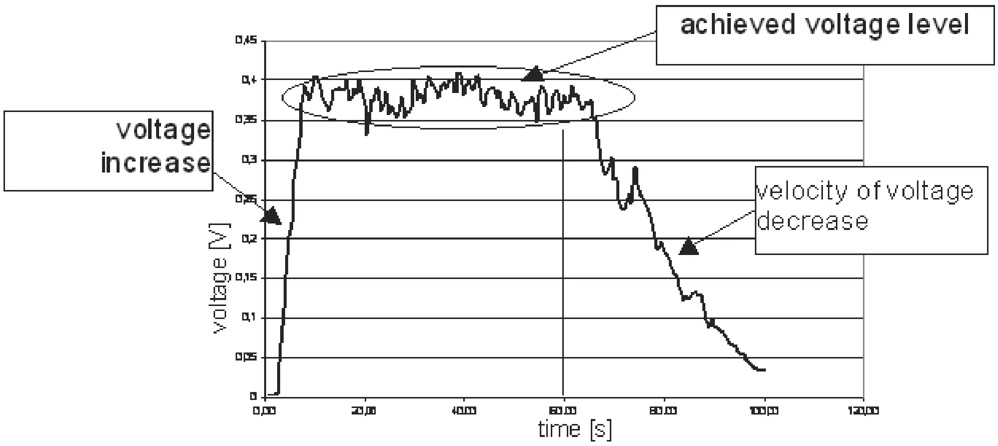

Fig. 2 Processed data for comparing

Measurement is performed for the same position of the measuring probes in the hearth and with different types of nozzles and their location in the hearth. By their comparison is then selected the most appropriate nozzle design and its location in the hearth with regard to the bath (melt) movement intensity (homogenization) [1][1].

The measured value shows the differences in the quality of homogenization (mixing) (expressed by level of electric signal) for various blowing elements configurations and different blowing modes.

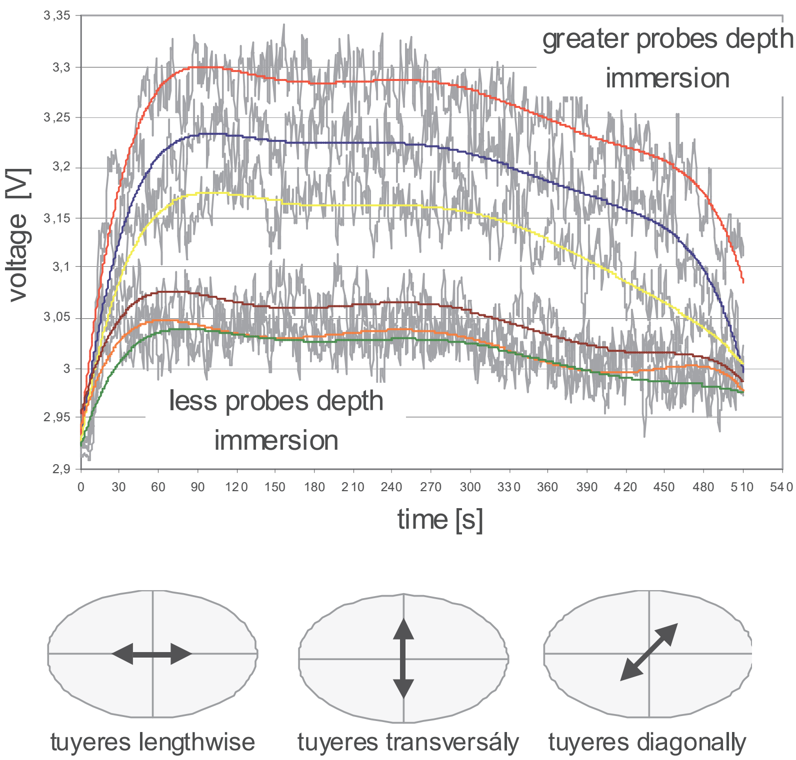

Fig. 3 Measurements with one two-hole nozzle (curves in the graph are sorted according to legend)

As an example can be mentioned following **Fig. 4**, which shows the quality of mixing using a two-hole nozzles with output flows from individual nozzles in a horizontal plane (expressed by voltage on the probes) during measurement in an oval hearth.

Measurements could be performed for two different depths of blowing nozzle immersion under the water level in model and for varying degrees of rotation due to the longitudinal axis of the hearth. As can be seen from **Fig. 4**, in this case, nozzle oriented in the direction diagonally to the axes of the hearth has the highest intensity of the homogenization.

Further measurements can performed in order to achieve even better results (better homogenization in the shortest time). In this context various design of nozzles including the shapes of the hearth are tested. As an example we can take **Fig. 5** from which it is evident that the mixing quality depends on the shape of the hearth.

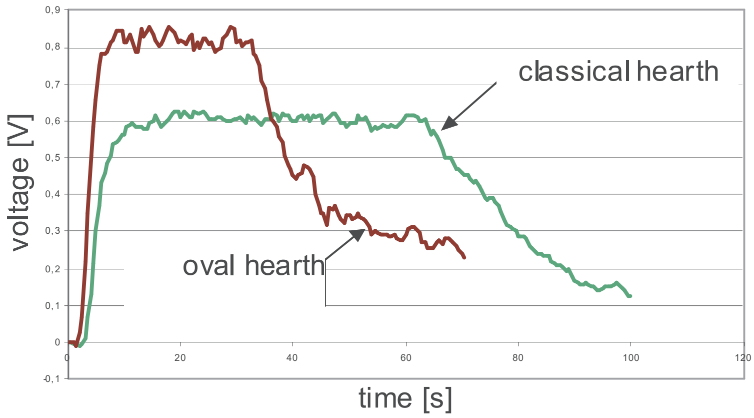

Fig. 4 Mixing quality (voltage level at probes versus time) within a specified depth below the surface level

Similar measurements are carried out for the comparison of different models of bottom tuyeres. Detail view on the measurement arrangement in the classical hearth is in **Fig. 6**.

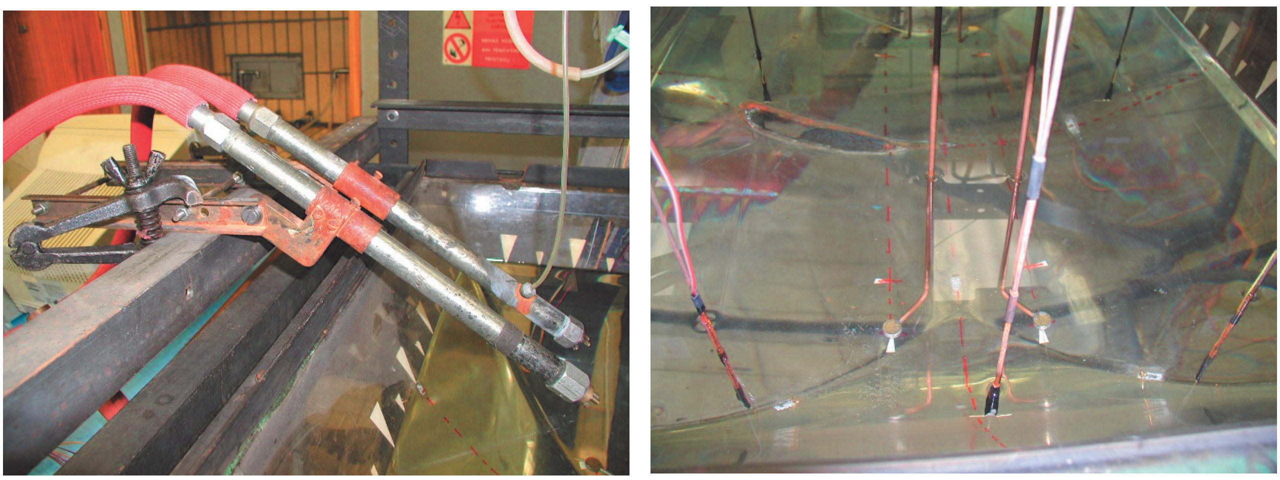

Fig. 5 Detail of upper nozzles (on the left) - detail of probes placement (on the right)

CONCLUSION

Experimental research of bath homogenization on hearth physical models intends to establish the optimum operation method of homogenization, the number of blowing blocks, tuyeres, the number of nozzles and their placement in the furnace hearth.

Physical model implementation is based on the dimensional and technological operating parameters. Based on the results of physical modeling it is possible to recommend operating characteristics of gaseous media blowing to the melt in the hearth including alternative blowing nozzles design, their number and location in the furnace hearth.

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