M. SATERNUS, T. MERDER

A FLOW RATE OF GAS VERSUS THE LEVEL OF GAS DISPERSION IN PHYSICAL MODEL OF CONTINUOUS REFINING REACTOR

Today there are many reactors used in refining of primary and secondary aluminium. Continuous reactor URC-7000 is one of them. The model of such reactor was built at 1:3 scale. The physical modelling research was conducted taking into account the flow rate of refining gas and its influence of the dispersion level. There are two nozzles introducing a gas. The carried out tests included the different flow rate of a gas through the nozzles (from 5 to 15 dm^3/min). Additionally, the mixing characteristics were measured and discussed for different flow rate of an inert gas.

Key words: aluminium, refining, argon, hydrogen, physical modelling

INTRODUCTION

Today aluminium refining, especially using blowing with inert argon has become one of the main stages of aluminium production. During this operation the hydrogen in liquid metal as an impurity is removed. There are many technological solutions of this process, however generally they can be divided, taking into account the way of operation, into the bath and continuous reactors [1].

As a refining gas chlorine and/or argon are used. The efficiency of applying such gases is comparable; the final hydrogen concentration is almost at the same level. However, the removal of metallic impurities when using argon is very slight. Additionally, the layer of dross is considerably heavier. It is quite opposite when applying chlorine as a refining gas. It removes even 70% of impurities and the layer of dross is very light. After taking into account the harmfulness of chlorine and its negative impact on the environment, the argon is today the most popular used gas for aluminium refining [2].

Refining gas can be introduced to the liquid aluminium by many different ways; by means of lances, ceramic porous plugs, or the most popular rotary impellers. Such equipment is very important because decides if the refining gas is well mixed in the liquid metal, so the uniform dispersion in the whole volume of the reactor can be obtained. It also influences the course of the process and refining time [3,4].

One of the popular reactors used for continuous refining is Polish URC-700 reactor. Such reactor is equipped with two chambers: refining and filtration. In refining chamber gas is introduced into the liquid metal

by two ceramic porous plugs placed in the bottom of the reactor. Then the liquid metal is fulfilled with gas bubbles, which as a consequence absorb hydrogen and pick it up to the surface together with nonmetallic impurities. In this process the most important factors influencing the process are: time, temperature and the area of mass exchange. The smaller gas bubbles, the better their dispersion in the liquid metallic phase – area of mass exchange is bigger so the way of hydrogen diffusion is shorter [5,6].

The choice of appropriate processing parameters for such reactors is very important taking into account their correct and economical work. Because it is hard to test such reactors in industry, modelling research both physical and numerical is often used [7-10].

METHODOLOGY OF THE RESEARCH

The aim of the research was to determine the optimal technological parameters (mainly the flow rate of refining gas) of the blowing aluminium by inert gas in the reactor URC-7000. The speed of mixing was also checked when the porous plugs introduced the refining gas into the liquid metal with different flow rate.

Research was carried out using the test stand of URC-7000 reactor water model – see Figure 1. Such model was made at the scale 1:3.

Such model is used when the simulation of hydrodynamic conditions occurring in the liquid aluminium during its refining needs to be obtained. The similarity of the model to the real URC-7000 reactor is fulfilled basing on the geometrical, dynamic and kinetic similarity. To determine the dynamic similarity the rule of criterial numbers equality in the model and real object was applied. Kinetic similarity was determined by means of scale method, in which the modified Froude`s number was used [11].

M. Saternus, T. Merder: Silesian University of Technology, Institute of Metals Technology, Katowice, Poland
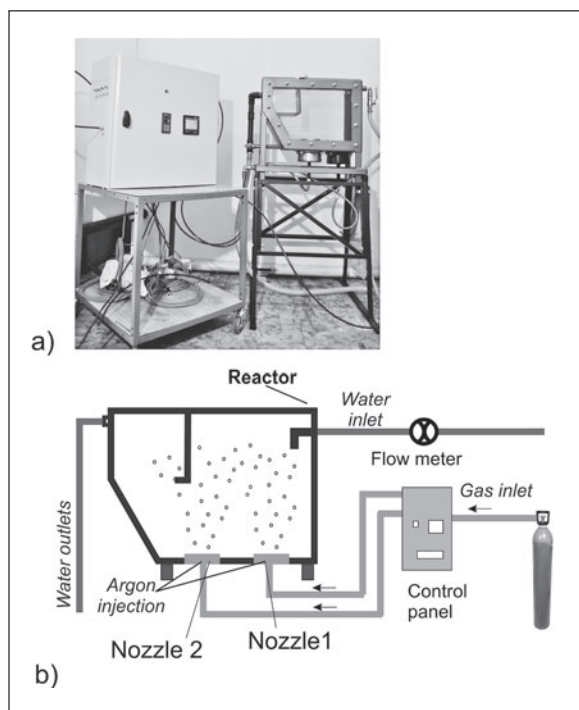
Figure 1 a) The test stand used for modelling research b) with the description

The carried out research was divided into two stages. First stage was based on measuring the change of modelling agent conductivity after introducing tracer into the system. As a tracer 5 % water solution of NaCl (150 g) was used. Such tracer was introduced near the inlet through 5 s (impulse signal input function). The variation of tracer concentration was registered continuously in the chosen measurement points (see Figure 2) by means of conductometers. The conducted measurements enable to determine the distribution of tracer concentration changes in the chosen points of the reactor working zones.

In the second stage the visualization research was conducted. Such research enables to determine the level of gas bubbles dispersion in the liquid metal for the tested cases.

Table 1 shows the variants of different flow rate of the refining gas introduced by ceramic porous plugs (nozzle 1 or 2).
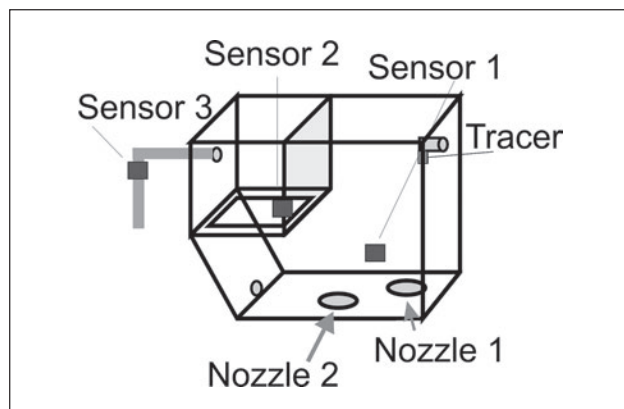

Figure 2 The places of: tracer introduction and conductometers sensor fixed

RESULTS OF RESEARCH
– Analysis of mixing curves

Figure 3 presents the chosen results of conductivity research after introduction of tracer to modelling agent for case A, C and E for all three sensors (concentration versus the time).

Table 1 The variants of flow rate of refining gas and water used in the modelling research

Case	Flow rate / dm³·min⁻¹		water
	argon		
A	Nozzle 1	5	
	Nozzle 2	5	
B	Nozzle 1	10	
	Nozzle 2	10	
C	Nozzle 1	15	
	Nozzle 2	15	
D	Nozzle 1	5	
	Nozzle 2	10	
E	Nozzle 1	10	11
	Nozzle 2	5	
F	Nozzle 1	5	
	Nozzle 2	15	
G	Nozzle 1	15	
	Nozzle 2	5	
H	Nozzle 1	10	
	Nozzle 2	15	
I	Nozzle 1	15	
	Nozzle 2	10	

Analyzing the curves presented in Figure 3, particularly in the range from 0 to 50 s, the considerable difference can be seen between single curves corresponding to the place of sensor fixing. The course of curves suggests that the flow in the studied object is complex and differentiated. In the place of fixing the sensor No 1 for all studied cases the highest point is observed (the highest value of tracer concentration). Its maximal value depends on the studied case. That means in the region of fixing sensor No 1 the bypass flow can occur.

For the sensor No 3 some leaps of conductivity are observed – such turbulences can be explained by the place of its fixing (on the outlet from the reactor), so there is incorrect contact with the modelling agent. This is why the measurement coming from this sensor was neglected in the next stage of analysis.

To obtain dimensionless characteristics they had to be calculated according to [12]. For the accurate presentation of the curves, the axes of time were limited to 50 s. Analyzing the obtained curves the considerable difference between them can be seen. Time of tracer moving to the sensor No 2 (see Figure 4) is much longer than to the sensor No 1. The considerably lower peak of maximal concentration for the sensor No 2 can be also seen.

It is a result of sensor fixing and also the structure of the flow and it is also connected with the processing parameters of the research, so mainly the flow rate of refining gas.
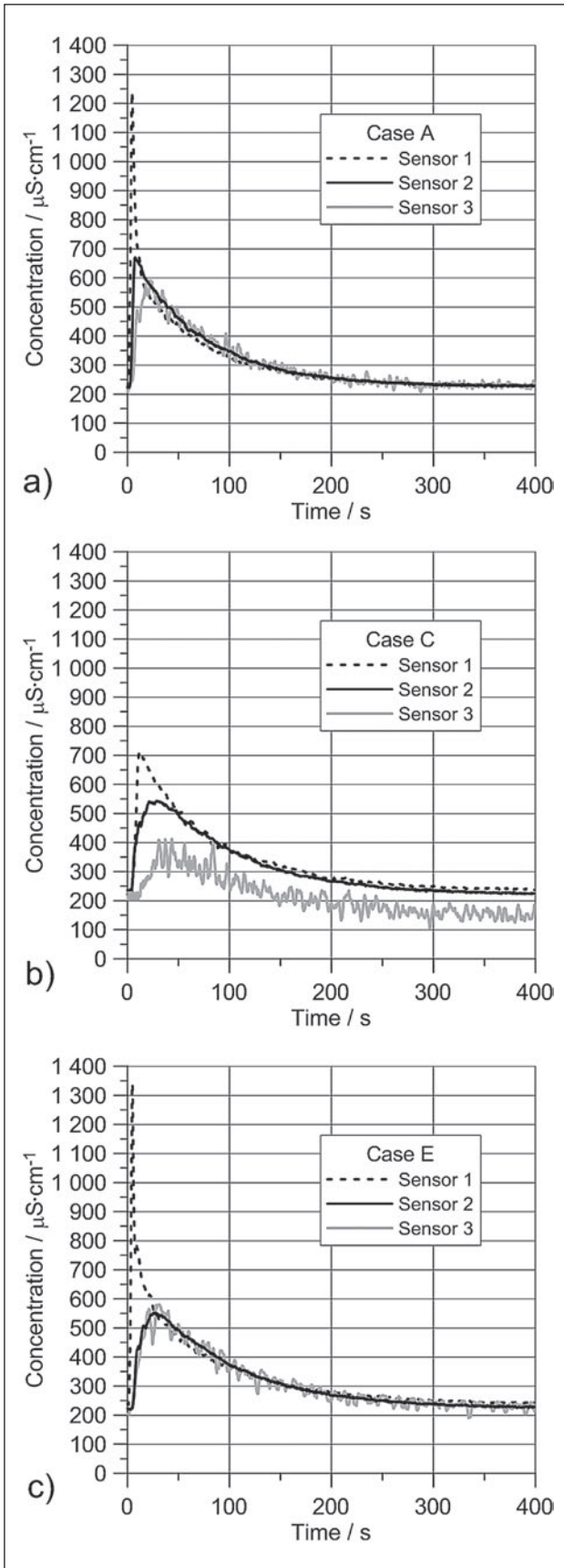
Figure 3 Concentration of tracer (in studied points) as a function of time: a) Case A, b) Case C, c) Case E

Figure 4 Dimensionless characteristics for:
a) sensor No 1, b) sensor No 2

D; for this case also the highest point is seen. For Case C (flow rate of gas through both nozzles is 15 $dm^3 \cdot min^{-1}$) time of tracer moving to the sensor is the longest. For Case F such time is comparable however there is almost no peak of maximal concentration.

Analyzing the curves obtained for the sensor No 2 the shortest time of tracer moving to the sensor and the highest point of maximal tracer concentration is observed for Case B.

For some studied cases, among others Case B (see Figure 4b), the occurring of the backing circulation especially in the area of the sensor can be clearly seen (renewed increase of tracer concentration). That means, that in the studied cases there is not enough mixing (tracer distribution) in the whole object.

The longest time of tracer coming to the sensor is observed for the Case G, whereas in Case F and H there is no clear peak.

To sum up, the characteristics of the tracer distribution allow to estimate the influence of the change of the processing parameters (flow rate of refining gas). They also give information about the structure of the flow

Figure 4 presents the characteristics of mixing for the studied cases; they are in the dimensionless form for the purpose of direct comparison. The shorter time of tracer moving to the sensor No 1 is observed for Case
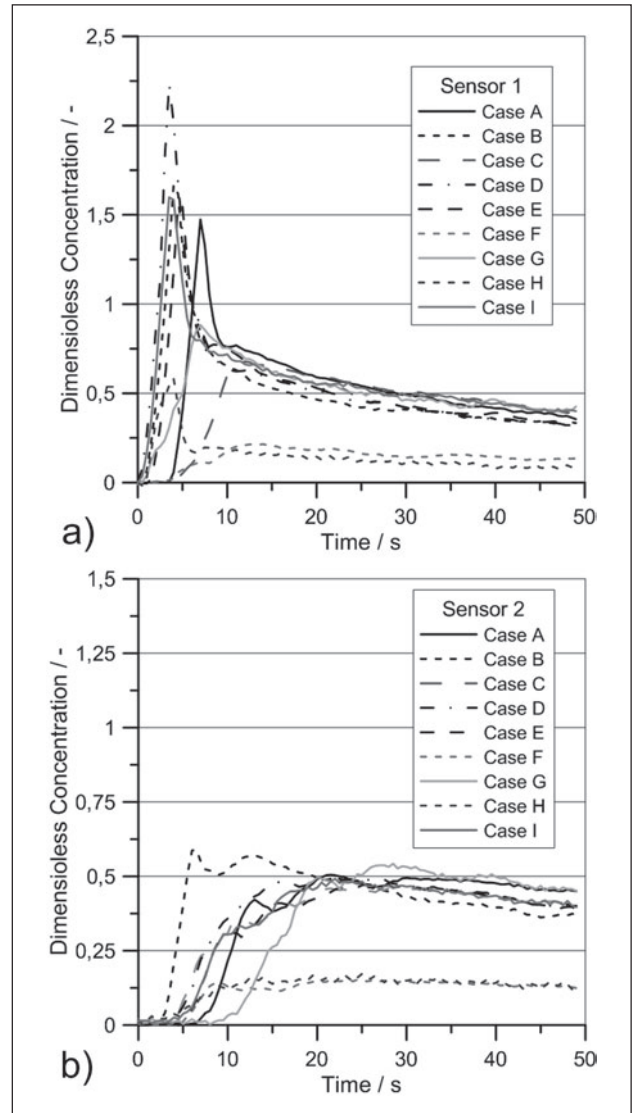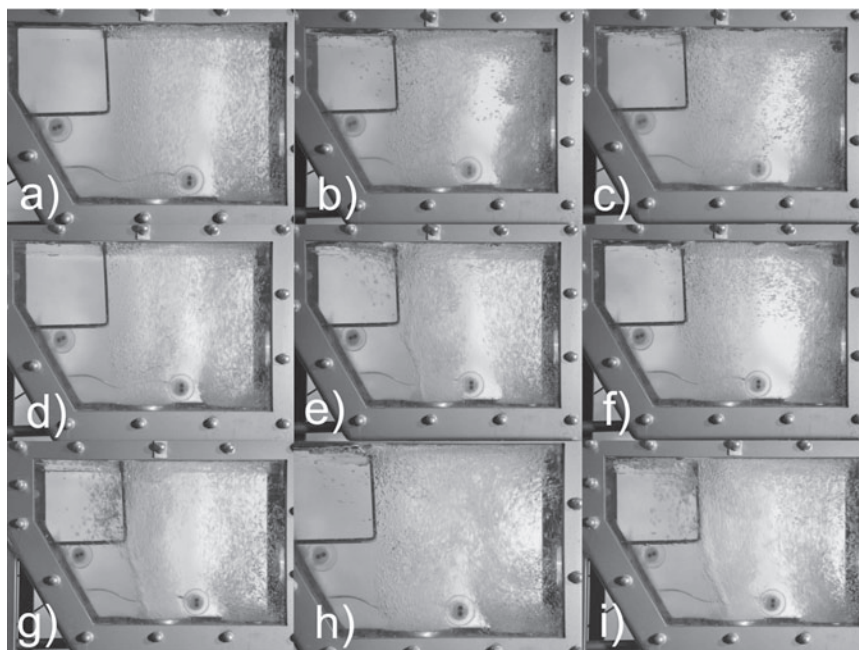
Figure 5 Characteristics of dispersion occurring in the process of argon blowing through water in the dependence of the flow rate of refining gas: a) Case A, b) Case B, c) Case C, d) Case D, e) Case E, f) Case F, g) Case G, h) Case H, i) Case I

(the condition of mixing) that occurs in the studied object. The most favourable conditions for refining process conducted in URC-7000 reactor are for Case C.

–˝Determination of gas bubbles dispersion

Figure 5 shows the chosen measurements illustrating the gas bubbles dispersion in modelling agent in the whole volume of the reactor. For Case A and B the minimal dispersion is seen. It is characterized by the single gas bubbles rising up to the surface – such dispersion is seen only in the area of bubbles generation – there is no mixing in the whole reactor. For Case C, D, H and I the uniform dispersion is observed. The single gas bubbles and also bubbles chains are rising up to the top of the reactor. Well mixing of gas bubbles with liquid is seen, there is no dispersion only in the bottom part of the reactor (near the nozzles); swirls on the upper part of the reactor cause mixing in that area. For case E, G and I swirls are observed, which are not favourable for the studied process, because they can again adsorb hydrogen to the liquid metal.

CONCLUSIONS

Basing on the conducted research the following conclusions were drawn:
- Variable parameters of flow rate of refining gas introduced into the model influence the process course. Physical modelling makes it easy to choose the appropriate parameters in the real process.
- Time of tracer coming to the sensor No 1 is shorter in Cases E, G and I; in these cases the flow rate of gas introduced by the nozzle 1 is higher than by the nozzle 2.

- When the flow rate of gas is small (in case of all nozzles – Case A) dispersion of gas bubbles in liquid is seen only in some parts of the reactor, the same situation is observed for Cases B, D and F.
- For Cases E, G and I swirls are occurring, which are not favourable to the studied process.
- The most favourable conditions of working are obtained for Cases C and H taking into account the curves of mixing and the dispersion of gas bubbles.

Acknowledgements

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