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MODELLING RESEARCH OF HYDROGEN DESORPTION FROM LIQUID ALUMINIUM AND ITS ALLOYS

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The refining process is essential for the removing undesirable hydrogen and harmful impurities from liquid aluminium and its alloys. Physical modelling allows to observe the level of refining gas dispersion in the liquid aluminium. Test stand for physical modelling of the barbotage process of aluminum for the bath reactor (URO-200) and continuous reactor (URC-7000) were built. Measurements of the oxygen removal from water were carried out as analogy of the hydrogen desorption process from liquid aluminium. In the research the distilled water saturated with the compressed oxygen was used. The level of water saturation with oxygen and then oxygen desorption from water was reached by means of the dissolved oxygen meter Elmetron CO-401.

Key words: aluminium refining process, physical modelling, hidrogen desorption, Al and Alloys

Modelsko istraživanje desorpcije vodika iz rastaljenog aluminija i njegovih legura. Proces rafiniranja je vrlo značajan zbog odstranjivanja nepoželjnog vodika i drugih štetnih nečistoća iz rastaljenog aluminija. Fizikalno modeliranje dopušta da se uoči razina disperzije rafiniranog plina u tekućem aluminiju. Izrađen je pristup za fizikalno modeliranje procesa rafiniranja aluminija. Mjerenja odstranjivanja kisika iz vode su provedena po analogiji procesa desorpcije vodika iz tekućeg aluminija. U istraživanju je korištena destilirana voda zasićena komprimiranim kisikom. Razina zasićenosti kisikom i desorpcija kisika iz vode je postignuta pomoću okigenometra Elmetron CO-401.

Ključne riječi: proces rafiniranja aluminija, fizikalno modeliranje, desorpcije vodika, Al i Al slitine

INTRODUCTION

Barbotage is one of the most universal methods used for refining process of aluminium and its alloys. In this process tiny gas bubbles are generated and during their rising up to the surface the hydrogen is removed. In the same time some inclusions such as sodium, calcium and non-metallic particles, like oxides or borides can be also eliminated from the liquid metal due to flotation [1].

There are several technological solutions of the barbotage process. The method of gas introduction to the metal such as lance, ceramic porous plugs, nozzles or rotary impellers plays an important role in these solutions. Nowadays many batch reactors are replaced by continuous reactors and the continuous refining process becomes more and more popular [2].

URO-200 AND URC-7000 RECTORS

Several reactors are used for the refining process of aluminium and its alloys. In Poland typical representative of reactors that can be used for the barbotage process are URO-200 and URC-7000 reactors. These reactors were designed in the Lights Metals Division OML Skawina, the branch of the Institute of Non-Ferrous Metals IMN - Gliwice. URO-200 and URC-7000 reactors are presented in Figure 1 and Figure 2 respectively.

URO-200 reactor is used for batch refining process. It consists of a rotary impeller and a power feed. The rotary impeller is put into liquid metal in furnace or crucible. To obtain the uniform mixing of the refining gas in the liquid metal, it is very important to choose properly the processing parameters like flow rate of refining gas and rotary impeller speed. The refining time is rather short – about ten minutes.

Figure 1 View of URO-200 reactor

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Figure 2 View of URC-7000 reactor [3]

URC-7000 reactor consists of two chambers: refining and filtration. The ceramic porous plugs are located inside the refining chamber. Removal of hydrogen and non-wettable nonmetallic particles from liquid metal is the main task of this chamber. In filtration chamber the filter is installed, and above it in the upper part of the cover - a burner used to warm the filter and chambers.

PHYSICAL MODEL OF THE URO-200 AND URC-7000 REACTORS

In the laboratory of Metallurgy Department at the Silesian University of Technology there are two test stands for modelling research. The first test stand is used for simulating conditions that can be reached during the work of URO-200 reactor. This test stand is at the 1:1 scale. Figure 3 presents the scheme of this test stand. It consists of the transparent tank with modelling agent, power feeding for the change the rotary impeller speed and the rotameter to control the flow rate of the refining gas.

For modelling research of the URC-7000 reactor the second test stand at the 1:4 scale was built (see Figure 4). This modelling unit consists of the transparent tank with modelling agent for observation of gas dispersion, two rotameters to control the flow rate of refining gas introduced by the ceramic porous plugs and the flow meter of a modelling agent. In both cases water is used as a modelling agent, and argon as a refining gas.

The results obtained from physical models can be representative only if could be transformed to real conditions, the built test stands have to fulfill the rules from the theory of similarity [4,5]. It is possible to solve these problems using appropriate criterial numbers, which values should be the same in case of model and real object. For the refining process of aluminium and its alloys with barbotage the most important numbers are: Reynolds, Weber and Froud. The values of these numbers for water and aluminium for both reactors: URO-200 and URC-7000 were calculated and are shown in Table 1.

TEST OF OXYGEN REMOVAL FROM MODELLING AGENT

The test of oxygen removal from water was carried out as analogy of hydrogen desorption from liquid aluminium. This method is commonly used by the company producing reactors for refining process [7]. Laboratory tests for the URO-200 reactor were carried out using distilled water oxygenated to the level of full saturation at the particular temperature. The level of oxygen saturation in water was measured by means of the oxygen meter Elmetron CO-401 (see Figure 5). The meter was calibrated and operated in the mg O_2/dm^3. The meter was equipped with automatic temperature compensation. The oxygen sensor was placed vertically downward near the shaft which aim is to reduce existing whirl when the speed of rotary impeller is high.

After full saturation the refining gas was introduced to water. The flow rate of refining gas was changed from 5 through 10 to 15 dm^3/min. The influence of the rotary impeller speed was also investigated. Laboratory tests

Figure 3 The view of test stand for the modelling research in the URO-200 reactor

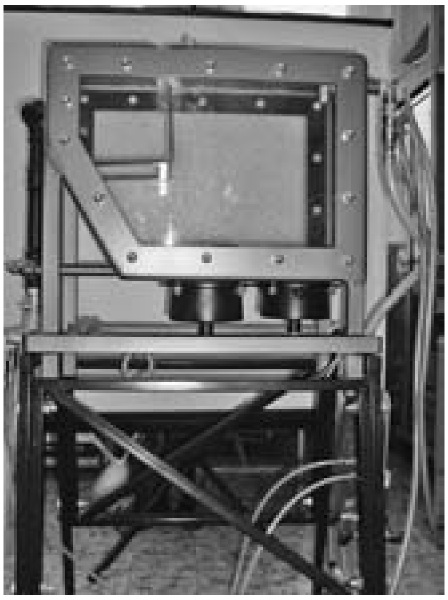

Figure 4 The view of test stand for the modelling research in the URC-7000 reactor

Table 1 **Comparison of the criterial numbers values calculated for water and aluminium for the URO-200 and URC-7000 reactor** [6]

Criterial number	Water	Aluminium
Temperature	293 K	973 K
URO-200 reactor		
Reynolds, Re	27 802	67 392
Weber, We	84,24	21,41
Froud, Fr	$2{,}9 \cdot 10^{-4}$	$2{,}9 \cdot 10^{-4}$
URC-7000 reactor		
Reynolds, Re	1 905,9	4 620,0
Weber, We	0,467	0,118
Froud, Fr	$2{,}8 \cdot 10^{-4}$	$2{,}8 \cdot 10^{-4}$

Figure 5 Oxygen meter Elmetron CO-401

were carried out for the rotary impellers speed in the range from 200 to 500 rpm taking into account every 100 rpm. Dissolved oxygen readings were taken every minute for ten minutes – the work time (every refining process) in the URO-200 reactor. The obtained results are presented in Figure 6. For each rotary impeller speed the comparison of removed oxygen level for three different flow rates of refining gas were determined.

For the URC-7000 reactor running water was used as a modelling agent. After measuring its level of oxygen (in the range 7,67-7,73 mg/dm^3) the test started.

The flow rate of water was constant of 11 dm^3/min. The influence of flow rate of refining gas on the level of oxygen removal was investigated. The flow rate of refining gas changed from 2 through 6 to 10 dm^3/min. Dissolved oxygen readings were taken every minute for six minutes and after, the readings were at the constant level. The results, for three different flow rate of refining gas, are presented in Figure 7.

DISCUSSION OF RESULTS AND CONCLUSIONS

The built test stands give the possibility to observe what happens during the refining process. Process of creating the bubbles and then the mixing of gas bubbles

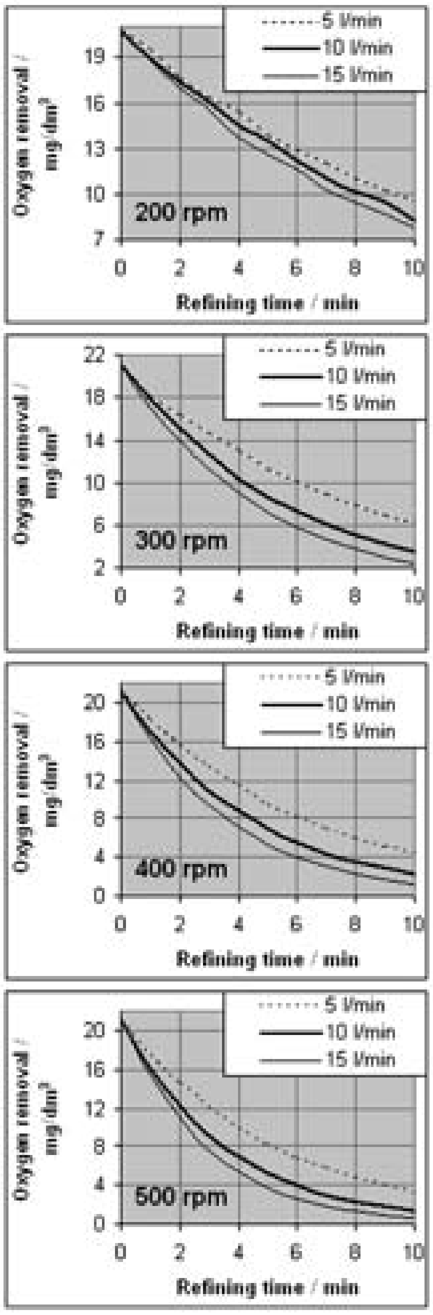

Figure 6 Results of oxygen removal from water in URO-200 reactor

with liquid metal is rather complex and difficult to describe it in analytical way. For this reason, the modelling research is carried out. In this research oxygen was removed from water as analogy of hydrogen desorption from liquid metal. The test stand for modelling research was build in accordance with the theory of similarity.

In case of URO-200 reactor the research was carried out considering the different flow rate of refining gas (5-15 dm^3/min) and of the rotary impeller speed (200-500 rpm). From the industrial point of view the most satisfactory results are obtained applying the following parameters:

– flow rate of refining gas – 15 dm^3/min, rotary impeller speed – 300 rpm,

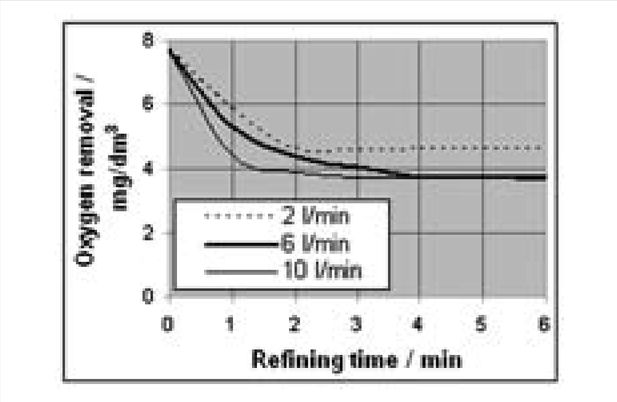

Figure 7 Results of oxygen removal from water in URC-7000 reactor

– flow rate of refining gas – 10 dm^3/min, rotary impeller speed – 400 rpm.

In both cases the refining gas dispersion with liquids is uniform – see Figure 8.

It seems that the rotary impeller speed of 200 rpm and 500 rpm is not efficient. At the lower speed the level of oxygen removal is not satisfactory because the refining gas dispersion with liquids is minimal (there are places without bubbles). The higher speed of rotary impeller is not the best solution because requiring great argon consumption. Almost the same results can be obtained at the speed of 400 rpm. Thus, there is also the possibility of swirls especially on top of liquids that can make the removed hydrogen return to the liquids.

The results of oxygen removal from water in the URC-7000 reactor confirm that the flow rate of refining gas influences the refining process. When the flow rate of refining gas equaled 2 dm^3/min, the removal of oxygen was slower than the flow rate was 10 dm^3/min. The higher the flow rate of refining gas, the higher the level of gas dispersion in liquids. Also, the gas bubbles are better mixed with liquids and the area of dispersion is bigger. By bigger interfacial area between refining gas bubbles and liquids, the oxygen is more efficiently removed. However, when the flow rate of refining gas is higher than 10 dm^3/min the surface of liquids is more turbulent – see Figure 9. As mentioned before, this is not advisable, since removed hydrogen can return to the liquid metal.

A further research concerning the type of head of rotary impellers and the optimal refining parameters will be scheduled.

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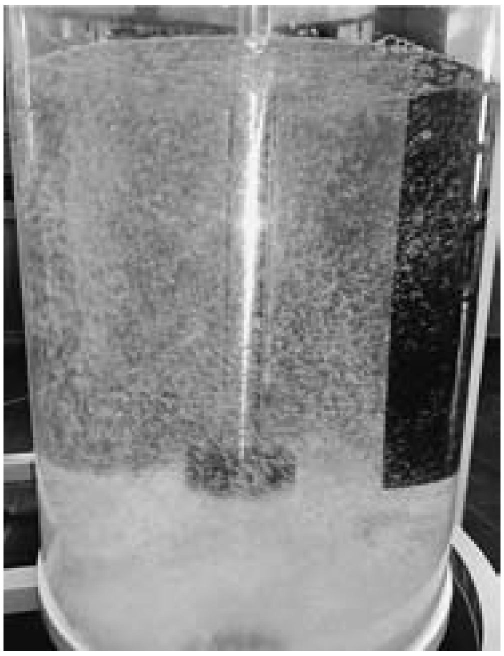

Figure 8 Uniform dispersion of refining gas in the liquid metal (400 rpm, 10 dm^3/min)

Figure 9 The view of turbulent surface of liquids (15 dm^3/min)

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Note: The responsible translator English language is M. Kingsford, Gliwice, Poland.