Advanced Engineering Days

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Determination of the optimum deoxidant addition in steelmaking process and the investigation of an alternative deoxidant material

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Cite this study: Tülüce, F., Erbakan, B., Yoloğlu, A., Zor, M. M., Kesim, S., & Uz, V. (2022). Determination of the optimum deoxidant addition in steelmaking process and the investigation of an alternative deoxidant material. 5th Advanced Engineering Days, 29-32

Keywords
Steelmaking
Steel casting
Deoxidation of steel
Alternative deoxidant material

Abstract

It is known that the oxygen in the liquid steel causes problems in the process and quality of steel. Nowadays, the addition of aluminum to molten metal is the most common application for deoxidation of liquid steel. In this study, the optimum aluminum addition levels have been determined and an alternative material that can be used as a deoxidant has been evaluated. The optimum addition amount and the optimum alternative deoxidant were determined by optical emission spectrometry, active oxygen measurement in liquid steel, microstructure investigations, and destructive/nondestructive testing methods.

Introduction

The active oxygen level in the liquid steel is an important factor for the quality of the steel casting. For this reason, the deoxidation process should be done in liquid steel after the melting process. Today, the usage of metallic aluminum alloys for this purpose is the most common practice in steelworks and steel foundries. However, metallic aluminum costs are quite high. In this study, the optimum aluminum addition amount and more economical alternatives will be determined.

According to the results of our research and feasibility studies, the most suitable alternative deoxidant material was chosen as aluminum dross.

Material and Method

Within the scope of this study, Al dross was obtained from an aluminum casting company (Döktaş Dökümcülük) and an active oxygen measuring device (Celox-Lab E) from an international technology supplier (Heraeus) (Fig.1).

Figure 1. a- Aluminum dross b-Celox-Lab E

During the studies, firstly, the efficiency of our standard deoxidation process was examined and the success of the current process was determined by using an active oxygen level measuring device. After the optimization studies, the amount of aluminum and aluminum dross addition rate will be determined.

There is no chemical process that accelerates the melting process (oxygen blowing etc.) in our foundry, which melts with an induction furnace. Active oxygen level and temperature controls were performed on a regular basis without changing the process in order to identify the trend of the current melting process's oxygen levels (Fig. 2).

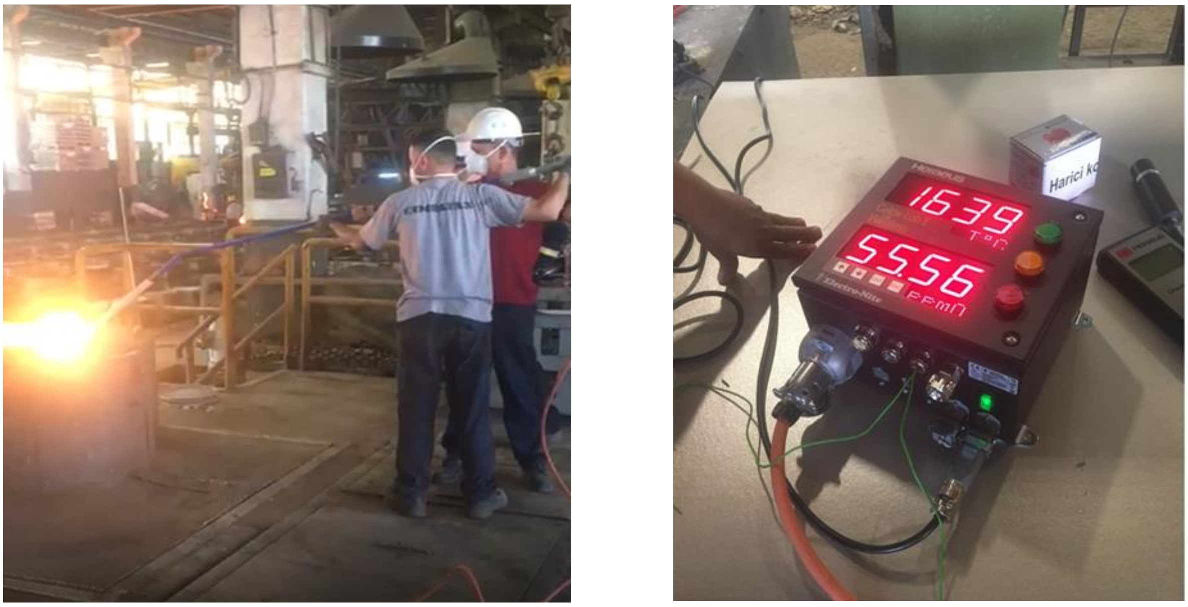

Figure 2. Temperature and oxygen levels measurements in induction furnaces

As expected, it was observed that the dissolved oxygen in the liquid steel increased during the process (Fig. 3).

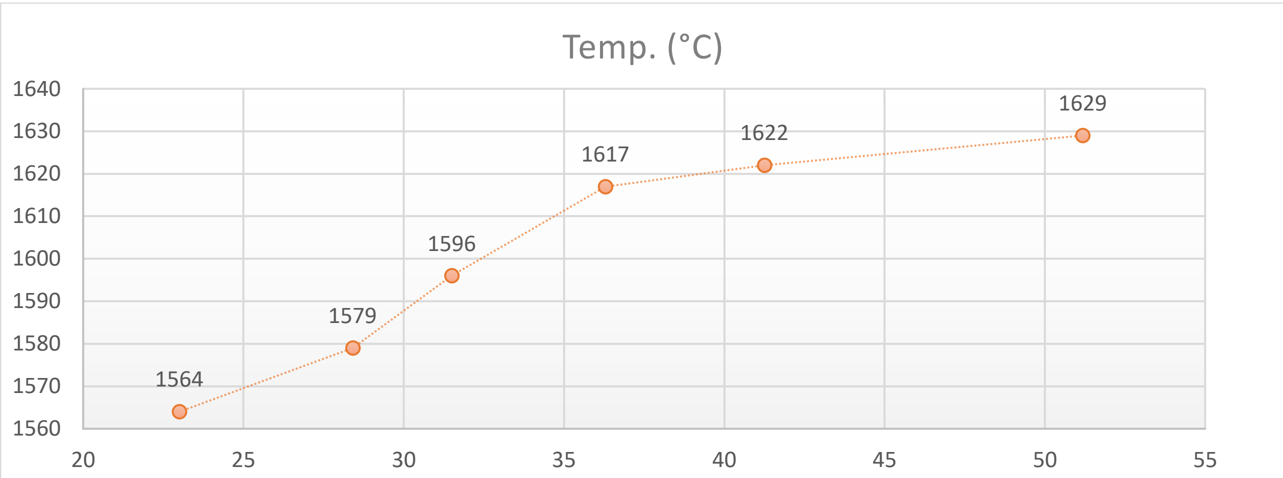

Figure 3. Active oxygen level measurement results during the melting process

After determining the active oxygen level change throughout the process, 3 different deoxidant applications were made in the same melting process in the same furnace. Since the deoxidant application is made while the liquid metal is being transferred to the laddle at the last stage of melting, all studies were performed in the same melting process, ensuring that all other steps are exactly the same except for deoxidation.

In the literature, it is stated that deoxidation occurs more slowly below the oxygen level of 20 ppm. In these measurements made immediately after the addition of Al, if the oxygen level is measured below 20 ppm, the deoxidation will be considered successful [1-5].

Oxygen levels were determined before and after deoxidation in the current process (600 ppm Al) with an active oxygen measuring device and the results were recorded for theoretical calculations. The findings obtained from the experiments show that the currently applied deoxidation process is sufficient and even the amount of Al used may be more than necessary (Fig. 4).

As a result of the theoretical calculations, it was decided to add 500 ppm Al to the second laddle and the oxygen level was measured again.

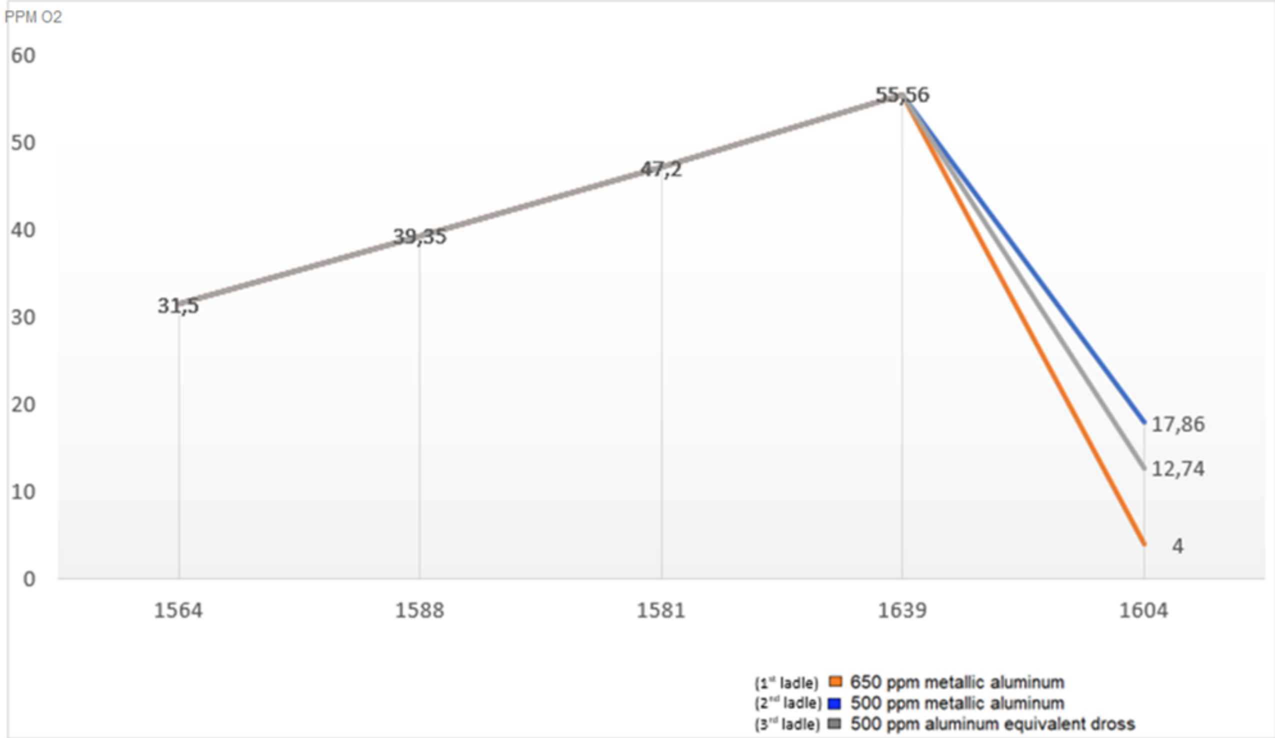

Figure 4. Oxygen level decrease in the ladle after the addition of aluminum deoxidant

2nd laddle contains less residual aluminum according to the optical emission spectrometer. Residual aluminum is bad for mechanical properties. For this reason, the addition of 500 ppm Al was found to be more reliable.

In order to evaluate the deoxidation success of aluminum dross according to the equation found, studies were carried out by using aluminum dross instead of metallic aluminum (Fig. 4).

In the last experiment, 500 ppm aluminum equivalent dross was added and it was observed that the oxygen level decreased to 12.74. After the studies, destructive non-destructive inspections and metallographic examinations were made on all samples, and no adverse events were encountered in the tested samples.

Results

As a result of the measurements, it is seen that the oxygen in the liquid metal increases as the process progresses. This confirms the information in the literature that oxygen solubility increases with increasing temperature and that dissolved oxygen will increase over time [6,7]. There are many sources for the deoxidation of liquid steel in the literature, but the recommended additional amounts and/or relations in these sources depend on the type of deoxidant used, grade, furnace type, how the deoxidation is done, climate, etc. It depends on many variables within the foundry/meltshop. Therefore, there may be changes according to the operating conditions. In this study, which we aim to start with a theoretical approach and find the optimum amount of addition experimentally, the best results were obtained with the addition of 500 ppm aluminum for 1 ton of 25CrMo4 material melted with an induction furnace.

As a result of the studies, successful deoxidation was achieved with aluminum dross. While the oxygen level decreased to 17.86 in the experiment with 500 ppm metallic aluminum, the oxygen level decreased to 12,74 in the experiment with the equivalent amount of aluminum dross. From this point of view, it can be said that aluminum dross is more successful in terms of deoxidation than metallic aluminum used in equivalent amounts. This observation is the result of the large surface area of metallic aluminum in the aluminum dross [8]. As a result of the metallographic, destructive and non-destructive investigations, it was observed that the trace amounts of inclusions (strontium, titanium, silicon, magnesium, and their oxides) in the aluminum dross did not have any negative effect on the casting part properties.

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