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Efficiency of different kinds of aluminium during deoxidation at the Steelworks of ISD Dunafer Co. Ltd.

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Abstract. In all areas of life, cost-effectiveness is increasingly emphasized. It is true for materials used in metallurgical processes too. In many cases, however, not only the composition of the materials used affects the efficiency, but also their consistency. The use of various Al carrier alloys used for deoxidation during converter steel production differs due to different degrees of burns. In this article we will compare the utilization of cast (solid) “mokka” aluminium and the loose waste “shredder” aluminium used in ISD DunaferZrt. Steel Works during the deoxidation process and the economics of the use of two deoxidation aluminiums.

The experiment involved a total of 67 heats. Taking into account the results of the statistical analysis, 3 heats were excluded from the heats deoxidized with “mokka” aluminium. The calculations related to the experiment were performed on the basis of 35 heats deoxidized with “mokka” aluminium and 29 heats pre-deoxidized with “shredder” aluminium. In the calculation of aluminium utilization it can be observed that the “mokka” aluminium is ~ 2.3% better utilized in comparison to the „shredder” aluminium and it can be observed also based on the total amount of aluminium delivered during the whole production process, that the total aluminium utilization is ~ 3.7% better for heats where pre-deoxidation was made with “mokka” aluminium.

On the basis of economical calculations it can be stated that the use of “shredder” aluminium is only economical, if its price per tonne does not exceed ~ 80% of the price of “mokka” aluminium.

1. Introduction

In a BOF process [1, 2], a mixture of solid steel scrap and liquid hot metal (Dunafer practice is 20-25% solid steel scrap and 75-80% liquid hot metal) is blown by high purity oxygen, in consequence of which hot metal components (Si, Mn, C, Fe, etc.) burn out (oxidize) in a thermodynamic order [3–5] and develop heat. The resulting heat melts the solid scrap.

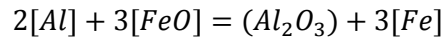
As a result of oxygen blowing, the steel bath is highly over-saturated with oxygen, which can reach 400-1200 ppm (work experiment). For the rest of the steel production, the presence of oxygen is harmful, therefore the active oxygen level required for steel after ladle treatment is 2-5 ppm (Dunaferpractice, depending on their quality). There are basically two methods for removing active oxygen in steel: diffusion and precipitation [1, 2, 4].

The primary requirement for diffusion oxygen removal is to have enough time to process, but this is not feasible due to the production rate, as the average tap to tap time is ~ 45 minutes, of which ~ 20 minutes is the duration of oxygen blowing.

Therefore, under the operating conditions, the precipitation method is applied to the steel which has a higher oxygen potential than iron and the reaction with oxygen forms a separate (removable) phase at the steel production temperature [1, 2, 4].



The most commonly used material in precipitation deoxidation for Si free steels is aluminium [1, 2, 4], the oxide of which forms a solid phase at the steel production temperature. During steel tapping, the aluminium-oxygen reaction takes place rapidly.



Aluminium oxide inclusions remained in steel are detrimental to the purity of steel [6–9] because they cause casting problems, surface defects, and subsequent mechanical anisotropy in the rolled product. There is limited scope for removal, so it is important to minimize its generation [10–12].

The consistency of aluminium used for deoxidation greatly influences the place of oxidation.

The smallest aluminium pieces with high surface area burn in the atmosphere already prior to entering the ladle due to radiant heat and ambient oxygen. Medium-sized aluminium pieces with medium surface cannot sink deep enough into the steel bath and therefore they cannot utilize in steel and discards into the secondary slag covering the steel bath, which is not harmful but ineffective.

Only larger aluminium pieces with small surface can effectively perform their deoxidation tasks in the steel bath.

Since the amount of aluminium used to deoxidize the steel bath significantly influences the quality of the steels produced and the cost of steel production, we thought it is worth considering the extent to which they should be used in steel.

In the steel mill of ISD DunaferrZrt. cast (solid) “mokka” aluminium and loose waste “shredder” aluminium is used for deoxidation.



Figure 1. “Mokka” (left) and “shredder” (right) deoxidizing aluminium

2. Implementation of the experiment

Analysis of the samples taken from both types of aluminiums showed that the content of Al is in the range of 95-99%, but because of its consistency shredder contains also non-Al-based waste (e.g. copper-based faucet, foundry magnesium block, etc.), therefore the minimum Al-contents indicated by distributors have been taken into account for calculations.

Table 1. Minimum Al-content of deoxidation aluminium

Al carrier	Min. Al
Mokka	99%
Shredder	97%
Wire	99%

Aluminium was used for pre-deoxidation in the form of “mokka” for 38 heats and in the form of shredder for 29 heats, of the 67 heats of the experiment. Heats with outliers were excluded based on the Boxplot analysis. Taking into account the results of the analysis 3 heats, which were deoxidized with “mokka”, were excluded from the experiment, two of them because of the Al content of the final sample (Figure 2.) and one of them because of the quantity of Al used (Figure 3.).

The following studies were based on the data of 35 “mokka” pre-deoxidized and 29 “shredder” pre-deoxidized heats.

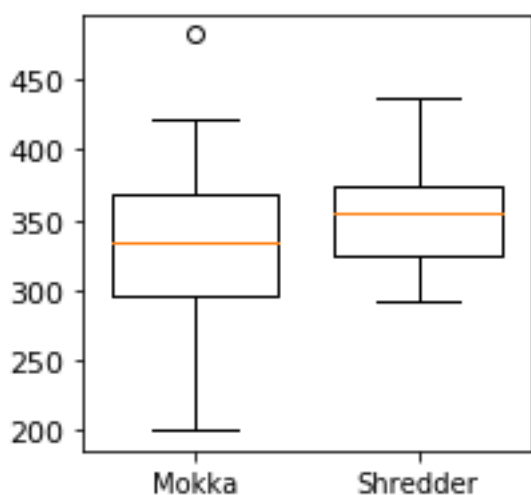


Figure 2. Al consumption analysis [kg]

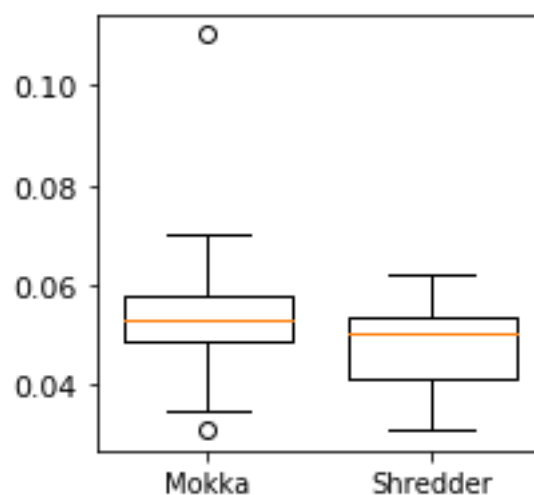


Figure 3. Final Al content analysis [%]

3. Determination of deoxidation Al utilization

In calculating the utilization, the aluminium burns resulting from the difference in the tapping temperature of heats produced using the two types of pre-deoxidizing agents and from the difference in the degree of active oxygen content are ignored because the aluminium content of steel does not change significantly due to these differences (only the 4th decimal is influenced during the measurement with the accuracy of 4 decimals). The tapping temperature and the measured active oxygen concentration are shown in Table 2.

Table 2. Steel temperature and active oxygen measurement results before tapping

	Temperature (°C)	O (ppm)
Mokka	1683	662
Shredder	1678	689

It is apparent from Table 3 that aluminium utilization of “mokka” aluminium is about 2.3% higher than that of the “shredder” aluminium during pre-deoxidation.

Table 3. Al-utilization of pre-deoxidizing Al

	Mokka	Shredder	
Pre-deoxidizing Al	277	298	kg
Al dissolved in steel	79,1	78,7	kg
Al utilization	28,6	26,4	%

Aluminium utilization throughout the process can only be observed by taking into account also the amount of correction Al-wire supplied at the ladle treatment station. In Table 4, the utilization of the Al amount of all deoxidation aluminium (“mokka” or “shredder” + wire) shows that total aluminium utilization is ~ 3.7% better when “mokka” aluminium is charged. Figure 4. and Figure 5. illustrate the utilization during BOF process of aluminium calculated based on the aluminium content of the sample taken after pre-deoxidation and that of the final sample.

Table 4. Utilization of all aluminium until final sampling

	Mokka	Shredder	
Total deoxidizing Al	325	344	kg
Al dissolved in steel	74,4	65,8	kg
Al utilization	22,9	19,1	%

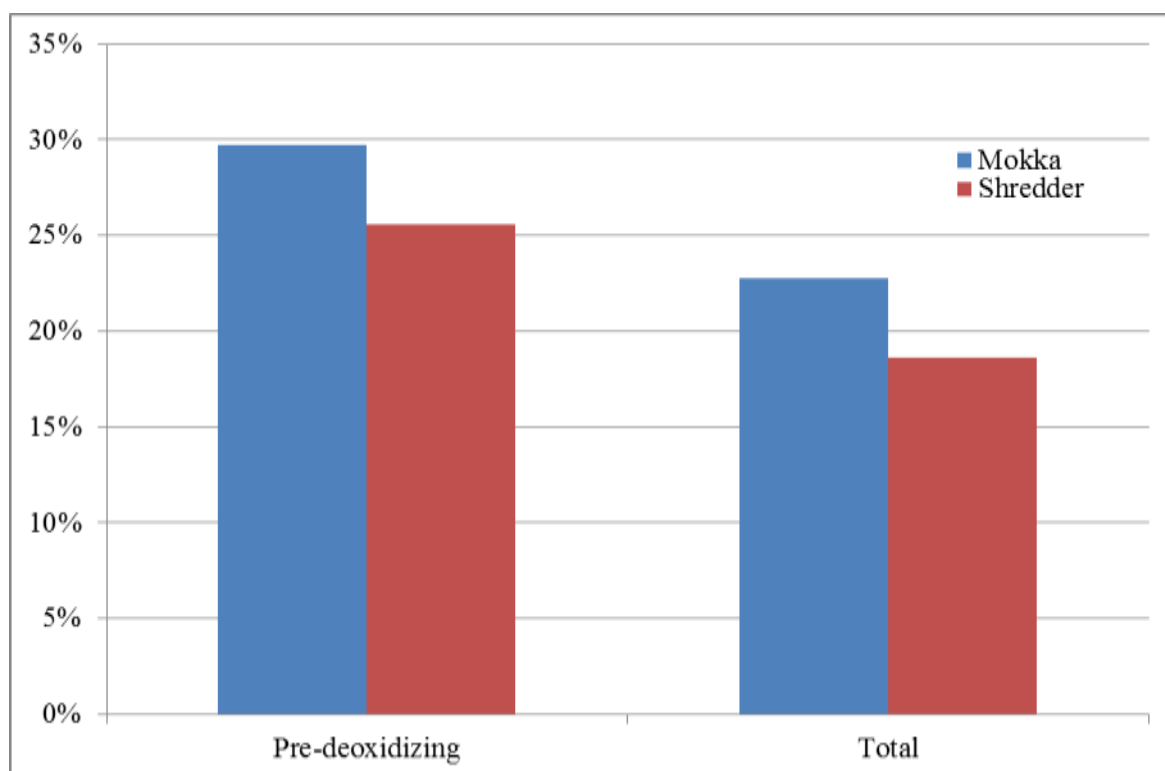


Figure 4. Utilization of Al during BOF process

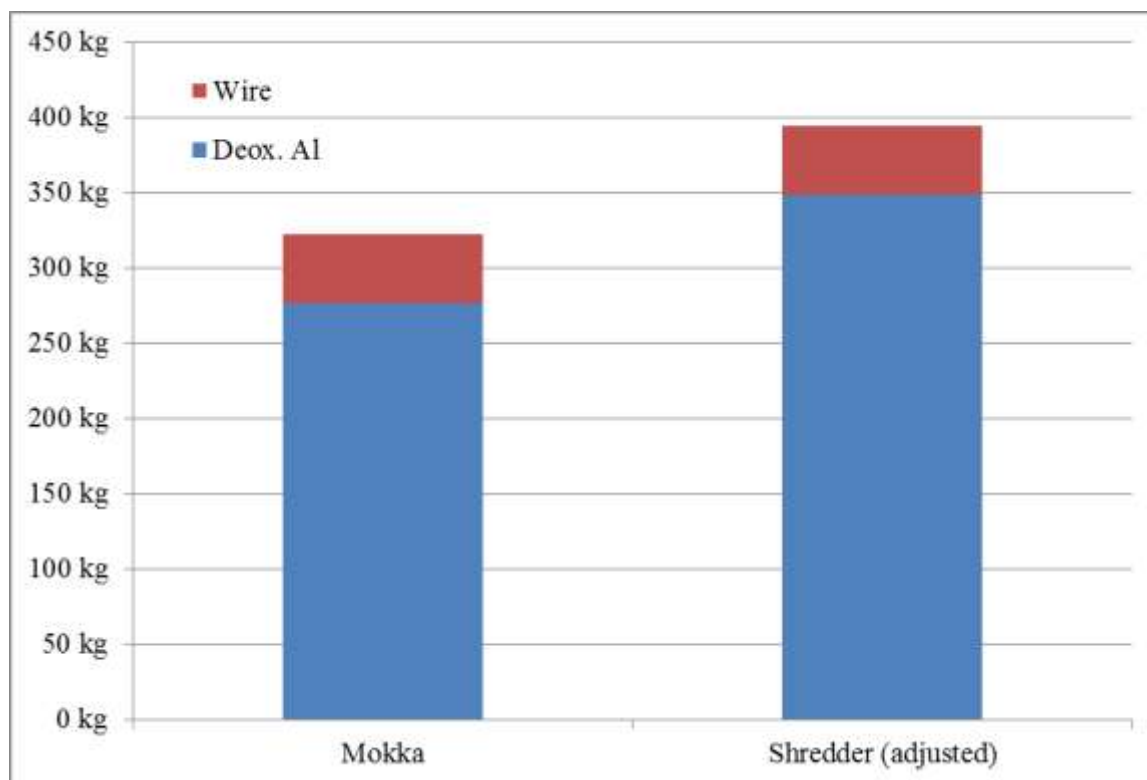


Figure 5. Total deoxidization Al consumption

4. Economic calculations

To perform the economic calculation, the amount of Al-wire used in the heats produced with the two types of pre-deoxidationaluminiums (Table 5) and the Al content of the final sample (Table 6) were tested by a statistical two-sample t-test.

Table 5. Results of two-sample t-test for the used Al-wire amount

	equal variance		non equal variance	
	Mokka	Shredder	Mokka	Shredder
Expected value	49,23	46,41	49,23	46,41
t value	0,4016		0,4269	
P(T<=t) double edged	0,6893		0,6709	
t critical double edged	1,9971		1,9983	

The results show that the difference between the Al-wire amounts used in addition to the two types of pre-deoxidizing agents does not significantly affect the result of the economic calculation and can be regarded as statistically identical. It is clear that the economy is influenced only by the price of the two different types of pre-deoxidizing agents and that the cost of Al-wire is negligible in comparison.

Table 6. Two-sample t-test for the final Al content

	equal variance		non equal variance	
	Mokka	Shredder	Mokka	Shredder
Expected value	0,0531	0,0477	0,0531	0,0477
t value	2,7188		2,6940	
P(T<=t) double edged	0,0085		0,0093	
t critical double edged	1,9990		2,0025	

The results show that the difference in the Al content in the final sample of heats produced with the two types of pre-deoxidizing agents is statistically not negligible, for comparability correction is required.

In the calculation of the correction, the amount of “shredder” aluminium (including burns and purity) was determined, with which the aluminium content of the final sample would equal to the aluminium content of the “mokka” aluminium at pre-deoxidized heats in the final sample. Based on the expected value of the two-sample t-test, an additional 40.54 kg of Al „shredder” is required to increase the Al content by $\sim 0.005\%$. (Wire data are only for information)

The corrected results are shown in Table 7, and the specific results are shown in Table 8.

Table 7. The amount of deoxidation Al added during steel production

	Pre-deoxidizing Al	Al wire	Σ Al	
Mokka	279	49,2	329	kg
Shredder (adjusted)	348	46,4	395	kg

Table 8. Specific amount of deoxidation Al added during steel production

	Pre-deoxidizing Al	Al wire	Σ Al	
Mokka	2,02	0,36	2,38	kg/t
Shredder (adjusted)	2,52	0,34	2,86	kg/t

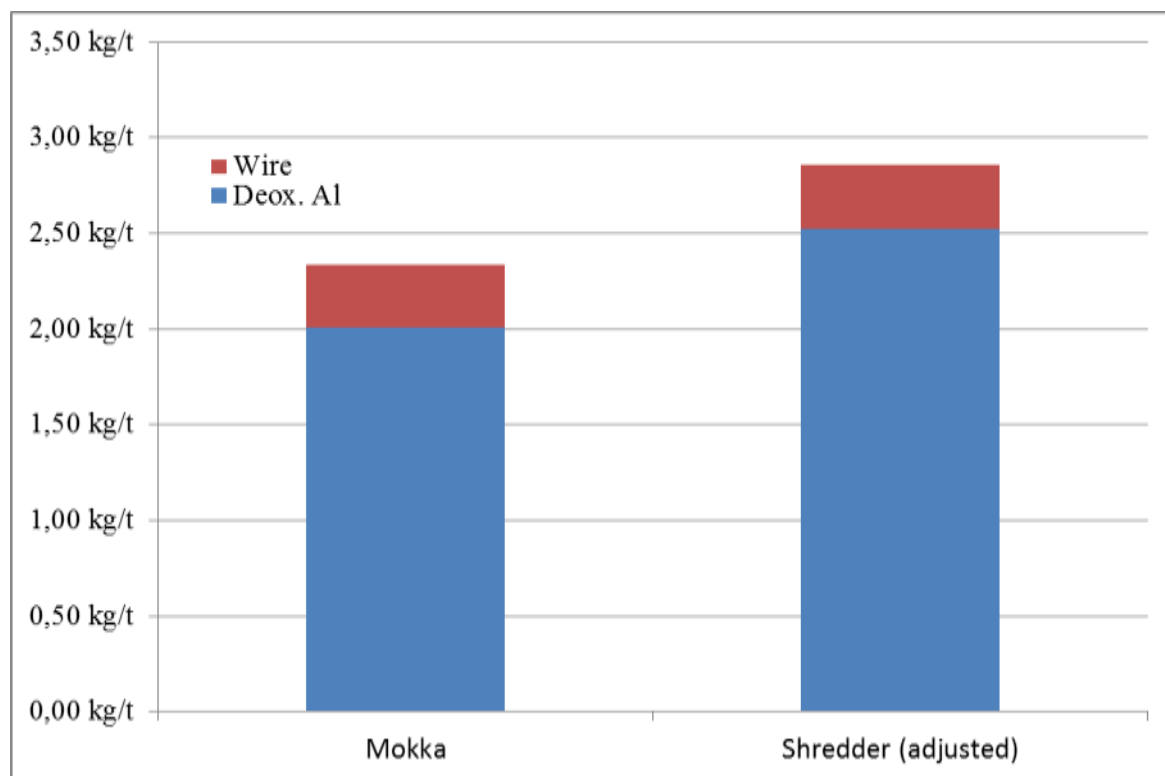


Figure 6. Total specific deoxidation Al consumption

The calculations made show that if the price of “shredder” per tonne exceeds $\sim 80\%$ of the price per tonne of “mokka”, its use is no longer economical.

5. Summary

The experiment involved a total of 67 heats.

The experiment was based on the data of 35 “mokka” pre-deoxidized and 29 „shredder” pre-deoxidized heats.

In the calculation of aluminium utilization it can be observed that the “mokka” aluminium is ~2.3% better utilized in comparison to the “shredder” aluminium during pre-deoxidization and ~3.7% during the whole production process.

On the basis of economical calculations it can be stated that the use of shredder aluminium is only economical, if its price per tonne does not exceed ~ 80% of the price of “mokka” aluminium.

Acknowledgement

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