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Analysis of effectiveness of bottom stirring after the modernization on basic oxygen furnace

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ABSTRACT

The significant modernization effort in the steel shop at HBIS Group Serbia is the introduction of a Basic Oxygen Furnace, which features bottom stirring with argon and nitrogen, along with the capability for slag splashing with nitrogen through the lance tip after steel tapping from the converter. Implementing this new technology presented a challenge, as it was our first encounter with such advancements. The primary objectives of this modernization were to achieve a lower dissolved oxygen content in steel while reaching the targeted carbon level at the end of the blowing process. This aims to optimize the steel's oxidation degree [%C] [%O], reduce the use of Al as a deoxidizer, increase yield, and achieve a low phosphorus content in steel at the end of blowing. Additionally, it aimed to increase the lining's lifetime through slag splashing and decrease the refractory mass consumption needed for lining repairs. This analysis covers a 7-month period since the start of the campaign with the new refractory lining, based on research conducted on 3,150 heats. Our examination of the process led us to conclude that while certain parameters met our expectations, some results did not reach the anticipated level.

Keywords: BOF, bottom stirring, slag splashing, de-phosphorylation.

1. Introduction

The Steelshop division in HBIS Group Serbia, located in Smederevo, is a part of the primary operation tasked with producing steel slabs. It consists of iron and scrap preparation, steelmaking, an argon stirring station, and steel casting.

- The unit for the preparation of iron and scrap is composed of several facilities: an iron desulfurization station, a mixer (capacity 1300t), scrap preparation, preparation of non-metallic additions, and slag treatment.The steelmaking unit consists of 3 BOFs that produce heats of 105 t weight.
- The stirring station unit consists of 3 lines for Argon stirring, final de-oxidation, and alloying.
- The casting unit consists of 2 radial Casters with a capacity of 1.1 million tons each, i.e., 2 radial casting machines for slab casting, and a slab yard.

The Steelshop has successfully implemented technology for producing and casting low carbon and medium carbon steel grades, steel grades for Tin plate production, low alloyed steel grades with increased hardness (HSLA) alloyed by niobium, titanium, and vanadium, and alloyed manganese steel grades, with a total number of different steel grades exceeding 100 (Gigić and Jevtić 2018).

In the steel shop, we use 3 converters. Converter No.1 (BOF1) and No. 3 (BOF3) are identical, while Converter No. 2 (BOF2) was modernized in 2020. It features bottom stirring of Ar and N2 and the possibility of slag splashing with Nitrogen.

Specifications of BOF2 include 7 bottom stirring nozzles integrated into the converter with a flow of Ar and N_2 in the range of 3-10.4 Nm/min, where the nozzles of the lance tips have an angle of 14°, unlike other converters where the angle is 12°. The volume of the converter has been increased to 94.6 m³, and the specific reaction volume has been increased to 0.9 m³/t (Gigić and Jevtić 2018).

2. Materials and methods

In this research, we compared parameters such as the oxidation degree of steel [%C][%O] across all converters, phosphorus content in steel at the end of blowing, the phosphorus distribution factor L(%P_2O_5)/[%P], and slag (%P_2O_5) content in all converters, as well as Fe content in slag in all converters and the height and erosion of the bottom in converter No. 2.

The goal of the modernization was to achieve lower dissolved oxygen content in steel while reaching the targeted carbon level at the end of the

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blowing process. This would optimize the steel's oxidation degree [%C][%O], reduce the use of Al as a deoxidizer, increase yield, and achieve low phosphorus content in steel at the end of blowing. Furthermore, we aimed to improve the phosphorus distribution factor L(%P_2O_5)/[%P] and slag (%P_2O_5) content. Additionally, we sought to achieve better results with less production loss and higher productivity by increasing the lining's lifetime through slag splashing, reducing the refractory mass consumption needed for lining repairs, and minimizing converter pit cleaning (Bilgiç 2016, Guoguang et al. 2012).

3. Results and discussion

This analysis spans a 7-month period starting from the launch of the campaign with the new refractory lining, covering research conducted on 3,150 heats during this time.

Figure 1 illustrates the effectiveness of bottom stirring as the product of carbon content and the amount of dissolved oxygen in ppm. According to these results, bottom stirring was most effective prior to the 1,400th heat, where the majority of the [%C][O] product values fell within the optimal range of 12-25. Subsequently, the product values increased, indicating a decrease in bottom stirring effectiveness.

Figure 2 displays the average maximum and minimum heights of the bottom in BOF2, plotted against the incremental heat number. After the 1,400th heat, there was a buildup on the bottom due to the erosion of refractory bricks. These results highlight a correlation between the effectiveness of bottom stirring and the height of the bottom in the BOF.

Table 1. Comparison of average values of (C) x (O) in all 3 Converter

	Average Carbon (% wt.)	Average Oxygen (ppm)	Average (C) x (O)
With stirring, BOF2	0.034	759.0	26.1
Without stirring, BOF1	0.036	779.6	28.1
Without stirring, BOF3	0.036	789.7	28.4

In Figures 3 and 4, as well as in Table 1, there is a comparison of [%C][O] in the converter with bottom stirring (BOF2) and without bottom stirring (BOF1), from which it is evident that the results with bottom stirring were lower. In BOF2, better results for the product [%C][O], ranging from 17 to 23, were observed, showcasing one of the effects of bottom stirring.

Bottom stirring enhances the removal of Phosphorus due to better mixing under stirring conditions, leading to improved interaction between the metal and slag phases. As illustrated in Figures 5 and 6, the Phosphorus content at the end of blowing in BOF2 is predominantly within the range of 0.004-0.009, in contrast to BOF1, where the Phosphorus contents are higher. Furthermore, the Phosphorus distribution factor (Lp) is significantly higher in BOF2 than in the other converters.

With the modernization of BOF2, one of the most notable benefits is slag splashing with Nitrogen through the lance, leading to a reduced consumption of refractory mass for repairing the lining. Figure 7 highlights a significant difference, with the average mass consumption on BOF2 being 1.47 kg/t, compared to the other two converters without slag splashing, where the average mass consumption is 2.57 kg/t.

Table 2. Average parameters in slag in all 3 converters

Column1	%T-Fe	%MnO	%P2O5	%S	%(FeO+MnO)
Stirred, BOF2	18.7	2.61	1.35	0.042	21.31
Unstirred, BOF1	18.34	2.62	1.35	0.045	20.96
Unstirred, BOF3	17.97	2.71	1.37	0.04	20.68

Although the expected benefits of bottom stirring include a higher yield and lower Fe content in slag, Figure 8 and Table 2 reveal that the results across all three BOFs were similar and did not meet expectations.

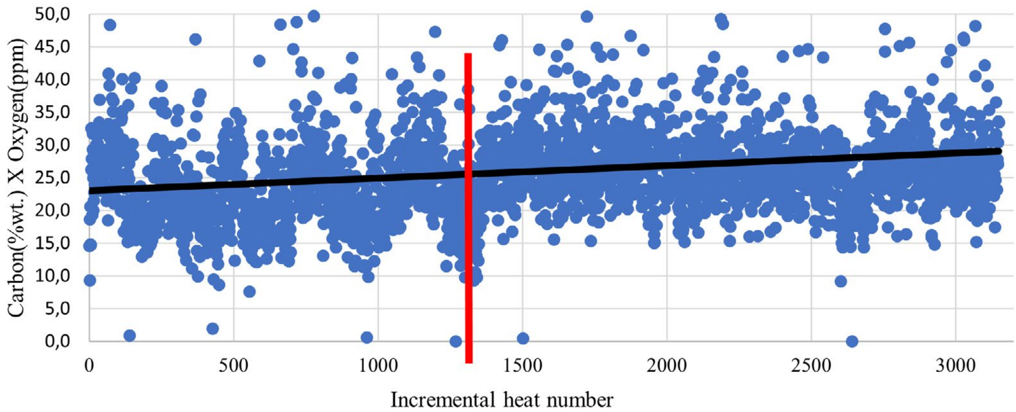

Fig. 1. Production of Carbon and Oxygen for six months on BOF2

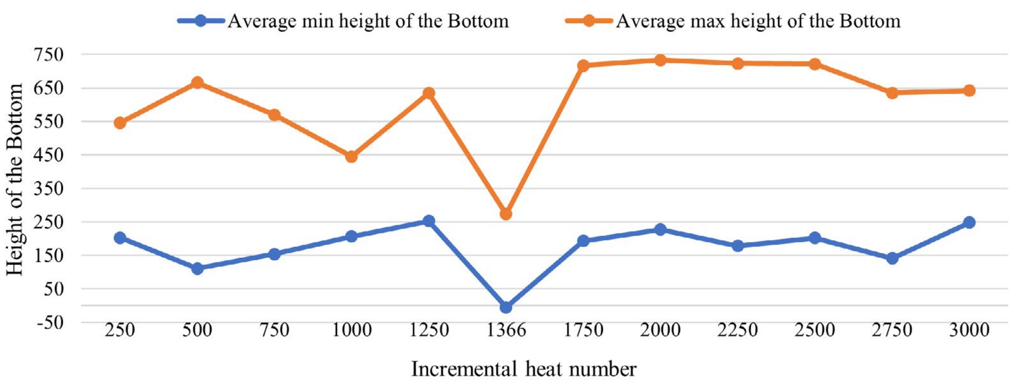

Fig. 2. Average height of the bottom on BOF2 (cm)

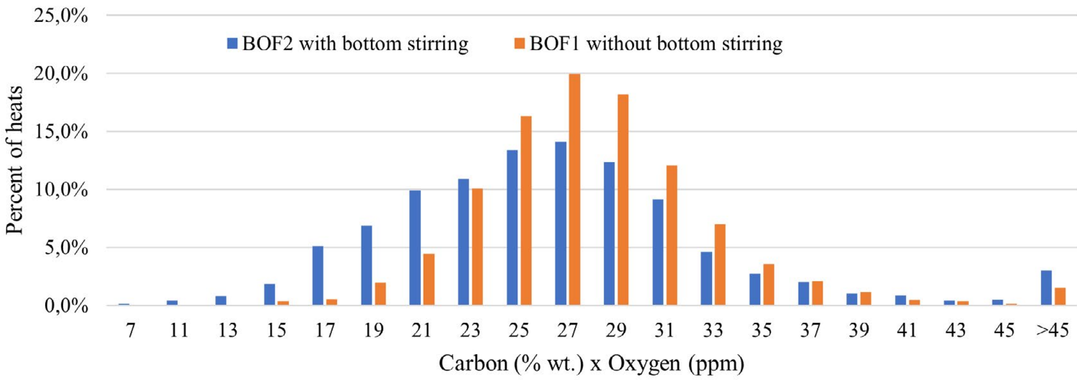

Fig. 3. Comparison of product of carbon and oxygen

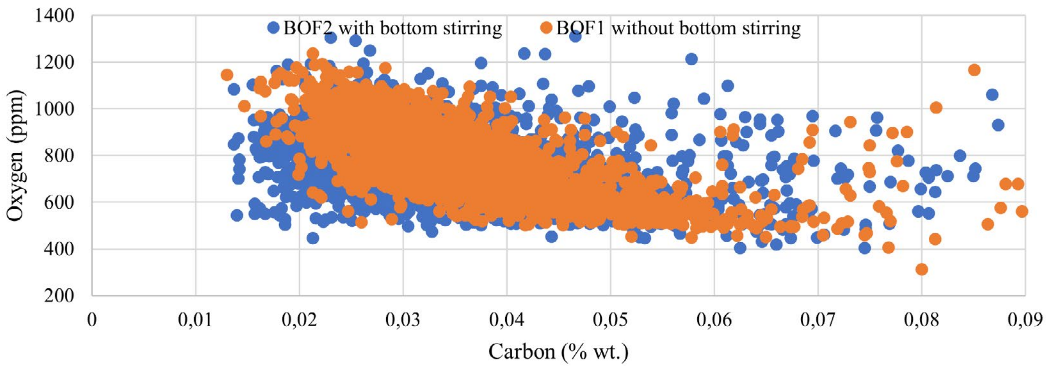

Fig. 4. Carbon and oxygen distribution for stirring condition

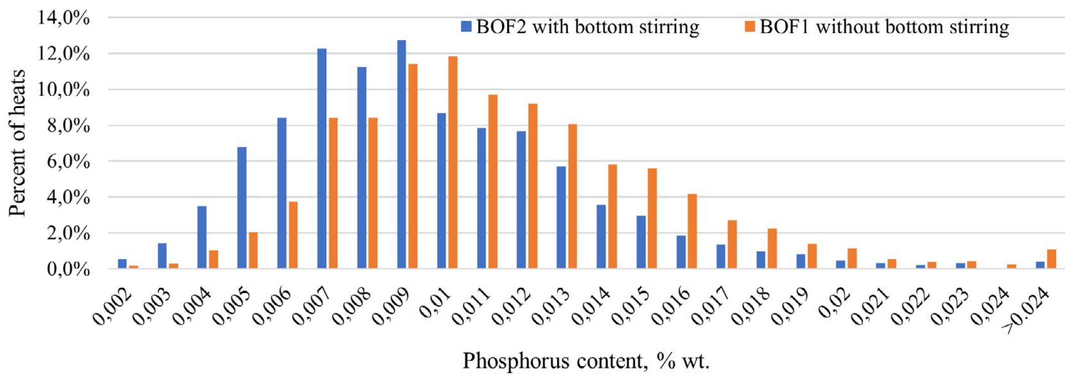

Fig. 5. Comparison of phosphorus content in BOFs

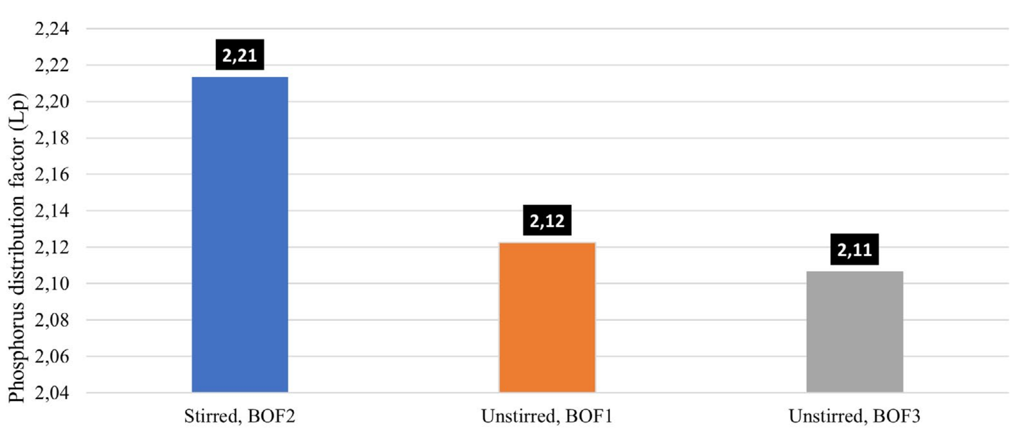

Fig. 6. Phosphorus ratio in slag/steel (Lp) for stirring and unstirring condition

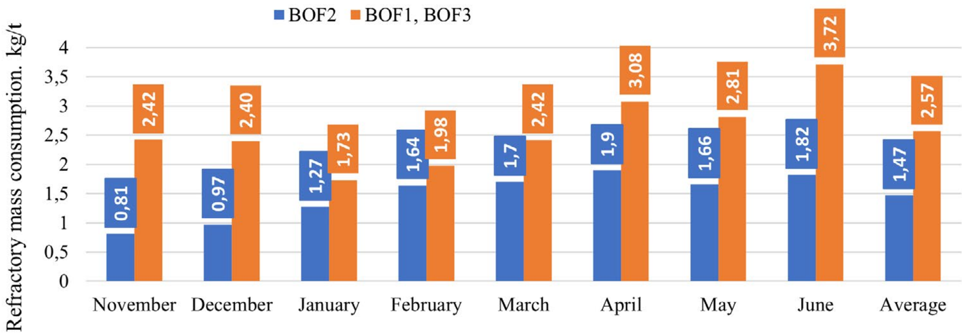

Fig. 7. Monthly consumption of refractory mass on Converters

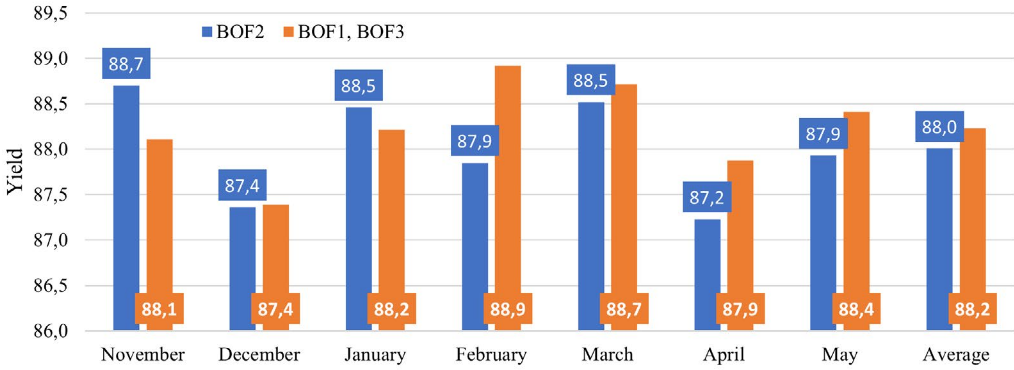

Fig. 8. BOF Yield per month

4. Conclusion

The implementation of bottom stirring has yielded numerous advantages, such as a lower oxidation degree of the melt and enhanced carbon removal, which has reduced the consumption of aluminum for steel deoxidation. Another significant benefit of bottom stirring is the improved dephosphorization of steel in the BOF. Additionally, slag splashing has proven to be a valuable BOF technology for achieving a longer lining campaign life with reduced consumption of refractory mass for repairs. However, the improvements in BOF yield and lower Fe content in slag, which were anticipated, have not been realized.

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