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THE REFINING OF STEEL BY SYNTHETIC SLAG TREATMENT

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ABSTRACT

Treating the liquid steel with synthetic slag in the casting ladle is an efficient and relatively cheap method of reducing the non-metal inclusion content by reducing the sulphur and oxygen content. The synthetic slag used in the experiments corresponds to the CaO – Al_2O_3 system, which ensures, by their composition, the extraction of sulphur and oxygen from the liquid steel, based on Nernst's repartition law, and have a density and fluidity that ensure the efficiency of their separation compared to the metal bath. The method also has the advantage of being applicable in all the processing technologies (EAF, BOF, and so on)

The paper presents the results and conclusions of the laboratory experiments regarding treatment of steel with various composition synthetic slags. The experiments were conducted using a Tamann furnace at the Hunedoara Engineering Faculty.

1. INTRODUCTION

The essence of the process of using synthetic slag consists in making a contact on a large surface between the melted steel and a slag having a composition selected to ensure an advanced steel deoxi-dation and desulphurization.

The disadvantages of diffusion (extraction) deoxidation are removed by this procedure as it is made by emulsioning the steel with the slag (which does not contain CaC_2) and the process is very fast (10 to 12 minutes) [1].

The admixture represents 2 – 4% of the liquid steel quantity in case of using solid synthetic slag and 3 – 6% in case of using melted slag.

It was proved by practice that the most effective slag are the ones from the systems CaO – Al_2O_3, CaO – Al_2O_3 – CaF_2, CaO – Al_2O_3 – CaF_2 + NaF. Composition of some slag on the market are presented in Table 1.

[2]. The composition of these slag can be modified according to the requirements of the users in the metalurgic industry.

The used calcium-aluminate synthetic slag are liquid at work temperature and they participate not only in the deoxidation process (by oxygene diffusion) but also in the removal of inclusions they come in contact with. When solid Al_2O_3 inclusions come into contact with CaO – Al_2O_3 liquid slag, the alumina inclusions are absorbed and form liquid calcium-aluminates which are richer in Al_2O_3. The reaction between Al_2O_3 and slag can be represented as follows:

$$\underset{\text{solid inclusion}}{xAl_2O_3} + \underset{\text{liquid slag}}{CaO(Al_2O_3)_y} \rightarrow \underset{\text{liquid slag}}{CaO(Al_2O_3)_{x+y}}$$

TABLE 1. SYNTHETIC SLAG AVAILABLE ON THE MARKET

	CaO(%)	Al_2O_3(%)	SiO_2(%)	CaF_2(%)	MgO(%)	Na_2O(%)	FeO(%)
1.	72-77	0-2	19-24	2-4	-	0,5-1,5	-
2.	75-80	12-15	0,7-1,5	4-6	-	-	-
3.	17-20	63-68	< 4	-	7-10	-	-
4.	70	15	0,9	-	2,5	-	0,5
5.	50	42	2	-	1,5	-	1,5

Beside the deoxidation effect, the synthetic slag, mainly the ones with a high content of CaO, due to their increased bazic capacity and fluidity, high dispersion and contact surface increase capacity ensure favourable conditions for advanced desulphurization of steel.

2. EXPERIMENTAL RESULTS

Laboratory experiments were conducted to verify the efficiency of synthetic slag deoxidation and desulphurization capacity. Experiments consisted in melting in a Tamann furnace steel samples with the next composition:

TABLE 2. COMPOSITIONS OF STEEL BEFORE THE TREATMENT

C [%]	Mn [%]	Si [%]	P [%]	S [%]	O_{total} [p.p.m.]
0.34	0.56	0.28	0.031	0.030	78

TABLE 3. CONTENTS OF OXYGEN AND SULPHUR BEFORE AND AFTER TREATMENT

	Slag compositions [%]		Oxygene [ppm]		Sulphur [%x10^3]	
	CaO	Al_2O_3	before	after	before	after
1	45,0	55,0	30	24	78	52
2	47,5	52,5	30	21	78	42
3	50,0	50,0	30	19	78	35
4	52,5	47,5	30	16	78	36
5	55,0	45,0	30	14	78	42
6	57,5	42,5	30	15	78	48
7	60,0	40,0	30	16	78	60

A quantity of 4 kg of steel was melted for each determination of oxygene and sulphur content after a treatment under 80 grams synthetic slag for 10 minutes. The compositions of the synthetic slag and the results of the oxygene and sulphur content measurements after treatment are shown in Table 3 and in Figure 1.

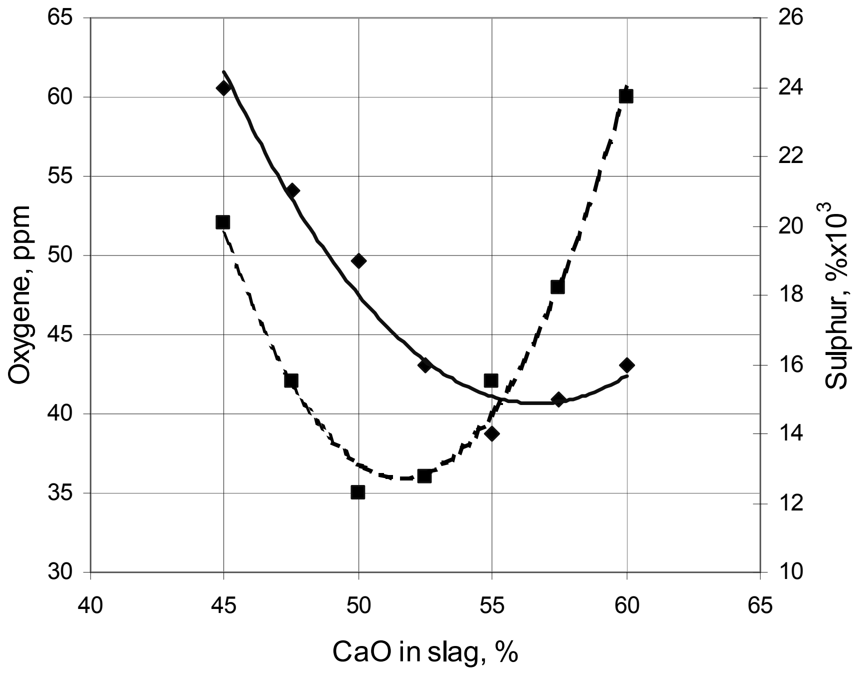

FIGURE 1. Influence of slag compositions to oxygene and sulphur contents of steel oxygene (- - -■- - -) and sulphur (—♦—) after treatment

The dependence between slag compositions and oxygen and sulphur contents of steel after treatment is:

$$[O] = 0,3524 \cdot (CaO)^2 - 36,386 \cdot (CaO) + 975,19 \qquad R^2 = 0,98$$

$$[S] = 0,0705 \cdot (CaO)^2 - 7,9857 \cdot (CaO) + 241,1 \qquad R^2 = 0,96$$

In conclusion, calcium-aluminate solid synthetic slag, with a content of CaO between 51 ... 56% will ensure a removal of about half of initial quantity of sulphur and oxygen from treated steel.

For establishing the regression equations between the quqntities of synthetic slag and final contents of oxygene and sulphur were made experiments using diffrent quantities of slag, with a duration of 10 minutes.

Dependence between the oxygene and sulphur contents of steel after treatment and the quantity of synthetic slag is presented in table 4 and in figures 2 and 3.

Quantity of synthetic slag Q is in percent from the quantity of steel and the high values of correlation coefficient shows a tide interdependency between the oxygen and sulphur contents of steel, after treatment and the quantity of synthetic slag.

TABLE 4. DEPENDENCE BETWEEN THE OXYGENE AND SULPHUR CONTENTS OF STEEL AFTER TREATMENT AND THE QUANTITY OF SYNTHETIC SLAG - Q [% FROM STEEL QUANTITY]

Slag composition		Oxygene [ppm]		Sulphur [%x10^3]	
CaO [%]	MgO [%]	Regression equation	Coef. of corelation R^2	Regression equation	Coef. of corelation R^2
45	55	$[O] = 80,783 \cdot e^{-0,1826 \cdot Q}$	0,9002	$[S] = 29,915 \cdot e^{-0,0902 \cdot Q}$	0,7596
50	50	$[O] = 69,961 \cdot e^{-0,2654 \cdot Q}$	0,8495	$[S] = 31,115 \cdot e^{-0,1973 \cdot Q}$	0,8739
55	45	$[O] = 76,786 \cdot e^{-0,2672 \cdot Q}$	0,9141	$[S] = 30,797 \cdot e^{-0,3027 \cdot Q}$	0,9229
60	40	$[O] = 80,401 \cdot e^{-0,1143 \cdot Q}$	0,8406	$[S] = 31,947 \cdot e^{-0,2822 \cdot Q}$	0,8756

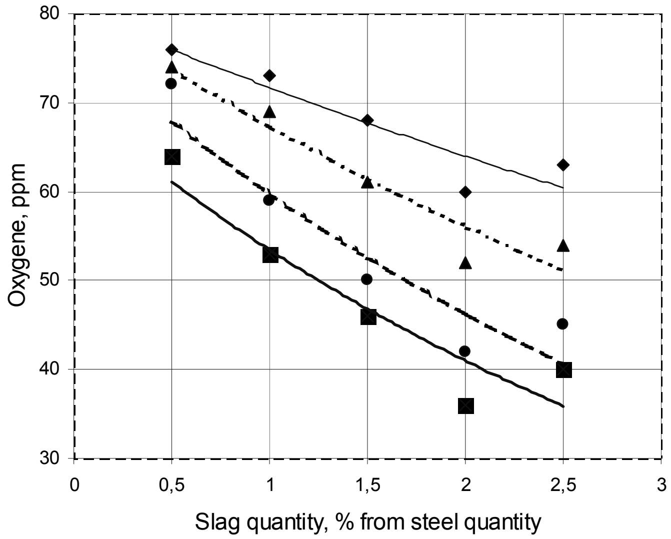

FIGURE 2. INFLUENCE OF SLAG QUANTITY TO OXYGENE CONTENTS OF STEEL

$CaO-Al_2O_2$ slag with:
- ▲ 45% CaO
- ■ 50% CaO
- • 55% CaO
- ♦ 60% CaO

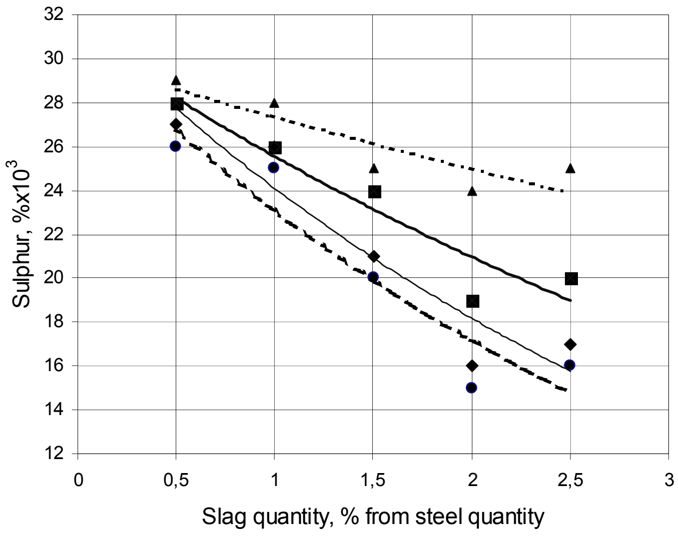

FIGURE 3. INFLUENCE OF SLAG QUANTITY TO SULPHUR CONTENTS OF STEEL

For establishing the regression equations between the duration of treatment and final contents of oxygen and sulphur were made experiments using 80 grams of synthetic slag (representing 2% from the steel quantity) with different contents.

Dependence between the oxygen and sulphur contents of steel after treatment and the duration of treatment is presented in table 5 and in figures 4 and 5.

The equations which describe the dependency between the oxygen and sulphur contents of steel, after treatment and duration of treatment are either exponential or lineal, but both ensure the increasing of deoxidation and desulphurization process, through increasing treatment duration (τ is in minutes).

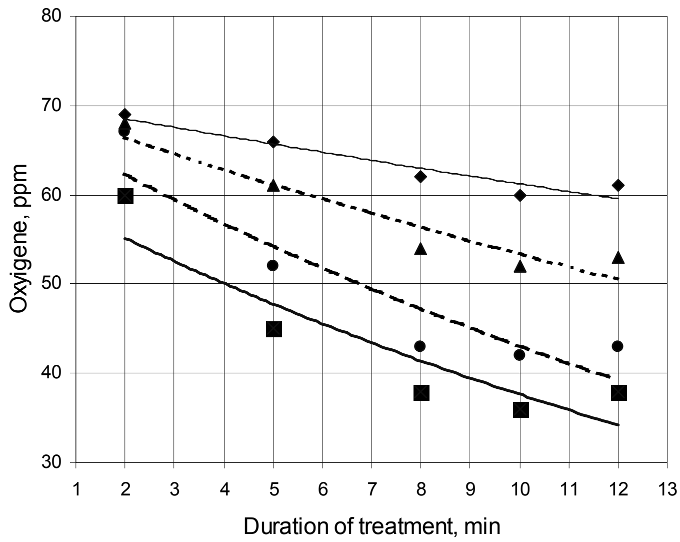

FIGURE 4. INFLUENCE OF TREATMENT DURATION TO OXYGENE CONTENTS OF STEEL

$CaO-Al_2O_2$ slag with:

—▲— 45% CaO

—■— 50% CaO

—•— 55% CaO

—♦— 60% CaO

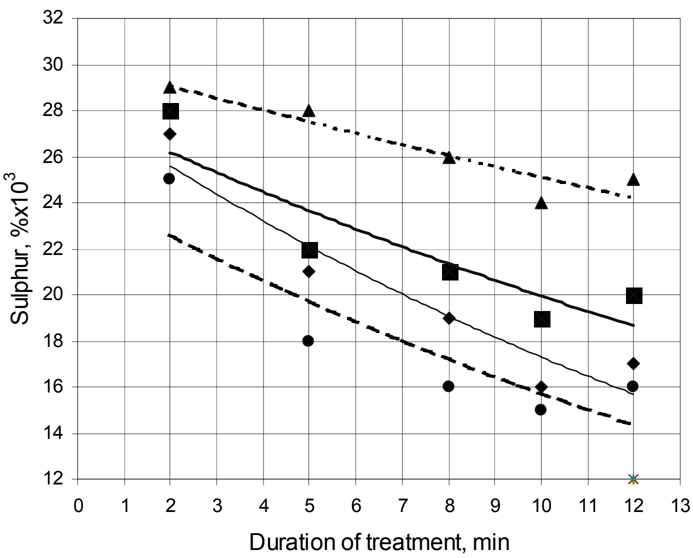

FIGURE 5. INFLUENCE OF TREATMENT DURATION TO SULPHUR CONTENTS OF STEEL

TABLE 5. DEPENDENCE BETWEEN THE OXYGENE AND SULPHUR CONTENTS OF STEEL AFTER TREATMENT AND THE DURATION OF TREATMENT WITH SYNTHETIC SLAG - τ [MINUTES]

Slag composition		Oxygene [ppm]		Sulphur [%x10^3]	
CaO [%]	MgO [%]	Regression equation	Coef. of corelation R^2	Regression equation	Coef. of corelation R^2
45	55	$[O] = 70{,}088 \cdot e^{-0{,}0272 \cdot \tau}$	0,8974	$[S] = 30{,}152 \cdot e^{-0{,}0183 \cdot \tau}$	0,8647
50	50	$[O] = 60{,}625 \cdot e^{-0{,}0477 \cdot \tau}$	0,8219	$[S] = 28{,}031 \cdot e^{-0{,}034 \cdot \tau}$	0,8084
55	45	$[O] = 70{,}335 \cdot e^{-0{,}0518 \cdot \tau}$	0,8539	$[S] = 27{,}492 \cdot e^{-0{,}0582 \cdot \tau}$	0,8450
60	40	$[O] = 70{,}469 \cdot e^{-0{,}0 \cdot 14\tau}$	0,9043	$[S] = 28{,}237 \cdot e^{-0{,}049\tau}$	0,8937

3. CONCLUSIONS

The following conclusions can be drawn regarding the deoxidation and desulphurization effect of synthetic slag:

- the optimal contents of CaO from calcium – aluminate slag is situated between 50 ... 55%, richer in CaO ensuring a better desulphurization of steel;
- the contents of oxygen and sulphur are decreasing exponentialy with increasing of slag quantity, a quantity of solid slag representing 1,5 ... 2 % from steel is optimal, using a bigger quantity is not justified because it raise melting problems;
- the optimal duration of treatment is 8 ... 10 min., an increasing is not justified because it causes an excesive coldness of liquid steel;
- steel treatment with synthetic slag can be considered as the most accesible and safe method to effectively improve the qualities of regular steels, having positive economic effects by reducing the duration of furnace processing and decreasing the ferro-alloy consumption.

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