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REFINING OF STEEL BY USING SYNTHETIC SLAG

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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 - Al₂O₃ system, which ensures, by their composition, the extraction of sulphur and oxygen from the liquid steel, based on Nernst's repartition law. The method also has the advantage of being applicable in all the processing technologies. The paper presents the results and conclusions of the laboratory experiments regarding treatment of steel with various composition synthetic slags.

KEYWORDS: synthetic slag, steel, desulphurization, deoxidation

❖ 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 deoxidation and desulphurization.

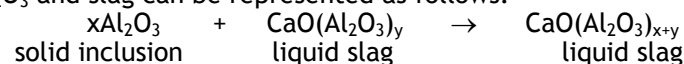
The disadvantages of diffusion (extraction) deoxidation are removed by this procedure as it is made by emulsion the steel with the slag (which does not contain CaC₂) and the process is very fast (10 to 12 minutes) [1].

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 - Al₂O₃, CaO - Al₂O₃ - CaF₂, CaO - Al₂O₃ - CaF₂ + NaF.

Compositions of some slag on the market are presented in Table 1 [2]. The composition of these slags can be modified according to the requirements of the users in the metallurgic industry.

The used calcium-aluminate synthetic slag are liquid at work temperature and they participate not only in the deoxidation process (by oxygen diffusion), but also in the removal of inclusions they come in contact with. When solid Al₂O₃ inclusions come into contact with CaO - Al₂O₃ liquid slag, the alumina inclusions are absorbed and form liquid calcium-aluminates which are richer in Al₂O₃. The reaction between Al₂O₃ and slag can be represented as follows:



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

Table 1. Synthetic slag available on the market

	CaO(%)	Al ₂ O ₃ (%)	SiO ₂ (%)	CaF ₂ (%)	MgO(%)	Na ₂ O(%)	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

❖ DISCUSSIONS

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)

A quantity of 4 kg of steel was melted for each determination of oxygen 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 oxygen and sulphur content measurements after treatment are shown in Table 3 and in Figure 1. The dependence between slag compositions and oxygen and sulphur contents of steel after treatment is:

$$[O] = 0,3524 \cdot (CaO)^2 - 36,386 \cdot (CaO) + 975,19 \quad R^2 = 0,98 \quad (1)$$

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

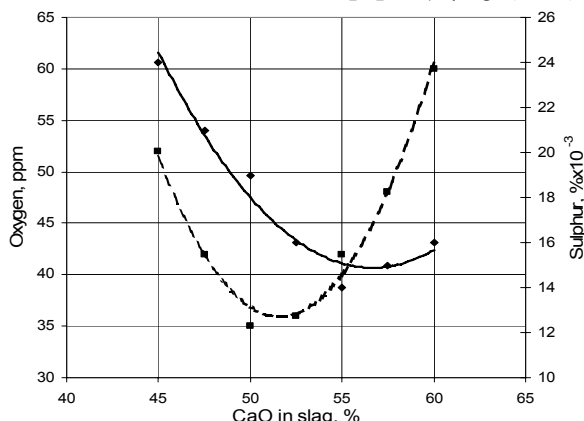


Table 3. Contents of oxygen and sulphur before and after treatment

	Slag compositions[%]		Oxygen [ppm]		Sulphur [%x10 ⁻³]	
	CaO	Al ₂ O 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

Fig. 1. Influence of slag compositions to oxygen and sulphur contents of steel. oxygen (---■---) and sulphur (—◆—) after treatment

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 quantities of synthetic slag and final contents of oxygen and sulphur were made experiments using different quantities of slag, with a duration of 10 minutes.

Dependence between the oxygen and sulphur contents of steel after treatment and the quantity of synthetic slag is:

$$[O] = a \cdot e^{-bQ} \quad (3)$$

$$[S] = c \cdot e^{-dQ} \quad (4)$$

and 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 tide interdependency between the oxygen and sulphur contents of steel, after treatment and the quantity of synthetic slag.

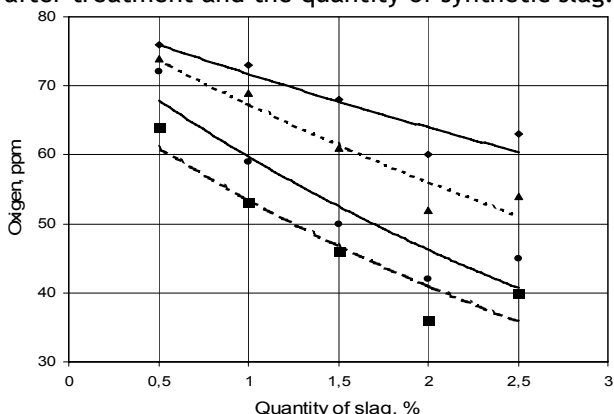


Fig. 2. Influence of slag quantity to oxygen contents of steel. CaO-Al₂O₂ slag with: —▲— 45% CaO —■— 50% CaO —●— 55% CaO —◆— 60% CaO

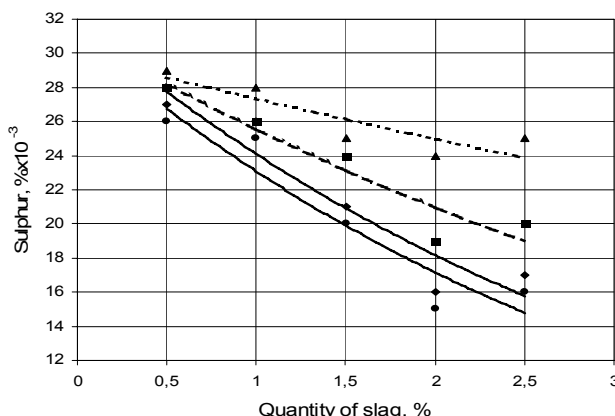


Fig.3. Influence of slag quantity to sulphur contents of steel. CaO-Al₂O₂ slag with: —▲— 45% CaO —■— 50% CaO —●— 55% CaO —◆— 60% CaO

Table 4. Dependence between the oxygen and sulphur contents of steel after treatment and the quantity of synthetic slag - Q [% from steel quantity]

Slag composition		Oxygen [ppm]			Sulphur [%x10 ⁻³]		
CaO [%]	MgO [%]	Coefficient of equation		Coeff. of correlation R ²	Coefficient of equation		Coeff. of correlation R ²
		a	b		c	d	
45	55	80,783	0,1826	0,9002	29,915	0,0902	0,7596
50	50	69,961	0,2654	0,8495	31,115	0,1973	0,8739
55	45	76,786	0,9141	0,9141	30,797	0,3027	0,9229
60	40	80,401	0,1143	0,8406	31,947	0,2822	0,8756

For establishing the regression equations between the duration of treatment τ 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:

$$[O] = a \cdot e^{-b\tau} \quad (5)$$

$$[S] = c \cdot e^{-d\tau} \quad (6)$$

and is presented in table 5 and in figures 4 and 5.

Table 5. Dependence between the oxygen 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 [%]	Coefficient of equation		Coefficient of correlation R ²	Coefficient of equation		Coefficient of correlation R ²
		a	b		c	d	
45	55	70,088	0,0272	0,8974	30,152	0,0183	0,8647
50	50	60,625	0,0477	0,8219	28,031	0,0340	0,8084
55	45	70,335	0,0518	0,8539	27,492	0,0582	0,8450
60	40	70,469	0,0140	0,9043	28,237	0,0490	0,8937

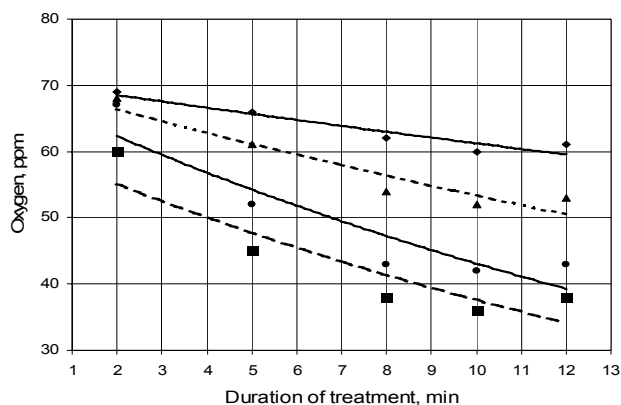


Fig.4. Influence of treatment duration to oxygen contents of steel

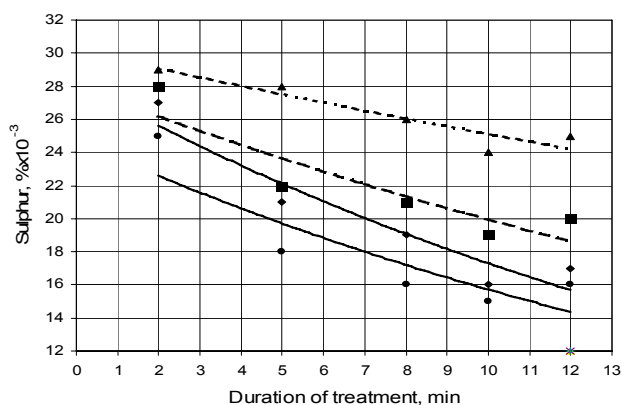


Fig.5. Influence of treatment duration to sulphur contents of steel. CaO-Al₂O₃ slag with:
 — ▲ — 45% CaO ; — ■ — 50% CaO ;
 — • — 55% CaO ; — ◆ — 60% CaO

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 the deoxidation and desulphurization process, through increasing treatment duration (τ is in minutes).

❖ 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 exponentially 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 excessive coldness of liquid steel;
- ❖ the steel treatment with synthetic slag can be considered as the most accessible 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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