Researches concerning influence of magnesium, aluminum and titanium lime on steel desulfurization

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Abstract. The paper presents the results of laboratory experiments on steel desulphurisation with slag from the system MgO-Al₂O₃-TiO₂. To determine the influence, on the desulphurisation process, of the titanium oxide added in calcium aluminate slag, we experimented, in the laboratory phase, the steel treatment with a mechanical mixture consisting of lime, aluminous slag and slag obtained from the titanium making process through the aluminothermic technology. The steel melting was carried out in an induction furnace of 10 kg capacity, existent in the "Metallic Melts" laboratory of the Engineering Faculty of Hunedoara. During the research, we aimed to establish correlation equations between the sulphur distribution coefficient and the slag components (MgO, Al₂O₃, TiO₂). The data obtained in the experiments were processed in MATLAB programs, resulting multiple correlation equations, which allowed the elucidation of some physical-chemical phenomena specific to the desulphurisation processes.

1. General considerations
The steel refining with liquid slag or various powder mixtures of synthetic slag is based on the intensification of the unwanted impurities (sulphur, non-metallic suspensions & oxygen) passage from the liquid steel in the slag, mainly by diffusion, or partly through the entrainment of some suspensions by settling the synthetic slag particles found in the treated steel bath. The synthetic slag can be also obtained by adding mechanical mixture directly in the casting ladle; in this case, for compensating the cooling of the steel in the casting ladle due to the addition of materials (melting and superheating), the steel temperature should be at least 20-40°C higher than the normal one [1]. In the practice of deoxidation with synthetic slag, we usually use slag that correspond to the binary systems CaO-Al₂O₃, CaO-TiO₂ and CaO-CaF₂, or to the ternary systems CaO-SiO₂-Al₂O₃, CaO-CaF₂-Al₂O₃ and MgO-Al₂O₃-TiO₂, [2].

The viscosity of the synthetic slag has significant influence on the development of physical and chemical processes during the treatment of the liquid steel, interfering with significant weight on the emulsifying capacity of slag. The increase of the slag viscosity from 0,15 to 0,45 Ns/m² (from 1,5 to 4,5 Poise) determines the decrease with approx. 30% of the steel-slag interaction surface. Such increasing of the calcium aluminate slag viscosity can be seen when its temperature is decreasing (for example, from 1600°C to 1470°C). Therefore, it is very important to ensure, during processing the steel with liquid slag, the optimum thermal regime specific to the chosen slag type and to realize its convenient fluidity (viscosity).
The viscosity of the synthetic slag is also influenced by other components; it increases significantly with the increasing of the SiO$_2$ content, while MgO contents up to 8% are favorable. At temperatures higher than 1500°C, the viscosity is slightly decreasing when adding TiO$_2$ in the calcium aluminate slag [3].

Similarly, the bigger is the contact surface between the synthetic slag and the metallic bath, the faster is the passage of the significant elements to the slag, the contact surface being, along with the viscosity, another determinant element in treating the steel with synthetic slag [4].

2. Laboratory experiments
To determine the influence, on the desulphurisation process, with slag from the system MgO-Al$_2$O$_3$-TiO$_2$, we performed laboratory experiments, i.e. we treated the steel with liquid synthetic slag obtained by melting the mixture consisting of magnesia, aluniminate slag and slag obtained from the titanium making process through the aluminothermic technology.

The steel melting was carried out in an induction furnace of 10 kg capacity and the slag melting was carried out in a crucible furnace, both existent in the “METALLIC MELTS” laboratory of the Engineering Faculty of Hunedoara (Figure 1).

The charge to be melted consisted of steel samples (samples of steel for tubes, taken from the casting ladle before the LF treatment, i.e. before introducing the steel in the LF). The steel quantity obtained was 10 kg/heat, and the addition of liquid slag was 3% (300 g/heat). The synthetic slag was added directly in the casting ladle; so, the slag reached the ladle before the steel, ensuring a good mix between the two melts. To determine the sulphur distribution coefficient, we took steel and slag samples before and after the treatment, to find the sulphur content and the chemical composition. We also measured the steel and slag temperature before and after the treatment.

![Figure 1. Issues during laboratory experimentation phase](image)

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3. Results obtained from processing the experimental data

By processing the data in the MATLAB program, we obtained multiple correlation equations \( L_S = f(\%Al_2O_3, \%MgO, \%TiO_2) \), and, by graphically represented them, we obtained the correlation surfaces.

In these multiple correlation equations \( L_S \) is sulfur partition coefficient defined as

\[
L_S = \frac{(S)}{[S]}
\]  

where:  
\( (S) \) - the sulfur content in slag;  
\([S]\) - the sulfur content in steel.

Since this hyper surface cannot be represented in 4-dimensional space, recourse to replacement, in succession, by an independent variable with its mean value. These areas, which belong to the 3-dimensional space can be represented and interpreted by technologists (Figure 2 to 7).

To establish the optimum chemical composition range, we analysed the regression surfaces for finding the value of the \( L_S \), desirable above the average value obtained from the data afferent to the analysed heats. The average value for sulfur partition coefficient is \( L_{Smed} = 204,01 \). Independent parameters are likely to vary within certain limits of technological fields, such as values for \( L_S \) to be higher that 220 (shaded areas).

![Figure 2. The multiple correlation \( L_S = f(\%Al_2O_3)_{med}, \%TiO_2, \%MgO) \) - regression surface](image)
Figure 3. The multiple correlation $L_S = f(\%Al_2O_3_{med}, \%TiO_2, \%MgO)$ - level curves

Figure 4. The multiple correlation $L_S = f(\%Al_2O_3, \%MgO_{med}, \%TiO_2)$ - regression surface
Figure 5. The multiple correlation $L_S = f(\%Al_2O_3, \%MgO_{med}, \%TiO_2)$ - level curves

Figure 6. The multiple correlation $L_S = f(\%Al_2O_3, \%MgO, \%TiO_2_{med})$ - regression surface
Figure 7. The multiple correlation $L_S = f(\%Al_2O_3, \%MgO, \%TiO_2)_{med}$ - level curves

4. Conclusion:
Based on the experiments, on the results obtained from data processing and on the technical analysis of these data, we concluded the followings:

- The chemical composition of the slag has a significant influence on the L.S., either indirectly, due to the viscosity, or directly, due to the affinity of the oxide cautions to the sulphur anions;
- The distribution report of sulfur it is strongly influenced by major oxides slag used in the experiments, namely: MgO, Al$_2$O$_3$, TiO$_2$;
- Graphic representations for determining values for independent parameters (for oxides of slag) so as to result the sulfur distribution ratio desired value;
- Having regard to the joint influence of oxides on the distribution ratio for the content of oxides whose values lie within technology, it can get to $L_S$ values better than average;
- Correlations obtained are useful both for research and for practice of steel or its treatment with synthetic slag in LF type installations.

References

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