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MINERALOGICAL AND STRUCTURAL RESEARCH OF SEN AND DEPOSITS WITH THE PURPOSE OF DETERMINING THE CAUSE OF THE DEPOSIT FORMATION

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Abstract

The work is based on the results of the experiment, which involved observing and examining the behavior of 167 SEN (Submerge Entry Nozzle) during the continuous steel casting. The results of such research of the wall of SEN and the contact zone in the inner side of SEN, distinctly point out the background of the aluminum built as corundum and calcium aluminate deposited in the deposit of SEN.

The work has proved that with the formation of corundum and Hibonite - 5H deposit in certain number of SEN, the crucial part was played by the secondary oxidation of steel with slightly smaller number of SEN, beside the secondary oxidation, as cause of the formation of these two mineral phases, due to the reactions which take place in the material itself.

Keywords: Mineralogy, deposit, SEN, thickness, formation, casting

1. Introduction

The role SEN during the continuous casting of steel can be seen in

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providing an even flow of steel from the casting ladle into the mould. The most frequent problem with SEN is the appearance of the deposit in the inner side by the wall of SEN which often lessens the flow of steel, but also the life of SEN [1 - 4].

The experiment was done under industrial conditions at the radial continuous caster of the converter Steel Plant in Sartid Smederevo. Carbon, aluminum killed, silicium killed and alloyed steels from the current production were casted during the experiment. SEN, which is most often used in the Sartid, was build of refractory material on the basis of alumographite.

The results of this observation showed that deposits are most often formed during the casting carbon and aluminum killed steels whereas it is more rare with formation during the casting of silicium killed and alloyed steels. The greatest average value of deposit thicknesses 8.72 mm was recorded during the casting of carbon steels, whereas the smallest average value of deposit thicknesses 3.75 mm was recorded during the casting of alloyed steels. Mineralogical and structural research applying the optical method and X - Ray method showed that in mineral structure of the deposit of SEN as the fundamental phase appear α - Corundum (α - Al_2O_3) and Hibonite - 5H (CaO $3Al_2O_3$ $3Fe_2O_3$).

2. Experimental

The examination were done by using contemporary methods:

- Optical emission spectrometry (OES) - ARL - 4460
- Optical method, refracted light - Jena pol microscope
- Optical method, reflected light - Neophot 32 microscope
- Method X-Ray diffraction (XRD) - Simens , Kristaloslex 810
- Method X-Ray fluorescent spectrometry (XRF) - ARL 9800 IX -P
- Electronic microanalysis - Electronic microsonde JOEL , Electron microprobe JCXA -733

2. Results and Discussion

After viewing 167 series of casting, the thicknesses of deposits of SEN were measured which gave the average values of deposit thicknesses. In Table 1. the average values of deposit thicknesses and technological parameters are shown regarding continual steel.

Table. 1. The average values of deposit thicknesses and technological parameters

Number	Type of Steel	deposit thicknesses	Time of casting (min)	Casting rate (m/min)	Oxygen (ppm)	T (^{0}C)	T(^{0}C)	Add. Al (m)	Al After Ladle treatment (%)	Al on End casting (%)
1	A	8.67	165	0.82	2.5	1593	1554	90	0.054	0.039
2	B	8.72	203	0.82	2.61	1583	1553	76	0.055	0.042
3	C	4.91	148	0.79	4.81	1584	1552	43	0.036	0.025
4	D	3.75	147	0.84	2.42	1580	1553	60	0.044	0.052

A - Carbon steel
B - Aluminum killed steel
C - Silicium killed steel
D - Alloyed steel

Table. 2. shows the average values of chemical composition of steel casting during the experiment.

Table 2. The average values of chemical composition of steel

Number	Steel	C	Si	Mn	P	S	Cu	Al
1	A	0.05	0.009	0.267	0.011	0.01	0.039	0.039
2	B	0.101	0.022	0.523	0.014	0.012	0.057	0.042
3	C	0.094	0.199	0.459	0.015	0.013	0.056	0.026
4	D	0.13	0.125	1.088	0.011	0.006	0.031	0.044

Fig. 1. shows the macro image of SEN and the formed deposit during the casting of different types (D, A and B) of steel.

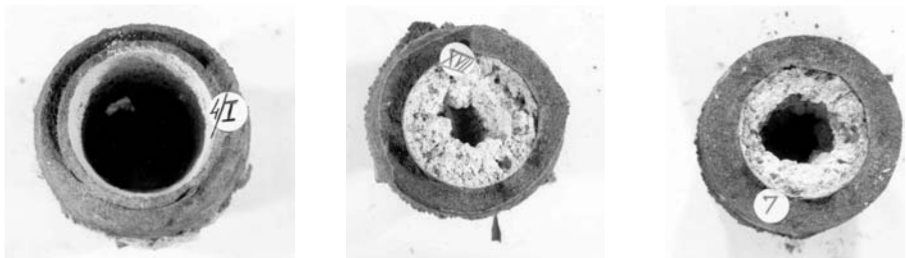

Fig. 1. The macro image of SEN and the formed deposit during the casting of different types (D, A and B) of steel

Looking at the Fig.1., it can be seen that the greatest thickness of the deposit of SEN is formed during the casting of steel B and the smallest during the casting of steel D. The formed scab is loose most often white, pink or gray - white.

Fig. 2. shows microphotographs of deposit (refracted light) and X – Ray diffractograms of the deposit.

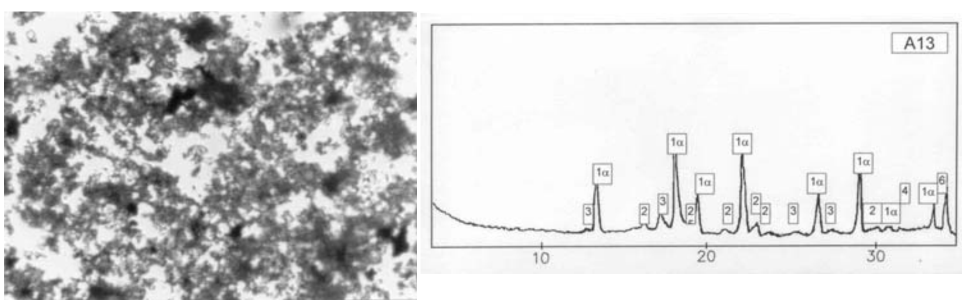

Fig. 2. microphotographs of deposit (refracted light , magnification x250) and X – Ray diffractograms of deposit, 1 – a Corundum, 2 – Hibonite - 5H, 3 – Hematite, 4 – Magnetite, 5 – Fe, 6 - Graphite

Both methods show that the identified mineral phases in the deposit are corundum, graphite, hibonite - 5H and magnetite. The examined wall of SEN, and especially the contact zone of SEN directly by the deposit, show that with certain number of SEN, a change in mineral composition and structure of the contact zone occured, whereas with others, the contact zone remained with the same mineral composition and structure. This can be easily seen in Fig.3. During the process of measuring the inner diameter of SEN, it was perceived that with certain number of SEN an increase of the original value of the inner diameter of SEN A6 and SEN A14 occured after the exploitation, where with others, the original value of the inner diameter did not change SEN B5 and SEN A2. An inner deposit with both of them was formed, which influenced the final value of the inner diameter.

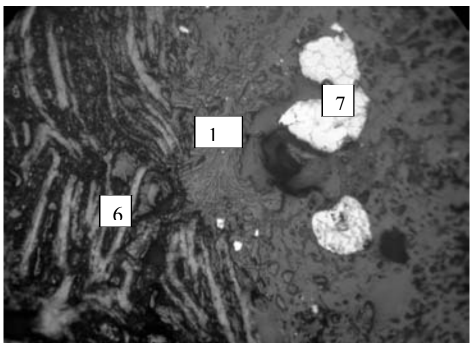

Fig. 3. The microphotographs of the contact zone SEN A14 directly by the deposit (reflected light, magnification x 400), 1a – Secondary Corundum, 6 – Graphite, 7 - Steel inclusion

This confirms the fact that, in the first case, the deposit formed due to the secondary oxidation, but also due to the reactions taking place in the very material of SEN. In the second case, the deposit was formed only due to the secondary oxidation of steel.

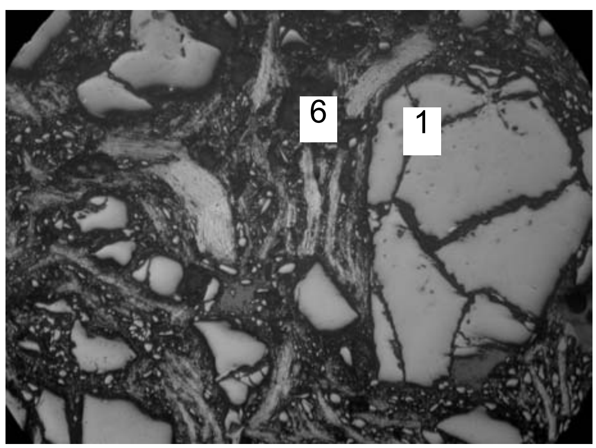

Fig. 4. The microphotographs of the contact zone SEN A8 directly by the deposit (reflected light, magnification x 400), 1 – Primary Corundum, 6 – Graphite,

In the SEN material A6 and A14, at the casting temperature of about 1558^{0}C the following reaction is taking place,:

$$|AL_2O_3| + |SiO_2| + 3|C| = \{Al_2O\} + \{SiO\} + 3\{CO\} \qquad (1)$$

because of the presence of graphite in the shape of strips and the remains of coke which was a desoxidant. During this reaction the gas sub oxides of Al and Si are formed. These sub oxides diffuse in the SEN wall at the temperature growth direction, i.e. towards the surface of the inner wall of SEN and they become a part of liquid steel.

On the contact border of refractory material of SEN and liquid steel, the reaction of gas sub-oxides oxidation is taking place:

$$\{Al_2O\} + 2[O] = Al_2O_3 \qquad (2)$$

where the oxygen, released from steel serves as an oxidant the consequence of the temperature drop in the layer close to the SEN wall but also to the oxygen released during the chemical reaction:

$$\{SiO_2\} = [Si] + [O] \qquad (3)$$

The results of the X – Ray fluorescent spectrometry of the SEN B5 and SEN A2 walls (Fig. 5.) show that the ray intensities are almost identical for Al, Si, Ca, Ti and Fe both in the contact zone of SEN and within the whole depth of the wall. This confirms the fact that in case of SEN B5 and SEN A2 there was no diffusion in the SEN material.

Fig. 6. shows that there was the increase of intensity of Al and Si in the contact zone 2 mm depth of the SEN A6 and SEN A14 walls, in contrast to the intensity of those elements where the depth is increased. This confirms their diffusion through the material.

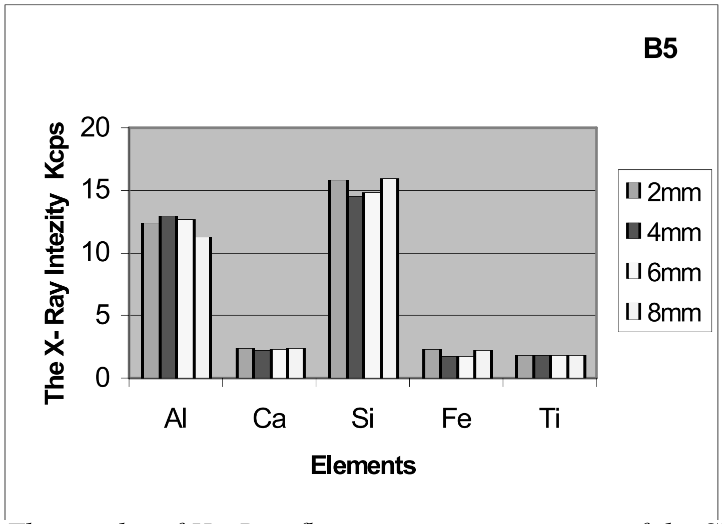

Fig. 5. The results of X - Ray fluorescent spectrometry of the SEN B5

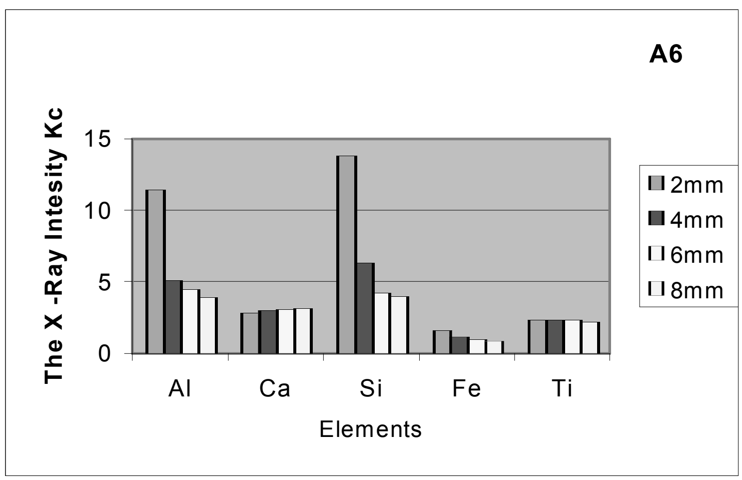

Fig. 6. The results of X - Ray fluorescent spectrometry of the SEN A6

Conclusion

On the basis of the results exposed in this paper and obtained during the research of great number of SEN the following can be concluded:

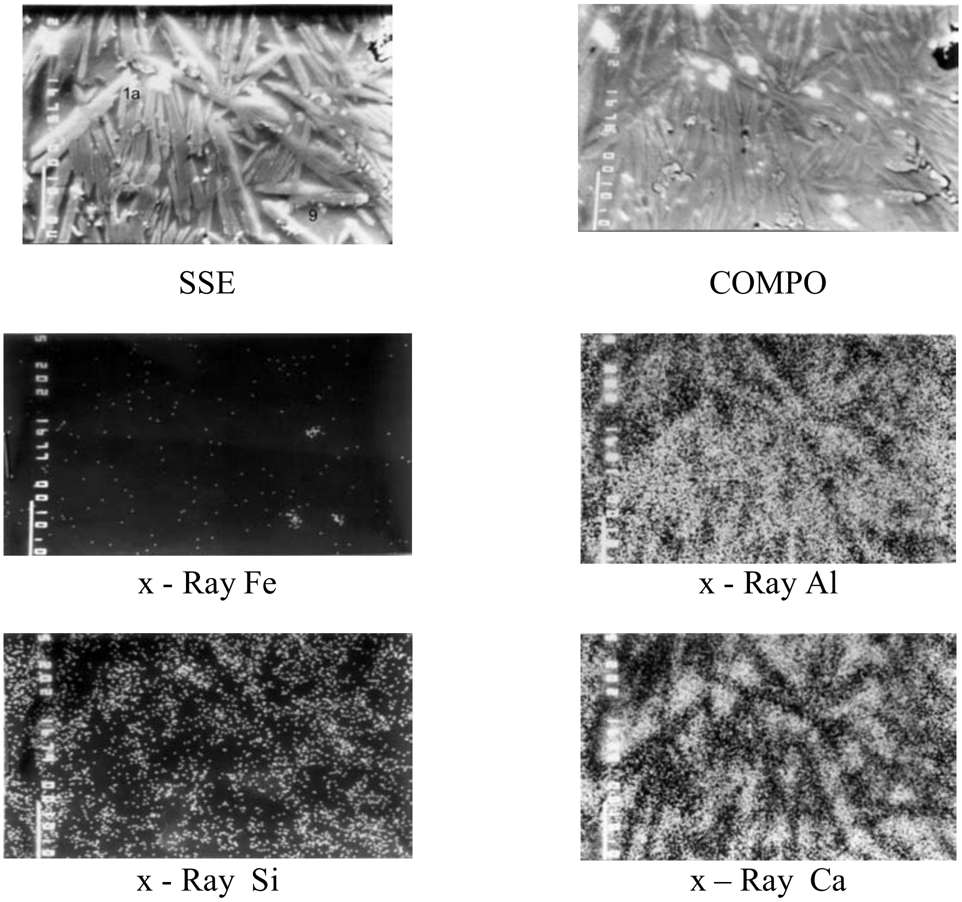

Fig. 7. The results of electronic microanalysis of the SEN D2 - contact zone (magnification x 2000), 1a - Secondary Corundum, 9 - Glass

The greatest average thickness of deposits formed in the inner side of the SEN wall was perceived during the casting of the aluminum killed steel type B.

The scab forming has been caused by processes of reoxidation and desoxidation of steel on one hand and by processes of desoxidation and reoxidation of steel and reaction between the SEN material and steel on the other.

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