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ISSN 0543-5846
METABK 56(1-2) 40-42 (2017)
UDC – UDK 669.15:621.746:621-49.775.002.61:669.782-541.451:669.71-541.451=111

CHANGE OF MOULD FLUX PROPERTIES DURING CONTINUOUS CASTING OF FERRITIC STAINLESS STEEL

Received – Primljeno: 2016-10-19
Accepted – Prihvaćeno: 2016-11-20
Original Scientific Paper – Izvorni znanstveni rad

During the continuous casting of stainless steel the performance of the mould powder is a key factor in this process. The content of Cr in the steel is up to 18 %, high corrosion resistance of the steel is improved with Al addition, up to 4 %. The aim of the paper was to study the change in physical properties of the casting powder, due to reactions between Al in the steel with SiO_2 in the mould flux during continuous casting. In order to identify the change in the ability of lubrication casting slag with time, depending on the increase in the content of alumina in the slag. On the basis of these results, the most suitable casting powder for continuous casting of ferritic stainless steel with high aluminium content was determined.

Key words: alloy steel, casting, powders-properties, SiO_2, Al_2O_3

INTRODUCTION

Mould fluxes have a major role in the continuous casting of steel [1]. The powders are fed onto the top of the molten metal surface, where they form a sinter layer, then a mushy layer and eventually a liquid slag (flux) pool. Liquid slag from the molten pool infiltrates into the mould/strand channel and lubricates the newly formed steel shell. The most of the first liquid entering the channel freezes against in the copper mould and forms a glassy, solid slag film. The liquid slag layer controls the lubrication, and the solid slag layer controls the horizontal heat transfer [2].

The composition of the casting powder depends on the composition of the steel. The essential characteristics of the casting powder are: the melting point, the crystallization temperature and the viscosity, which affects the heat transfer, lubricating ability and flux consumption. Mould fluxes [3] are usually made up of about 70 % CaO and SiO_2, 0-6 % MgO, 2-6 % Al_2O_3, 2-10 % $Na_2O(+K_2O)$, 0-10 % F with varying additions of TiO_2, ZrO_2, B_2O_3, Li_2O and MnO. Carbon particles in the form of coke, carbon black and graphite are added to control the melting rate. The basicity, (% CaO / % SiO_2) lies in the range from 0,7 to 1,3. Acidic fluxes are glassy, have high thermal conductivity and good lubricating ability. Basic fluxes tend to crystallize, have low thermal conductivity and poor lubricating ability.

EFFECT OF ALUMINIUM OXIDE

The increased Al_2O_3 content in the liquid flux effects T_{liq}, T_{sol} and viscosity which in turn result in reductions in the powder consumption and the lubrication supplied [4]. The Al_2O_3 promotes the crystalline phase at the expense of the glassy phase, which results in an uneven outflow of the casting slag through the casting slit, worse lubrication to the shell, unequal heat extraction and consequently, the formation of surface defects.

High Al steels have excellent properties since Al enhances austenite stability. However, the Al in steel reacts with the more reducible oxides in the slag to form Al_2O_3. Of the various constituent [5,6], SiO_2 is the most affected because of its high concentration in mould slags (eq. 1) but other oxides such as FeO, MnO, B_2O_3, TiO_2 also react with Al (eq. 2) where M = Fe, Mn, etc).

$$4[Al] + 3(SiO_2) = 2(Al_2O_3) + 3[Si] \quad (1)$$

$$2[Al]+(3/y)M_xO_y = (Al_2O_3)+(3x/y)[M] \quad (2)$$

The Al_2O_3 solubility in the slag can be very high. In two research studies the influence of the increasing content of Al_2O_3 from 5 to 20. % on the melting properties and the viscosity of the mould flux [7,8]. The melting temperatures of the mould flux are increased with higher Al_2O_3 contents particularly from 5 % on. The viscosity of the casting slag gradually increases with rising content of Al_2O_3, at temperatures above 1 200 °C, at the contents of over 10 % Al_2O_3 the viscosity significantly increases. A temperatures of 1 200 °C (near the melting temperature of the casting powder) even a small content of more than 5 % Al_2O_3, shows a significant increase of viscosity.

MATERIALS AND METHODS

Four different powders from the different manufacturers were used in this study. Two casting powders: Accutherm ST-E116 and Accutherm ST-C39/26-Al4D with a higher proportion of SiO_2 from Stollberg. Another casting powder was Termocont EŠ from Termit

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Domžale, the powder had acidic composition. The fourth casting powder was C489/ TW4 from Metallurgica, Scorialit with basicity of 1,0. The properties of the casting powders, which characterize the physical properties, are shown in Table1.

Table 1 Basicity of casting powder, temperature of onset of melting and melted powder, the content of free carbon and bulk density of powder

Powder	B	T / °C		density
	CaO/SiO$_2$	Melting start	Fully melted	kg/dm^3
ST-E/116	0,84	1 120	1 150	0,8
ST-C39/26-Al4C	0,55	900	970	0,65
Tremokont EŠ	0,55	705	740	0,71
C489/TW4	1	1 090	1 130	1
	Viscosity/ Pa s			Free C
	1 400 °C	1 300 °C	1 200 °C	mas.%
ST-E/116	0,17	0,29	0,55	3
ST-C39/26-Al4C	0,07	0,11	0,18	3,7
Tremokont EŠ	-	-	-	3,5-4,2
C489/TW4	-	0,6	-	5,6

The experiments were carried out on a 20 kg Leybold Heraeus induction melting furnace. Ferritic stainless steel with 4 % Al was melted in a ZrO_2 crucible and then casting powder was added onto the melt steel. Samples of the formed flux after the powder melting were taken to visually check the changes in viscosity, analysis with a melting microscope and for chemical analysis. The samples for the melting microscope were crushed and compacted into cubes. The flux samples with different content of Al_2O_3 were heated to 1 250 °C in an annealing furnace, to visually inspect the viscosity.

RESULTS AND DISCUSSION

Change in chemical composition of the samples taken of the casting slag, at intervals after meltdown show that increasing the content of Al_2O_3 from 3 to 4 % in the received casting powder, to a little over 50 % of Al_2O_3 at the end of the experiments as shown in Figure 1.

As the Al_2O_3 content increases, the SiO_2 content decreases. When the Al_2O_3 content is higher than 40 %, the SiO_2 content is below 10 %, this also causes an increase in basicity (CaO / SiO_2). The results from the melting microscope are given in Figures 2 and 3.

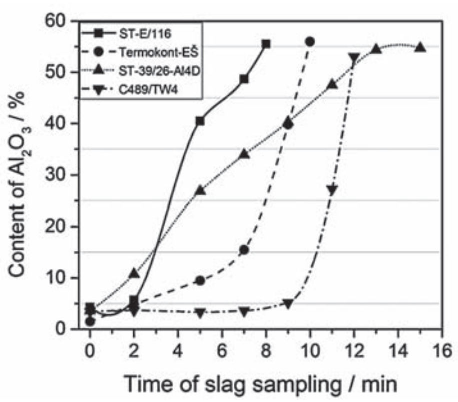

Figure 1 The increase of Al_2O_3 content in casting powders with time

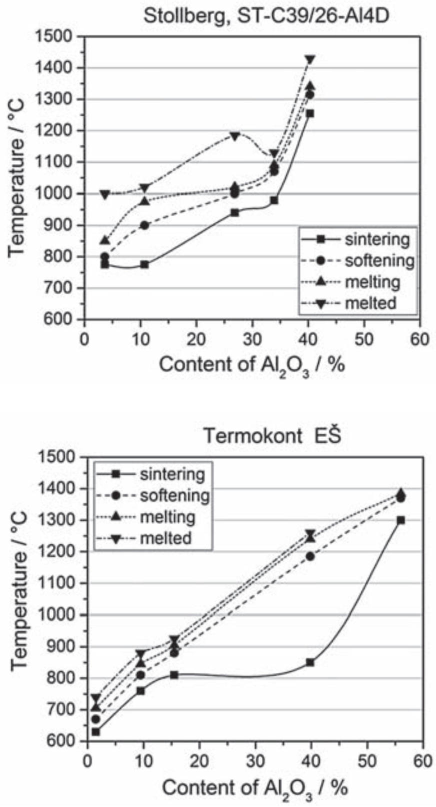

Figure 2 Change in important temperatures with increasing Al_2O_3 for Stollberg, ST-C39/26-Al4D and Termokont EŠ

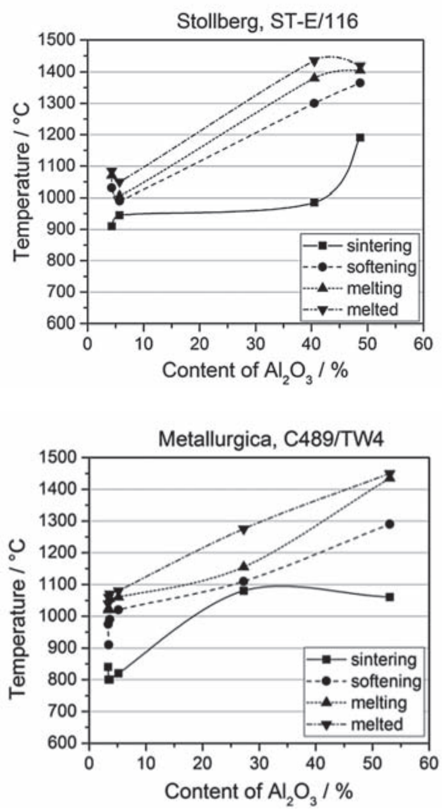

Figure 3 Change in important temperatures with increasing Al_2O_3 for Stollberg, ST-E/116 and Metallurgica, C489/ TW4

The sintering, softening, melting and molten slag temperatures of the casting powders change with different alumina contents. In general it can be said that the sintering softening, melting and liquidus (melted) temperatures increase with the Al_2O_3 content.

The lubrication ability of the casting powder changes due to the change in the chemical composition. This is the result of the reactions between the casting powder and the molten steel. The visual assessment of the flux viscosity gave us a rough estimate on the lubricating ability of the casting powder, the samples are shown in Figure 4.

Melting temperatures of the casting powders without and with saturation of Al_2O_3 were lower for the casting powder Accutherm ST-C39/26-Al4D (B = 0,55) and Termokont EŠ (B = 0,6), than for casting powder Accutherm ST-E/116 (B = 0,84) and Scorialit C489/TW4 (B = 1,0). The meltdown temperatures of casting slag with Al_2O_3 saturation were about 1 400 °C.

Table 2 **Visual evaluation of flux samples**

Casting powder	sample	time (min)	Al_2O_3 (%)	Visual assessment
Accutherm ST-E/116	1	2	5,70	fluid
	2	5	40,50	solid
	3	7	48,69	solid
	4	8	55,55	solid
Accutherm ST-C39/26-Al4D	1	2	10,73	fluid
	2	5	26,85	fluid
	3	7	33,92	fluid
	4	9	40,31	solid
	5	11	47,52	solid
	6	13	54,40	solid
	7	15	54,70	solid
Termokont EŠ	1	2	4,83	fluid
	2	5	9,48	fluid
	3	7	15,50	fluid
	4	9	39,80	melting
	5	10	56,00	solid
Scorialit C489/TW4	1	2	3,64	fluid
	2	5	3,35	fluid
	3	7	3,61	fluid
	4	9	5,16	fluid
	5	11	27,25	solid
	6	12	53,05	solid

The Al_2O_3 content in the casting powders rose sharply after the melting of the powder. According to the unit time, the fastest increase (exponent) of the Al_2O_3 content in the melted flux occurred in the Accutherm ST-E/116 casting powder. In the casting powder Accutherm ST-C39/26-Al4D the Al_2O_3 content increased linearly. In the case of Termokont EŠ and Scorialit C489/ TW4, the Al_2O_3 content increased sharply after the powder melted.

Visual evaluation of the flux viscosity at 1 250 °C indicates that the casting powders with acidic composition melt even at higher Al_2O_3 contents. Flux samples from Accutherm ST-C39/26-Al4D and Termokont EŠ powders are liquid up to 30 % of Al_2O_3. In the case of flux samples from Accutherm ST-E/116 and Scorialit C489/TW4 are liquid up 10 % of Al_2O_3.

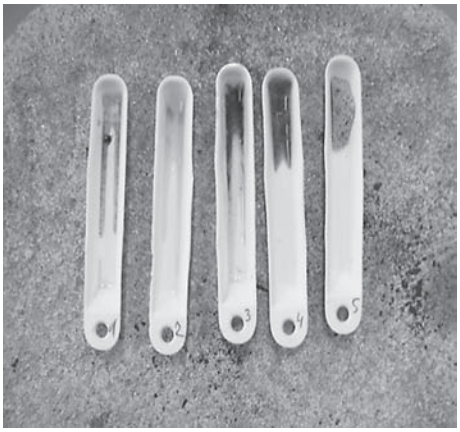

Figure 4 Samples for visual evaluation of flux viscosity

CONCLUSION

The results of the research of reactions between the melt of ferritic stainless steel with 4,5 % Al and casting powders fluxes has shown that Al_2O_3 content increase over time. The saturation of the casting powder flux in this study was achieved at levels of about 55 % Al_2O_3. The increase in Al_2O_3 has a profound effect on the casting powder properties. From the four investigated casting powders, based on the changes in physical characteristics during the reduction of SiO_2 from the casting powder flux with Al from the steel melt, the casting powder Accutherm ST-C39 / 26-Al4D is the most suitable for the casting of ferritic stainless steel (4 % Al).

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Note: Responsible person for English translationMarija Majda Travnik Vode, Sela, Slovenia