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ANALYSIS OF THE PROPAGATION OF DEFECTS GENERATED BY THE OSCILLATION MARKS ON LAMINATED PRODUCTS

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ABSTRACT

In this work was followed the determination of a method of diminishing the depth of the oscillating brands and identifying how the oscillating brands can influence the surface quality of hot rolled products (backgammon and strips). This study addresses the phenomena that take place at the initiation of the crust in the crystallizer and treats the theoretical aspects of the formation of the oscillating brands on the surface of the cast products continuously. Experiments carried out have enabled to reveal aspects regarding the relationship of oscillation brands – the quality of the products (molded or laminated) and the purity of the continuous cast slabs.

KEYWORDS: segregation in Sulphur, macroscopic inclusions, fragile silicates, purity of steel

1. Introduction

The present study addresses the phenomena occurring at the initiation of the crust in the crystallization and deals extensively with the aspects of the formation of the oscillating marks on the surface of the continuously cast products [1-2]. Experiments conducted at Mittal S.A., Continuous Casting Section 1 (TC1) allowed some aspects of the oscillation brands to be revealed - the quality of the products (cast or rolled) and the purity of the continuous castings. Continuous casting is a very widespread process, whose efficiency is strictly dependent on process parameter control and the implemented construction solution. For this reason, different automated control and process control systems are used worldwide, resulting in metal removal of over 98% [3-5]. The development of the assortment and the low degree of automation of the continuous casting machines of TC1 existing castings led to the emergence of classes of defects specific to continuous casting, of which the highest weight (in terms of material downgrades) and hard to be removed are the marks of oscillation and central cracks, also known as voids. The main purpose was to determine a method of diminishing the depth of the oscillating marks. A second purpose was to identify how oscillatory marks can influence the surface quality of hot-rolled products (sheets and strips) [6-8].

2. Experimental condition

Three bits were continuously poured at Mittal S.A./TC1. Communication of all batches was: 7.6 mm amplitude; the crystallizer lubricant (Accutherm ST - C 39/4S) and the absence of the protective tube between the pot and the distributor. Characterization elements of the bats are shown in Table 1.

Table 1. *Characterization of burdens and their chemical composition*

No. charge	Steel brand	No. MTC	Speed casting, [m/min]		No. oscillations, [cicli/min]		Chemical composition, [%]					
			F1	F2	F1	F2	C	Mn	Si	P	S	Al
923657	Ol 37 - 2k	1	0.73	0.70	84	84	0.12	0.64	0.30	0.020	0.014	0.005
923658	Ust 12 Al	4	0.92	0.90	107	115	0.03	0.30	0.02	0.016	0.013	0.045
936884	43 A	3	0.48	0.51	53	74	0.17	0.98	0.25	0.016	0.015	0.005

Between the three boreholes, transverse samples were taken from castings, which were then examined macroscopically and microscopically.

3. Results and discussions

Following the reception of castings, the only surface defects detected were slag traps on the surface only at bay 923657 (4 blanks on each wire). Following the reception of laminated products, superficial cracks were found and polished on a single sheet of sheet from batch 936884. Using the calculation formulas, the negative stripping times in Table 2 were determined. Also, in this table the depth of the corresponding oscillation mark is calculated according to the relationship:

$$h = 0.0682\, e^{0.167\,\delta}, \text{[mm]} \tag{1}$$

as well as the depth measured on samples taken.

Figure 1 shows the correlation between the formula used for calculating the oscillation marks and the depth determined by microscope measurements.

Table 2. *Negative stripping times and the depth of the oscillation mark*

No. charge	Negative stripping time, [s]		Calculated depth of the oscillating mark, [mm]		Measured depth of the oscillating mark, [mm]	
	F1	F2	F1	F2	F1	F2
923657	0.265	0.269	0.292	0.275	0.300	-
923658	0.209	0.200	0.288	0.253	-	0.225
936884	0.413	0.323	0.311	0.216	0.430	-

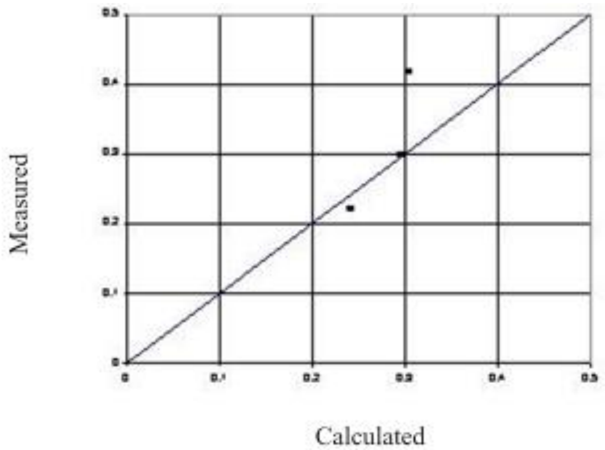

Fig. 1. *Comparison of calculated values with measured values for the depth of the oscillation marks*

The microscopic investigation of the samples taken was carried out for the highlight of the following aspects: the purity of inclusions situated at a distance of approx. 20 mm of slab surface, considering this quota as the maximum possible limit of crystallization influence (thickness of the crust at the output of the crystallization, for charges followed between 8-12 mm); the purity of the inclusions in the area of the oscillating brands (the area with a depth of approx. 5 mm from the surface; the solidification structure in the oscillating brands area.

3.1. Purity of inclusion in the area approx. 20 mm from surface sleb

The samples taken were analysed in cross section, on a direction perpendicular to the upper face of the slab. The analysis was accomplished by completing the entire thickness of the sample and counting the number of microscopic and macroscopic inclusions on each microscopic field.

It was observed that the maximum number of inclusions is placed in the field 10-15 mm from the slab surface. Macroscopic inclusions located in other areas than oscillating marks were observed only in the sample of charge 923657, i.e. 15 mm from the surface: 2 INM ø 40-80 µm and 1 INM ø > 80 µm. In this analysis it was started from the fact that the inclusions under 40 µm are endogenous, and those over 80 µm are exogenous. The investigation of the sample of charge 936884 in two parallel planes with the superior face of the slab, located at the rate of 5 and 15 mm, with dimensions 25 x 45 mm, emphasized that the problem of concentration of inclusion is not a local accident.

3.2. Purity of inclusion in the area of the oscillating brands

The purity analysis of all the samples in the area of the oscillating brands has emphasized, at charge 936884, the existence of the inclusion strings embedded in "hook" formed during negative stripping, in Figure 2 It is observed that the length of these strings does not exceed 100 µm. This phenomenon is characteristic of the entire sample analysed.

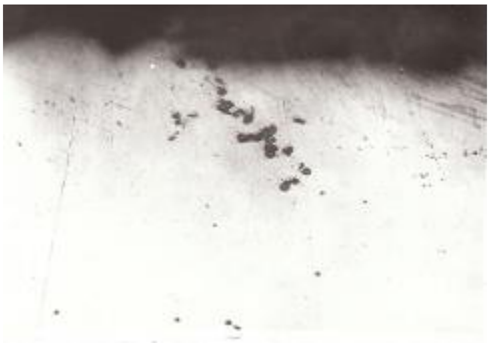

Fig. 2. *Non-metallic inclusions on the oscillation mark – charge 936884 – X250*

Fig. 3. *Group of non-metallic inclusions in the right of oscillation mark – charge 936884 – X 50*

Also, at this charge it was observed in the area of the oscillating brands, a group of macroscopic inclusions positioned at 3-4 mm from the surface. The appearance and layout of this grouping is shown in Figure 3.

The microprobe analysis of these grouped inclusions has emphasized the following: the inclusions have an aluminum base component; the following components as weight are magnesium and calcium; silicon content does not differ from the value of the base material (the content of Si inclusion is close to that of the steel). The results of the analysis are presented in Figures 4-9.

Fig. 4. *Composition image, X300*

Fig. 5. *Image of secondary electrons, X300*

Fig. 6. *Distribution Al, X300*

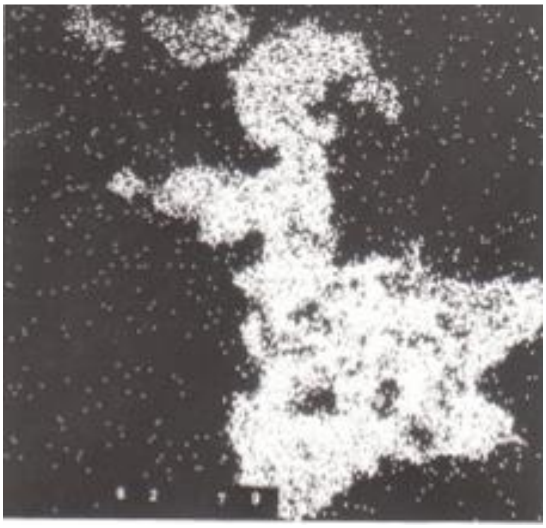

Fig. 7. *Ca Distribution, X300*

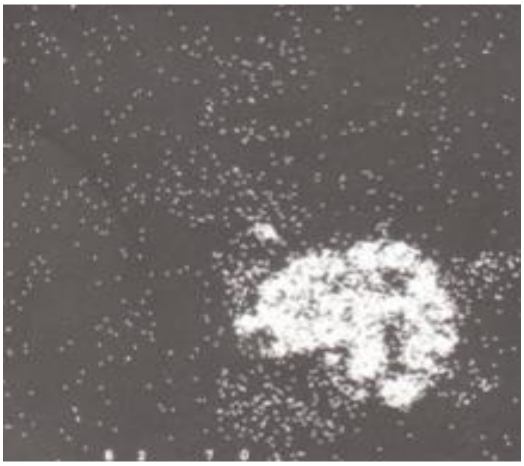

Fig. 8. *Mg Distribution, X300*

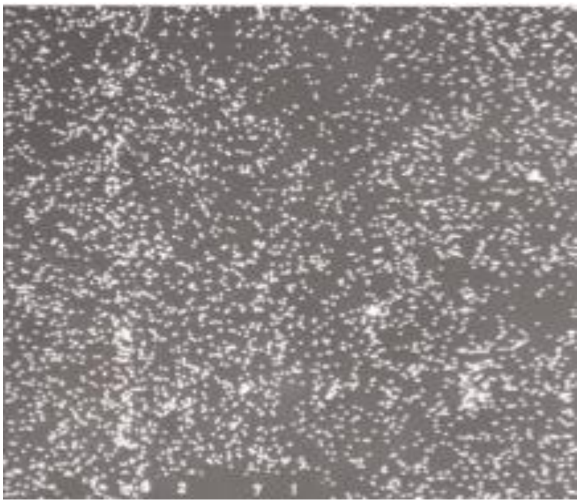

Fig. 9. *Si Distribution, X300*

3.3. The appearance of the hardening structure in the oscillating brands area

The analysis of the hardening structure in the area of the oscillating brands emphasized the following: at charge 936884 it was observed the presence of "hooks", Figure 10. At charge 923658 these "hooks" were virtually non-existent - Figure 11; Macroscopic inclusions analysed for charge 936884 9 (Fig. 3-9) were not retained by the deformation of the crust during the negative stripping, Figure 12.

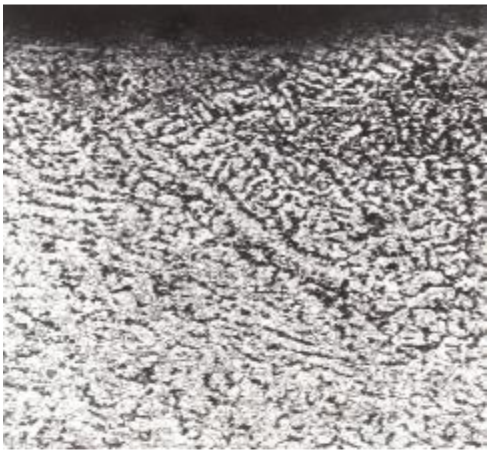

Fig. 10. *Hardening structure in the right of the oscillating mark at charge 936884 – X 100*

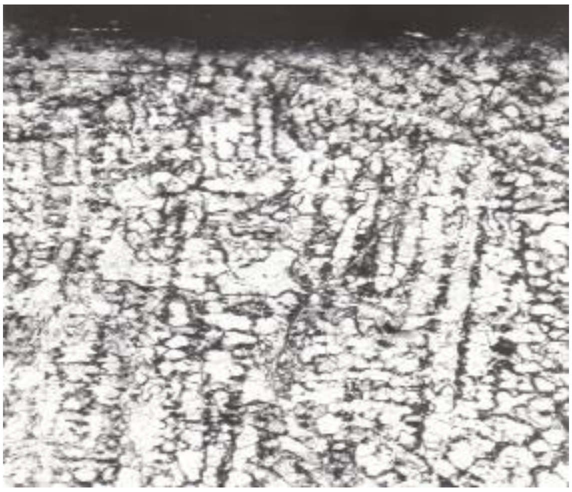

Fig. 11. *Hardening structure in the right of the oscillating mark at charge 923658 – X 100*

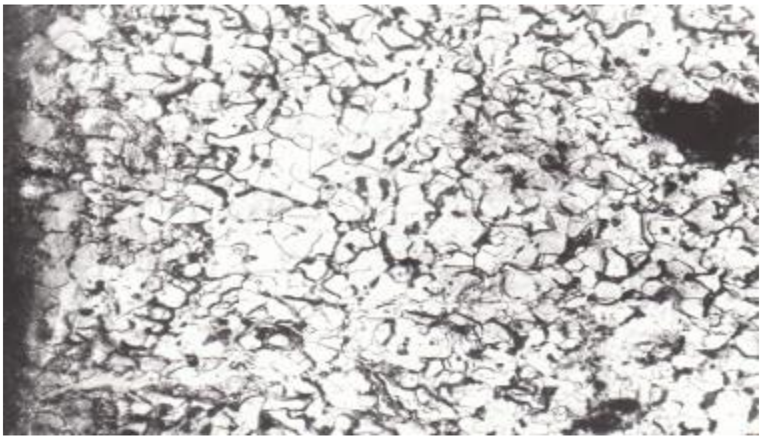

Fig. 12. *Solidifying structure in the area of macroscopic inclusions - charge 936884 – X100*

4. Conclusions

Oscillating marks cannot be considered as deceiving a defect, they are characteristic of continuous casting.

Oscillating marks may be an additional cause in the appearance of cross-sectional cracks, in conditions where the formation of the crust has been defective (deep oscillating brands with strong crust deformation and inclusion in the area of scarring).

Inclusions, especially exogenous ones, can be caught, now of negative stripping, in a subcutaneous area with a thickness of approx. 100 µm, as is apparent from the Figures 2 and 10.

Concentration of endogenous inclusions in an area of max. 20 mm thickness from the surface of the sleb is the characteristic to the curved wire casting machines. The only possibility to correct this is to ensure the purity of the upstream steel. These inclusions will affect the quality of the laminate product surface.

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