Analysis of the technology of ladle processing of IF steel and development of recommendations to improve the quality of the finished metal

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Introduction.
Modern trends in the automotive industry are aimed at reducing the weight of the car and increasing its safety. These challenges are met by using ultra-low-carbon steel grades such as IF steel, from which car bodies are produced by stamping and deep drawing. High strength combined with high formability of IF steel allows the use of thinner rolled products in the car body structure, which reduces its weight while maintaining high strength characteristics. To improve the quality of IF steel, it is necessary to control the content of dissolved nitrogen and carbon, as well as the state of the surface of rolled sheets. The cause of most sheet surface defects is associated with non-metallic inclusions. The purpose of this study is to analyze the change in the type and amount of non-metallic inclusions throughout the entire technological chain of smelting, ladle processing and casting of IF type steel.

Research methods.

IF steel is without free embedding atoms such as nitrogen and carbon. The main requirements for this steel are: Deep drawing -achieved due to chemical requirements. the composition is nitrogen and carbon in the amount of less than 50 ppm; High surface quality - achieved due to the purity of HB. In this paper, the technology of smelting IF in the converter shop of PJSC Severstal is considered, the target chemistry of which is shown in Table 1. The following slide shows the metal sampling scheme.

In the course of my work, I analyzed a selected samples of metal from a club by micro-X-ray analysis. The oxide inclusions isolated by me were conditionally divided into three groups.

Further, all the selected metal samples for bucket processing were analyzed by the FGA at the LECO TS-600 installation in order to determine oxygen in the HB and their distribution in the selected groups. To carry out this analysis, I cut out three samples from the second zone.

Technological scheme of IF steel smelting in the KCC of PJSC Severstal

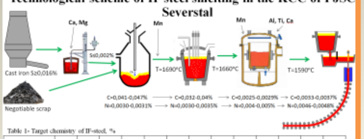
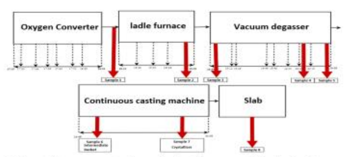


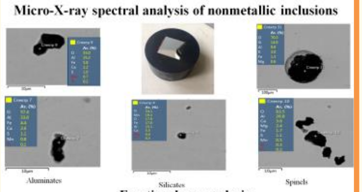
Table 1- Target chemistry of IF-steel, %

Element	C	Si	Mn	P	S	Cr	Ni	Cu	Al	Mo	Ti	Nb	N
Minimum value	0,003	-	0,55	0,04	-	-	-	-	0,02	-	0,02	-	-
Maximum value	0,005	0,03	0,70	0,06	0,012	0,05	0,03	0,05	0,07	0,008	0,045	0,008	0,005

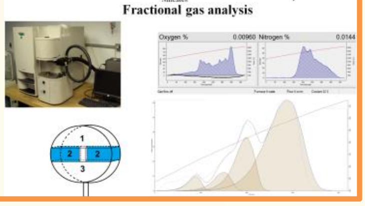
Metal sampling scheme



Micro-X-ray spectral analysis of nonmetallic inclusions



Fractional gas analysis



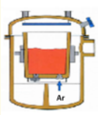
In this paper, the equilibrium carbon content was calculated after vacuum decarburization at 140 PA. The results of the equilibrium and actual carbon are given in the table. As can be seen, the actual value is significantly higher than the equilibrium value, which may indicate that the system does not reach its equilibrium as a result of operating at a higher residual pressure in the chamber. Which may be due to LEAKAGE through the vacuum seal.

Next, the steel degassing was calculated. The final gas content was extracted from the Geller equation after argon purging in vacuum and as a result of the formation of CO bubbles.

This slide shows a comparison of the calculated and actual nitrogen content. It can be seen that the data converge well with each other, which indicates that the role conditions of degassing are similar to the calculated ones.

In order to achieve the purity of the metal according to HB, I have read the necessary amount of calcium for the modification of aluminates. During the deoxidation of this amount of oxygen, such an amount of aluminates is formed that it is necessary to modify the given value of calcium given in the table. Also on this slide is a comparison of the actual calcium that is given and the necessary. From which it can be seen that much less calcium is given away in production, as a result of which not all aluminates are modified and well removed from the metal, as a result of which overgrowth of filling glasses and surface defects occur.

Vacuum decarburization



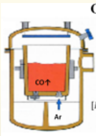
$$[C]+[O]=(CO)$$

$$\lg K_{CO} = \lg \frac{p_{CO}}{f_C[C]f_O[O]} = \frac{1168}{T} + 2{,}07$$

The vacuum chamber discharge is 140 Pa or 0.0014 atm.

Melting number	[C]н, ppm	[C] fact., ppm	[C]equilibrium., ppm	[O]н, ppm	[O]к, ppm
558	310	28	1	626	251
559	330	25	1	658	252
726	350	29	2	606	178

Calculation of steel degassing during vacuuming



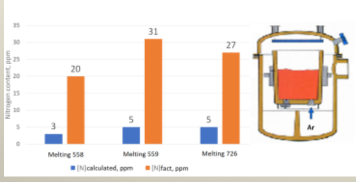
$$V_{general} = V_{Ar} + V_{CO}$$

$$[H]_{final} = \left(\frac{V_{general} \cdot f_H^2}{0{,}82 \cdot p \cdot m_{Me} \cdot 10^{-3}} + \frac{1}{[H]_{initial}}\right)^{-1}$$

$$[N]_{final} = \left(\frac{V_{general} \cdot f_N^2}{15 \cdot p \cdot m_{Me} \cdot 10^{-3}} + \frac{1}{[N]_{initial}}\right)^{-1} \quad V_{CO} = \frac{\Delta C \cdot m_{Me} \cdot V_m}{100 \cdot M_C}$$

	[H], ppm	[N], ppm
Melting 558	0,2	3
Melting 559	0,3	5
Melting 726	0,4	5

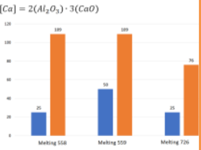
Comparison of the calculated nitrogen content and the actual



Calculation of the necessary calcium for the modification of aluminates

$$2Al_2O_{3_{TB}} + 3[Ca] = 2(Al_2O_3) \cdot 3(CaO)$$

Melting	[O]к, ppm	m_{Al2O3}, kg	m_{Ca}, kg
558	251	185	109
559	252	185	109
726	178	130	76



Results and Discussion.

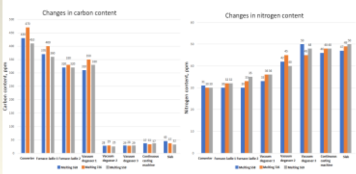
The paper analyzes a series of three swimming trunks. Changes in carbon and nitrogen content according to passport data are shown on the screen. From which it can be seen that the final carbon content after vacuuming is not affected by the initial content, which indicates the stability of the technology. It is also seen that the minimum value of nitrogen is reached at the converter and then only increases throughout the production technology.

This slide shows the results of the FGA for 558 melting. From which it can be concluded that the main HB are ALUMINATES. The formation of which is observed as a result of the recoil of aluminum as a deoxidizer and alloying element. After the vacuum breakdown, an increase in aluminates and nitrogen content is observed as a result of secondary oxidation. It should be noted that in this melting, a very intensive purge with an inert gas was carried out, which could serve to expose the metal and, as a consequence, secondary oxidation visible at this peak.

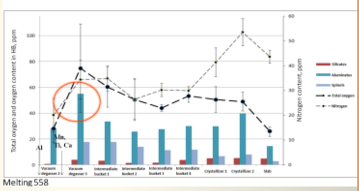
On this slide for 559 melting, we see a similar picture with one difference: the content of HB decreases as a result of good modification with calcium and softer purging with inert gas, which contributes to better removal of HB from the metal.

The results of FGA 726 melting are similar to 558 melting. We also observe secondary oxidations, but without such large emissions as in the 558 melting.

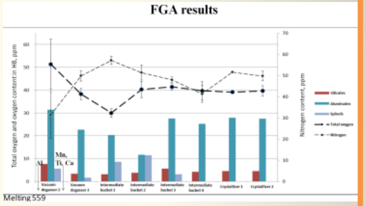
The change in carbon and nitrogen content stood up



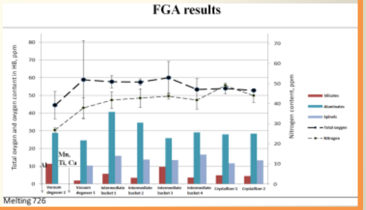
FGA results



FGA results



FGA results



Conclusions.

In the course of the analysis of the existing technology of smelting and ladle processing of IF-steel, it can be seen that during the processing of steel at the FCC, at the UVS after the breakdown of the vacuum and at the CPR, there is an increase in the nitrogen content in the steel. In order to minimize the ingress of nitrogen into the metal, this paper proposes a variant for the production of IF-steel without metal processing at the CPC, shown in Figure 17, since no technological operations will stand idle at this unit, and the content of dissolved nitrogen is growing. In order to implement this technology, it is proposed to increase the metal outlet temperature to 1720°C during steel smelting at an oxygen converter in order to compensate for temperature losses during production without the participation of additional heating at the FCC.

Also, in order to minimize the ingress of nitrogen into the metal, it is proposed to release the metal from the converter in a protective argon environment, as well as to protect the metal from secondary oxidation in the mold.

In the course of the work, it was found that the predominant amount of non-metallic inclusions is aluminates, which adversely affect both casting (overgrowth of steel-pouring nozzles) and the surface quality of the finished sheet. The main reasons for the formation of aluminates is that aluminum in the course of steel production is used not only as a deoxidizing agent, but also as an alloying element, and as a result of poor protection of the metal from secondary oxidation, after a vacuum break, the metal is saturated with oxygen, forming new aluminates. Also, during the secondary oxidation, the metal is saturated with nitrogen, which is a harmful element for this class of steel. It is recommended to take measures to increase the protection of the metal in the degasser after breaking the vacuum in order to protect against secondary oxidation.

In order to reduce the amount of non-metallic inclusions formed as a result of deoxidation of the metal with aluminum, to produce a return of a larger amount of calcium in order to modify the NI and better remove them from the volume of the metal.

Recommendations for changing the technology