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METALLURGICAL FEATURES OF THE STEEL PRODUCTION FOR THE AUTOMOBILE INDUSTRY IN MAGNITOGORSK IRON AND STEEL WORKS ("MMK")

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Abstract

The development of IF-steel at MMK started in 2002. The manufacturing of this product is organized according with the following production scheme:

BOF shop → hot rolling mill 2000 (shop №10) → cold rolling mill 2500 (shop №5) → 2-stand reverse mill (shop №5) → continuous hot galvanizing line (shop №6).

Fine cleaning of the ferrite matrix from interstitial atoms of carbon and nitrogen in production of highly formable cold-rolled steels provides grain growth, formation of the required structure and good plastic properties. Minimization of the content of these interstitial atoms of carbon and nitrogen elements and their stabilization through binding into carbides and nitrides determine the technical and economical characteristics. The general trend of the production process of this technological development is obtaining minimal values for the carbon and nitrogen content. The best results are obtained with a carbon content below 0.002% and a nitrogen content below 0.003%.

One of the most complex problems in production of 006/IF is the provision of a minimum carbon content in the final product. With this aim, the modernization of the circulation installation for steel vacuum degassing was performed. The modernization of the vacuum degassing installation made it possible to supply oxygen through a stationary installed tuyere mounted in the hood of the vacuum chamber. As a result of this modernization, a mean carbon content of 0.0035% (min.: 0.002%, max.: 0.006%) can be obtained in steel after vacuum degassing, nowadays.

Deep decarburization of the metal can be only realized through vacuum degassing. This process is limited by diffusion of reagents to the reaction zone and liberation of products into gas phase. Therefore the organization of well-developed mass-transfer processes and gas liberation surfaces is a compulsory condition of this technology. With this in mind the prerequisite conditions of this process are the permanent support of the oxidation potential by means of oxygen lancing, agitation of metal by argon, decreasing of surface-active substances, in particular sulfur and nitrogen.

High solubility of nitrogen in steel at temperatures of steelmaking, especially in reaction zones is characterized by higher temperature, caused by exothermic processes of nitrogen removal. It complicates the process of nitrogen removal. Obtaining low nitrogen content in steel requires complex measures of limiting its penetration into the metal during this technological process.

Metallurgists use clean raw materials and apply oxygen blast and protect liquid metal from contact with air.

Some changes were made in the technology of melting providing the variation of blowing intensity, slag foaming, metal jet and liquid pool surface protection during tapping, secondary treatment and continuous casting. The method of "low" temperature reheating of slabs was used during IF rolling on the hot rolling mill 2000. The optimum coiling temperature and corresponding schedules of hot rolling were also used. All these measures allowed for obtaining high quality IF-steel strip of the dimensions 2.2-3.2 x 1170-1541 mm on the hot-rolling mill 2000.

Introduction

"MMK" belongs to the most important Russian metallurgical companies with its share in the metal production of the country at approximately 20%. The high product profitability and the vantage of MMK became possible due to the rapid realization of the reconstruction of metallurgical processes and, first of all, steelmaking.

The "MMK" company pays considerable attention to the sequential implementation of the program of the development of a high-technology metallurgical complex for the production of rolled sheets and profiles with the subsequent deep processing of the metal products, which can be competitive in the world market on a long-term basis. A significant share in the assortment of the MMK metal products belongs to the automotive steels, among which automotive body sheets occupy a leading position.

The attempts of auto manufacturers to increase the corrosion resistance of steel articles led to the necessity of the development and application of hot-dip galvanized sheets with optimum formability and surface quality. Extra low-carbon steels stabilized by titanium and niobium or only titanium, so-called IF ("interstitial free") steels, without free interstitial atoms of nitrogen and carbon are used for the production of these sheets.

The required set of equipment for the smelting of this steel is available in the "MMK" Oxygen-Converter Shop (Figure 1):

- A desulfurization unit, which ensures the degree of desulfurization of 50-70% and brings the sulfur content in cast iron to 0.005% and less.
- Oxygen converters of 370 tons capacity.
- A steel-degassing unit of circulating type with the supply of oxygen into the degassing chamber.
- A two-position ladle-furnace unit, which permits steel heating, desulfurization, alloying, and modification.
- A steel continuous casting machine.

The production of cold-rolled IF steels in "MMK" was started in 2002 according to two processing schemes, namely with and without zinc coating.

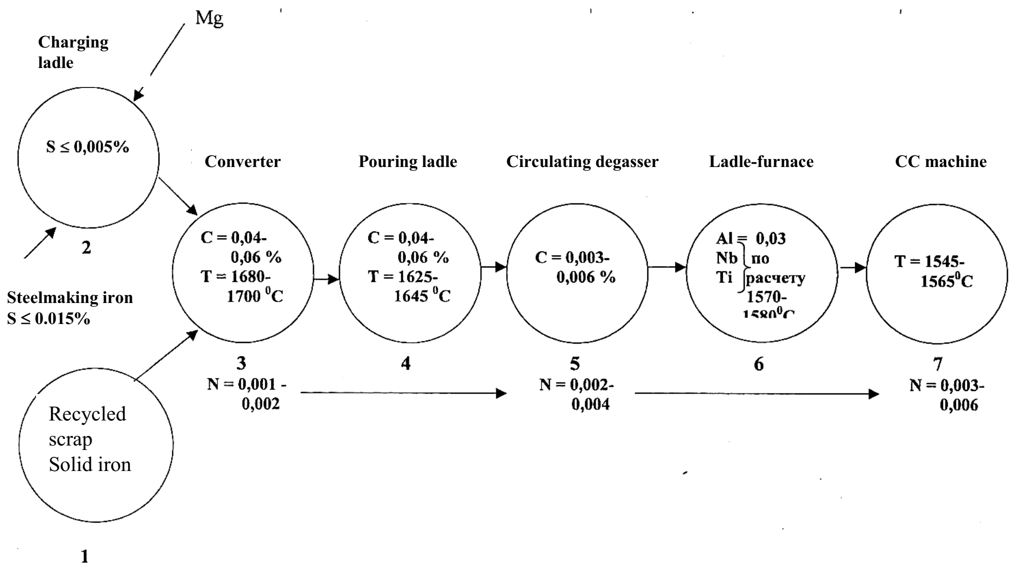

Figure 1. Processing scheme of the steel smelting.

Table I. Chemical composition of the IF steel produced in Oxygen-Converter Plant of "MMK".

Value	Content of elements, %								
	S	**Si**	**Mn**	**S**	**P**	**Al**	**Ti**	**Nb**	**N**
Average	0.0047	0.012	0.13	0.007	0.006	0.046	0.022	0.043	0.0045
Minimum	0.003	0.008	0.10	0.003	0.003	0.030	0.011	0.020	0.004
Maximum	0.007	0.020	0.18	0.009	0.012	0.057	0.045	0.074	0.007

The IF-steel chemical composition being represented in Table I for a particular version is characterized by very low concentrations of carbon, nitrogen, and sulfur, and also by the controlled relationship of microalloying elements (titanium and niobium) introduced into the steel depending on impurity content. This allows obtaining the required texture of the metal and, on this basis, producing cold-rolled sheets of the highest formability categories (OSV, VOSV).

However, the need of achieving a super-high purity of steel at the stage of steel smelting specifies the implementation of the technology of deep refining, the application of pure charge materials, the controlled addition of microalloying elements (niobium and titanium), and the special measures for the protection of liquid steel from the contact with atmosphere.

Decarburization

One of the basic and most complex problems in the IF-steel production is to provide the smallest possible carbon content in the finished steel. For this aim, a circulating degassing unit was reconstructed, first of all, for an increase in the capacity of the steam-ejector pump and oxygen supply.

The possibility of the oxygen supply with a flow rate ranging from 200 to 2000 m^3/h upon degassing allows a decrease in the carbon content after degassing, to increase the stability of the steel decarburization process. It also ensures heating of the degassing chamber in the period between melts without any electrical heating. In addition, the number of argon tuyeres in the suction branch of the degasser was increased from 6 to 12 and the new slit tuyeres of 3 mm in diameter were implemented, which made it possible to increase the flow rate of argon, to enhance the circulation, and to ensure a stable degasser operation during the entire campaign. The temperature of the steam for the steam-ejector pump was increased to 200 °C to provide a rarefaction of less than 1 mm Hg in the degassing chamber for the minimum time period.

Due to increased efficiency of the steam-ejector pump, the achievement of rarefaction was accelerated, and a rarefaction of 1 mm Hg was reached on the average for 10 minutes (before the reconstruction, it was reached for 15 minutes). In this case, the average carbon content after degassing was 0.003% (min. 0.002%, max. 0.005%).

To ensure the minimum degree of the carburization of the metal during steel pouring (in the mould and tundish), a low-carbon slag-forming mixture having a carbon content of 2-4% is used. The basicity of the mixture in the tundish is 1.2-1.4%.

The increase in the carbon content during pouring was 0 - 0.003%. Due to the rapid carbon depletion in the slag, the expenditure of mixture in the tundish was increased to 0.48 kg/t as compared to a conventional value of 0.4 kg/t.

Change in Nitrogen Concentration

The achievement of low nitrogen concentrations is complicated by its significant solubility in the metal at high temperatures, especially in the zones of reactions occurring with a substantial heat release, for example, upon lancing in the converter and the deoxidization of metal with aluminum in the pouring ladle.

Intense denitriding occurs only upon the intense decarburization in the converter bath. The nitrogen content changes during steel smelting in the converter. In the beginning, when the decarburization rate is high, the denitriding of the bath occurs under the condition of the minimum supply of nitrogen with blasting. Then, as the decarburization rate decreases at the end of blasting and the air suction into the reaction zone occurs, the nitrogen concentration can increase. Therefore, the technology of the smelting of steels with a nitrogen content below 0.004% is based on the use of pure charge materials, oxygen blast with the nitrogen concentration less than 0.1%, and the application of the means of metal protection from contact with the atmosphere during all technological operations. For this purpose, it is recommended:

- To finish the metal blasting in the converter at the lowered protective cover with maximum possible intensity of the oxygen supply and the application of limestone in a quantity of 1-1.5 t.

- To carry out the metal tapping from the converter under the condition of filling of the ladle volume with argon and the argon supply upon tapping at a rate of 30-40 m^3/h with its gradual decrease toward the end of tapping and the coverage of the surface of molten metal by the addition of 600-800 kg of lime.

The change in the nitrogen content upon the steelmaking technological operations is represented in Table II.

Table II. Change in the nitrogen content upon the IF-steel production.

Technological operation	Nitrogen content,%		
	Average	Minimum	Maximum
Converter turndown	0.0016	0.0010	0.0024
Tapping	0.0020	0.0010	0.0034
Beginning of degassing	0.0024	0.0020	0.0035
End of finishing	0.0030	0.0025	0.0045
Casting in CC machine	0.0045	0.0038	0.0070

An insignificant decrease in the nitrogen content is observed upon steel degassing in the ladle. To provide the nitrogen content in the finished metal at a specified level, it is very important to avoid the saturation of metal with nitrogen upon casting. For this purpose, it is necessary to use reliable protection of the steel from contact with the atmosphere in the joints of the steel-smelting ladle, tundish, and mould and, thus, to avoid an increase in the nitrogen content.

For the protection of the metal jet from secondary oxidation upon the continuous casting of the metal under the conditions at the "MMK" Oxygen-Converter Shop, a unit developed by TsNIIChERMET for the protection of the metal from secondary oxidation in the ladle-tundish circuit was tested for a number of heats. This provided an average nitrogen content of 0.0045% in the finished steel.

Control of the Impurity Content in the Steel

To provide the required mechanical properties, the automotive body steels should have the smallest possible contents of sulfur, phosphorus, chromium, nickel, and copper. It was necessary to use the metal charge of pure rolling scrap and cast iron with a sulfur content of maximum 0.010%.

In all heats of extra-low carbon steel, cast iron treated in the desulfurizing unit by blowing granulated magnesium ejected into the metal in a nitrogen jet was used. The initial sulfur content in the cast iron varied from 0.012 to 0.025%, the expenditure of magnesium was 200-400 kg per heat, and the sulfur content after desulfurization was 0.004-0.010%.

The achievement of the smallest possible silicon content in the steel was a serious problem. The spikes of the silicon content in the IF-steel production in essence are determined by the increased quantity of slag, which entered the ladle upon tapping of the metal from the converter, and by the recovery of silicon from its oxide upon the addition of aluminum and titanium, which are strong deoxidizers, into the ladle. As was established, up to 0.020% silicon can pass into the metal from the slag. Therefore, to provide a silicon content in the metal of less than 0.010%, the smelting technology was improved by adding the operation of slag running off from the converter and a complex of measures preventing the entry of converter slag into the ladle.

Microalloying with Titanium and Niobium

Upon the development of the technology of IF-steel production, the introduced content of the microalloying elements titanium and niobium is regulated depending on the actual contents of carbon, sulfur, and nitrogen.

The required niobium content in the IF steel was determined as a function of carbon content. In the beginning of the production technology development, the niobium recovery upon the introduction of lump ferro-niobium was 40-70%. The implementation of the technology with the composition correction by the introduction of ferro-niobium powder by cored-wire increased the niobium recovery to 90% and ensured the stability of the niobium content over the entire ladle volume.

Microalloying with titanium at the stage of the technology development was achieved by the addition of titanium sponge at the surface of metal at the end stage of finishing with the subsequent mixing by argon supplied through the upper tuyere. The analysis of titanium recovery showed that it could vary between 25 and 70%. To obtain the required titanium content, this parameter should be stabilized upon microalloying, since the titanium recovery can be strongly affected by the factors such as the quantity and chemical composition of the ladle slag, the intensity and time of metal mixing after the addition of titanium, and other poorly controllable technological factors. Furthermore, the addition of a large quantity of the strong deoxidizer titanium to the slag causes the recovery of silicon and manganese from the slag. To avoid this situation, microalloying of the metal by the introduction of a rich ferro-titanium powder by cored-wire can be applied. The analysis of such heats showed the following advantages of this version with an increase in the stability of titanium recovery, a guaranteed hit into the specified concentration limits, and the simplicity of titanium introduction.

Conclusion

The developed smelting and pouring technology showed that the set of equipment available in "MMK" and the proposed technological methods provide the production of extra low-carbon steels for the automobile industry in the specified volumes with the guarantee to achieve the required mechanical properties.