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DEVELOPMENT, PROCESS IMPLEMENTATION AND DELIVERY INCREASE OF NIOBIUM ALLOYED IF STEEL FOR AUTOMOTIVE

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Abstract

When there is an intense competition at the metal product market, the enterprise should have practices and equipment available to produce a wide range of steels and instantaneously react to the change of demand for metal products.

In this respect, the development of IF steel production was started at Severstal simultaneously to putting a steel ladle degassing plant treating up to 340 tons of molten steel into operation in the converter shop. This steel is intended for automobile body sheet production.

Process Implementation of IF Steel Production

Two stages of process implementation can be distinguished:

Stage I: Provision of required chemical composition.

Stage II: Provision of required quality level.

Provision of Required Chemical Composition (Stage I).

At the first stage, the process flow sheet included the following:

- Smelting in converter with top blowing
- Metal tapping from converter to steel ladle with three blow off plugs
- Metal treatment at ladle degassing plant (vacuum decarburization, deoxidation and micro alloying)
- Metal pouring by curved continuous steel casting plant

Pure metal charging (iron with a sulfur content less than 0.015%, scrap metal with sulfur content less than 0.015%, Cr, Ni, Cu less than 0.1%) is used for the steel production with a specified content of sulfur and residual elements (Cr, Ni, Cu). At metal smelting in the converter it is necessary to achieve a minimum content of N, S, Si, Ni, Cu, Cr, because at the next stages the attained concentration will be maintained (S, Ni, Cu, Cr) or in some cases, even increase (N, Si).

The current scheme of IF steel production provides the following parameters of the metal prior to tapping from the converter:

- Metal temperature 1700-1730 ^{0}C
- Carbon content 0.03-0.05%

Metal tapping is a separate special operation. For tapping, it is necessary to provide a free ladle side of 1200 to 1300 mm for metal degassing and to prevent the ladle from slag ingress. Nowadays this problem is solved by usage of the “Monocon” converter slag cutoff system by means of darts and indications by a thermal imager.

Degassing is the most critical operation of IF steel production when it is necessary to achieve carbon contents less than 0.002 %. The specified carbon content is provided by means of:

- Metal preparation before degassing. Before degassing the metal should have already a relatively low carbon content of not more than 0.05 % and metal oxidability should provide carbon elimination and be at least 550 ppm
- Metal treatment under deep vacuum at a pressure of less than 1 mm of mercury column (0.133 kPa) within 15-20 min
- Optimal argon consumption during metal degassing
- After oxidation degassing the metal is deoxidized and microalloyed

That moment at the beginning of the second process stage is to achieve an ultra low carbon content consisting of carbon concentration retention. The main sources of carbon at deoxidation and alloying are ferroalloys, ferrotitanium and ferroniobium in general, as well as the lining of the steel-smelting ladle containing carbon. The rise in the carbon content due to ferroalloys is 3 to 4 ppm. Therefore, the usage of ferroalloys having a carbon content of not more than 0.05 % to limit the rise to less than 2 ppm is planned.

The main carbon sources of metal during pouring are mould flux powders comprising carbon. IF steel mould flux powders of different manufacturers are used (Stollberg and Mineral Resources), of which the carbon content is not more 0.5 and 2.0 % for the intermediate ladle and ingot mold, respectively. At pouring, the average rise of carbon is 10 ppm with 3 ppm occurring in the intermediate ladle and the remaining part occurring in the ingot mold.

An ultra low nitrogen content in the finished steel is provided by the following:

- Assurance of minimum nitrogen content before metal tapping (blowing shutoff in the oxygen converter at higher carbon 0.04-0.06%)
- Prevention of nitrogen ingress to the metal during out-of-furnace treatment (reduction of metal treatment cycle at vacuum degasser, transfer of deoxidation and alloying under vacuum)
- Secondary oxidation protection of metal at pouring

Because of activities described before, a process providing the following IF steel composition has been developed (Table I):

Table I. Chemical composition of developed IF steels.

Alloying elements	**Composition of steel (wt.%)**								
	C	Si	Mn	P	S	Al	N	Ti	Nb
Ti+Nb	max. 0.005	0.03	0.08-0.15	0.012	0.012	0.02-0.06	max. 0.006	0.02-0.04	0.035-0.055
Ti	max. 0.005	0.03	0.08-0.15	0.012	0.012	0.02-0.06	max. 0.006	0.05-0.09	

Providing of Required Quality (Stage II).

To determine process features affecting steelmaking surface defects on the cold rolled strip, an analysis of process features influence on the finished rolled product reject caused by defects such as “shell” and “non-metallic inclusions” was carried out. The analysis shows that the nonmetallic inclusion level is determined by the following:

1. Oxidability of metal-slag system prior to deoxidation and alloying
2. Slag content after deoxidation and microalloying, i.e., the ability of the slag to assimilate resulting inclusions. To increase the slag assimilation ability, it should be free running. This is provided by a CaO/Al_2O_3 ratio set to a level of 0.8 to 1.1. The content of ferrous oxides in the slag prior to casting affects the quality of the finished products significantly. During casting when the upper metal portions interact with the slag, aluminum oxidation by ferrous oxides takes place followed by particle isolation. It can result in ladle nozzle clogging and thus a decrease in the casting rate.
3. Secondary oxidation of metal and slag during out-of-furnace treatment and pouring.
4. Temperature and rate of metal casting.

Based on the results of these investigations, the following activities were carried out to improve quality of IF steel:

- Converter slag cutoff is made for each heat providing a slag ingress to the ladle of not more than 3 kg/ton.
- Prior to degassing, the oxidability is controlled by limitation of the oxygen activity in the metal to within 800 ppm.
- The following scheme of metal deoxidation and alloying was developed and is being implemented:
    - After completion of vacuum decarburization, aluminum is added as aluminum piramidia together with lime under vacuum for complete deoxidation and alloying.
    - Then after 3 to 6 minutes of blending, blowing the metal oxidability is measured and if deoxidation is sufficient, titanium is added followed by full vacuum shedding.
- This scheme allows for a decrease in the slag oxidability prior to casting from 5 to 10% down to not more than 4%.
- To prevent secondary oxidation of the metal at casting, an upgrade of the protection pipe joint between the intermediate ladle and the casting ladle with a sliding shutter and replacement of the quartz protection pipes by corundum-graphite pipes are carried out. Also, casting through monolithic submersible ladle nozzles is being tested.

The influence of the following factors on the metal structure, properties and texture was investigated:

- Low and high temperature heating of slabs at 1180 - 1190 and 1220 – 1240 °C
- Coiling after hot rolling at 560, 630, 700 and 725 °C
- Total reduction at cold rolling of 75 and 81%
- One-stage recrystallization annealing in bell-type furnace at 710, 730 and 750 °C with different soaking periods
- Reduction at temper rolling from 0.5 up to 1.0%

The following ranges of mechanical properties for cold-rolled products are achieved:

- Yield strength: 120 - 160 N/mm²
- Tensile strength: 285 - 315 N/mm²
- Total elongation: 40 - 48%
- Anisotropy factor r_{90}: 2.2 - 2.9
- Hardening factor n_{90}: 0.22-0.24.

The output of commercial rolled products of IF steel is increased annually:

- 2002: 6,600 tons
- 2003: 21,000 tons
- 2004: 107,000 tons
- the first 6 months of 2005: 70,000 tons

In the period of 2004-2005, the following ratio of outputs regarding steel alloying was settled at 70% - Nb+Ti% and 30% - Ti. For these, the carbon content is between 0.003 and 0.005%.

Finished hot and cold-rolled products are delivered to automotive plants in Russia, CIS, Europe (Italy, Germany, Turkey, Spain), North America (USA, Mexico), India, and China. Besides coiled material, IF steel was also delivered as slabs in the period of 2004-2005.