Universal technology of refining of metal in the pony ladle
This technology is developed for the production of qualitative steel grades, in particular, steel for the pipes production, steel for the deep extension and other qualitative steel grades. The technology provides low content of gases, in particular, hydrogen and nitrogen, and the maximum deleting nonmetallic inclusions, without the process of steel degasification.
The experience of use of the pony ladles equipped with baffles, showed that most fully an inclusion of more than 20 microns in size is deleted. The steel refining from more small-sized inclusions whose quantity is at least 50%, can be possible only in case of the creation of additional lift force.

All known diagrams and devices for the steel refining became inert gas in the intermediate ladle of rather difficult construction, are calculated for the certain type of the continuous casting machine and don't provide any completeness of the output of this inclusion to the refining slag. On deleting nonmetallic inclusions it is possible to reach the maximum effect only in case of layout of blowing-off devices optimally approximate to the place of the outflow of metal from the pony ladle that gives the chance of deleting nonmetallic switching on, both exogenetic, and endogenous (as a result of the steel self-deoxidation) character.

The offered installation diagram and the device (tuyere) for the steel refining with inert gas, allow to delete as much as possible nonmetallic inclusions, and is applicable on all continuous casting machine types.

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TUYERE STRUCTURE

porous refractory mixture

 ceramic case

 collector

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The principle of refining with an inert gas is based on the flotation method, it means on the adhesion of nonmetallic inclusion to a bead of inert gas and the inclusion carrying out in the slag.

In the pony laddle two directions of hydrodynamic flows proceed. The first consists of the metal overflow from the turbostop (the metal receiver) in the pony ladle. The second is the metal outflow from the pouring nozzle therefore there are two types of relocation: the metal outflow on a vertical axis of the channel $\nu_1$ and the metal relocation across with radial speed $\nu_2$. The flow $\nu_2$ causes braking of the vertical outflow $\nu_1$ that leads to a congestion of the inclusions over the pouring nozzle. The tuyere installation in a zone of the greatest congestion of nonmetallic inclusions allows to make the maximum refinement, besides, the veil from the beads of inert gas causes the flow rate braking $\nu_2$ that in turn reduces turbulence of the overflow of the stream from the pouring nozzle, providing in that way a normal course of pouring.
UNIVERSAL TECHNOLOGY OF REFINING OF METAL IN THE PONY LADLE

The metal refinement just before the crystallization allows to lower not only the number of nonmetallic inclusions already being in metal, but also to prevent impact of endogenous inclusions in the ingot being formed as a result of the steel self-deoxidation in case of temperature drop in the pony ladle in the course of pouring.

Any steel-smelting reaction of oxidation (deoxidation) proceeds much quicker if there is a ready interfacial area, in this case the role of the ready surface is executed by the beads of inert gas which carry out directly the reaction product in slag. Other positive effect of metal refining just before the crystallization is the guaranteed obtaining low values of hydrogen and the partial deleting of nitrogen or the microalloying with nitrogen.
COMPARATIVE DATA OF DIFFERENT METHODS OF STEEL REFINING IN THE PONY LADLE

Pollution with nonmetallic inclusions

- Without purification
- Using other methods of cleaning
- Using the tmt company tuyere

Distance from the ingot surface, mm

Pollution index, µm
The specialists of the TMT company developed a complex technology of refining of metal for quality support of an ingot on nonmetallic inclusions and gases which includes:

- technology of a microalloying of metal in the pony ladle;
- Physical simulation of processes in the pony ladle;
- calculation of hydrodynamics of the flows of metal in the pony ladle;
- calculation and optimization of layout of blowing-off tuyeres and piece products;
- calculation of the consumption of argon;
- calculation of the temperature and the high-speed modes of pouring.
The individual and integrated approach provides maximum efficiency of the operation of slag and the opportunity to process all metal just before the crystallization. The implementation of the technology implies the manufacture and the delivery of the necessary accompanying equipment, raw materials and the other ones, the development and the transmission of technological documentation, the determination and the inclusion in the contract of the quantitative and quality operational performance.
The system of refining includes:
• system of the steel microalloying;
• turbostop, (5);
• as required - a baffle with holes for the metal overflow (executed so what to provide the maximum carrying out of nonmetallic inclusions in the refining slag of a certain composition), (12);
• the universal blowing-off tuyere (7) working in small bead mode and providing the flotation of nonmetallic switching on inclusions and the gas deleting.
The heat loss when using system of floatation refining are insignificant 0,1-2 0C min• t. and also are compensated with the raised metal flood. The argon consumption is, on the average 5 liters a minute for one tuyere. The option of heating of argon is also provided.
THE TUYERE OPERATION IN THE PONY LADLE

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The increase of the level of desulfuration of low-silicon steel with a mass fraction of silicon no more than 0,05%, providing receiving in ready metal the content of sulfur on mass no more than 0,005%.

The globularisation of sulphidic inclusions in the specified steel at the expense of their transfer to low-deformed sulfides in case of rolling and calcium oxysulphide that causes the increase of plasticity and impact strength of ready rolling.

The transformation of solid inclusions of alumina in liquid (at a pouring temperature) calcium aluminates which easily float and assimilate slag. Than they remove the possibility of skulling of holes of pouring nozzle with the congestions of solid inclusions of alumina.

The impurity of metal with inclusions with more than 10 microns in size decreases 2,5-3,5 times.

The mechanical properties and steel characteristics improve: the relative lengthening increases 1,5–2,2 times, impact strength at the negative temperatures increases for 15-20%.

The rejection of sheet rolling on the defects revealed by UZK, decreases to 30-40%.
The sharing of baffles of the pony ladle and the blowing-off ceramic tuyeres creates the universal system of the steel refining from the nonmetallic inclusions and gases in case of the continuous pouring, giving the maximum effect of purity of an ingot - without the degasification of metal. It allows to make high-quality steel grades, excluding an expensive process of degasification.
ADVANTAGES OF THIS TECHNOLOGY:

• Low capital expenditure;
• Short term of the implementation of technology - about 6-8 months;
• There is no need for any constructive change of the capital equipment;
• There is no need for the production stop;
• Decrease of prime cost of qualitative steel grades with the low content of hydrogen, nitrogen, nonmetallic inclusions (high-class pipe steel grades, deep drawing steel and others) at the expense of the partial or total renunciation of the steel gasification, at the expense of processing methods of the deoxidization, allowing to increase the coefficients of assimilation of expensive materials and energy carriers;
• Seriality stabilizing at the expense of the maximum decrease of the overgrowing of the immersion glasses and the nonswirl nozzle with nonmetallic inclusions;
• Provision of the ready metal with the low content of sulfur (less than 0,005%);
• Extension of the gage of products.
RESULTS OF THE PRACTICAL IMPLEMENTATION OF THE TECHNOLOGY ON ONE OF THE PLANTS OF KAZAKHSTAN

- Together with the system implementation of refining of metal in the pony ladle of the continuous casting machine, the production technology of pipe steel grades, without degasification process (at this enterprise, the installation for vacuum processing of steel is absent) was developed and implemented.

**Shortly about the technology and the results of the carried-out operations.**

- The complex of the actions was developed and implemented. This complex gives the chance to receive qualitative characteristics of liquid steel allowing to make pipe preparation from steel grades of J55, D, S90, St 20 GOST 1050-88 and GOST 633-80, without the degasification and the limit on nitrogen, hydrogen, defects and nonmetallic inclusions according to the rigid restrictions OCT14-21 that in turn allows to produce finished goods according to the API standard with requirements 2T and 2H on ASTME 45, method A.
RESULTS OF THE PRACTICAL IMPLEMENTATION OF THE TECHNOLOGY ON ONE OF THE PLANTS OF KAZAKHSTAN

• An average chemical analysis of 54 meltings according to the content of nitrogen and the hydrogen of one company of production of pipe workpiece of Ø210, Ø300 mm for July, 2008.

• N of-4,4 ppm (samplings were made in the pony ladle)
• N-ppm ppm (based on tests from the pony ladle)
• Throughout all process of tests the nitrogen gain during pouring wasn't watched (in comparison with the last test of UDS).
• For 30% of the meltings a decrease of the content of nitrogen in metal on 0,5 - 1 ppm (in comparison with the last test of UDS) is marked.
Results of the Practical Implementation of the Technology on One of the Plants of Kazakhstan

An average macroanalysis of 54 meltings of one company of production of pipe workpiece of Ø210, Ø300 mm for July, 2008

<table>
<thead>
<tr>
<th></th>
<th>Center porosity</th>
<th>Axis of chemical inhomogeneity</th>
<th>Liquating strips and cracks</th>
<th>Edge point pollutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average grade</td>
<td>0.7</td>
<td>1.2</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>

An average macroanalysis of 12 meltings of one company of production of pipe workpiece of Ø210, Ø300 mm for September, 2008

<table>
<thead>
<tr>
<th></th>
<th>Center porosity</th>
<th>Axis of chemical inhomogeneity</th>
<th>Liquating strips and cracks</th>
<th>Edge point pollutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average grade</td>
<td>0.2</td>
<td>0.85</td>
<td>0.66</td>
<td>0.625</td>
</tr>
</tbody>
</table>
1. The implemented technology provides the receiving of suitable production from the continuous casting machine which several times exceeds the requirements of OST on defects of the macrostructure.

Comparing of the defects of the macrostructure for carbon steels

<table>
<thead>
<tr>
<th>Macrostructure in grades</th>
<th>Requirements of OST 14-21</th>
<th>Average value of the received results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center porosity</td>
<td>≤ 3</td>
<td>0,7</td>
</tr>
<tr>
<td>Axis of chemical inhomogeneity</td>
<td>≤ 3</td>
<td>1,2</td>
</tr>
<tr>
<td>Liquating strips and cracks</td>
<td>≤ 2</td>
<td>0,7</td>
</tr>
<tr>
<td>Edge point pollutions</td>
<td>≤ 2</td>
<td>0,7</td>
</tr>
</tbody>
</table>

Comparing of the defects of the macrostructure for alloyed steel

<table>
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<th>Requirements of OST 14-21</th>
<th>Average value of the received results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center porosity</td>
<td>≤ 2</td>
<td>0,2</td>
</tr>
<tr>
<td>Axis of chemical inhomogeneity</td>
<td>≤ 2</td>
<td>0,85</td>
</tr>
<tr>
<td>Liquating strips and cracks</td>
<td>≤ 1</td>
<td>0,66</td>
</tr>
<tr>
<td>Edge point pollutions</td>
<td>≤ 1</td>
<td>0,625</td>
</tr>
</tbody>
</table>
2. The implemented technology provides receiving a suitable production after rolling 2 - 3 times exceeding API standard requirements for the nonmetallic inclusions.

As the results of research of the implemented system of refining show, the obtaining similar results with the technology of the degasification it is rather problematic, as steel, after the degasification is polluted at the last stage, the pouring.

Sharing in a technological chain of the degasificator and the systems of the steel refining from nonmetallic inclusions and gases in case of the continuous pouring, will give the maximum effect of purity of an ingot in case of the minimum expenses and will ensure practically any steel grades.

Having integrated two systems (two processes) in a unique one, there is an opportunity to make a slab on pipe steel grades of the class X100 – X120 or other steel grades of similar quality.
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