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INVESTIGATION OF THE EFFECT OF HIGH STRENGTH STRIPS STEEL MODIFICATION WITH RARE-EARTH METAL (REM)

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Preliminary Note – Prethodno priopćenje

The present work describes the study on influence of modifying steel with rare-earth metals on metallurgical quality of ingots and finished steel. To achieve the assigned task, the laboratory melting of 08G2NMDFBT (X100) pipe steel was carried as in open (UIP 100 – 2,4), so in vacuum induction furnace (ISV-0,01 - PI) with use of conditioning agents, which contain rare-earth metals. Next materials were used as conditioning agents: mischmetal (MM), which contain total amount of rare-earth metal (REM) up to 93 %, AlPCIr and RENTN which contain total amount of from 31 to 32,6 %.

Key words: steel, modification, REM, structure,strip

INTRODUCTION

Today many issues of creating pipe steels of different strength category are solved as in terms of chemical compound, so in terms of their smelting technology, secondary processing, teeming, thermo-mechanical processing and accelerated cooling. But the problem of structural and chemical inhomogeneity of smelted metal, which occur during plastic processing of inhomogeneity of sheet structure and anisotropy of mechanical properties at its cross-section, remains unsolved in general.

One of the main directions of improving quality of flat products for high-strength pipe steels is providing metallurgical heredity of continuous casting, which includes forming a homogeneous fine-grained structure of ingot, minimizing central segregation inhomogeneity, also preventing formation of surface defects and defects of macrostructure. The presence of hereditary boundaries, residual dendritic segregation, structural inhomogeneity, segregation streamer, non-metallic inclusion with unfavorable morphology in structure of metal sheet can be considered as the hereditary development of structural parameters of continuous casting (CC) [1]. The possible method of improving quality of cast and strained metal is an active forming their structure and properties by adding the conditioning agents and microalloying additives in melt before ingoting [2,3].

MATERIAL AND EXPERIMENTAL METHODS

Melting and holding of liquid metal for all vacuum melting were performed in vacuum with residual pressure equal to $2 \cdot 10^{-3}$ mmHg. And the process of smelting steel in open induction furnace was next. After smelting a furnace charge at 1630 – 1650 °C degrees alloying materials and deoxidizing agents (FeMn, FeSi, FeTi, FeV, FeNb and Al) were added in furnace. The tapping of metal from furnace was held at 1600 – 1650 °C degrees into two molds with use of intermediate ladle, which was heated up to 500 – 750 °C degrees. The first mold was filled with metal without conditioning agent; the second mold was filled with metal with conditioning agent. The experiments on the hot simulation of controlled rolling were carried on LPS-210 laboratory rolling mill by modes applied for low-carbon high-strength pipe steels.

A quantitative metallographic analysis of macro- and microstructure of cast and strained metal was held with use of Axiovert 200 MAT motorized light microscope and Meiji RZ stereoscopic microscope, equipped with Thixomet image analyzer. Electron micro probe analysis (EMPA) was performed on Zeiss Supra 55VP electron microscope with Inca attachment (Oxford Instruments).

The results of studying influence of conditioning agents on structure cast grain shown on Figure 1.

The Figure 1 shows the all-round images of macrostructure of cast metal of ingots from one smelting: non-modified and modified RZNTB in amount of 2,0 kg/t of steel. The average diameter of austenitic grain in presented structures decrease from 1 110 microns to 670 microns. Thus it was established that adding the conditioning agents, containing REM, into steel contributes to decrease of transcrystallization zone (up to 100 %) and refinement of cast austenitic grain (on the average up to 40 %), the size of which defines the further structure, obtained during the controlled rolling.

RESULT AND DISCUSSION

Analyzing results of conditioning agents' influence on dendritic strucutre of ingot showed that modifying

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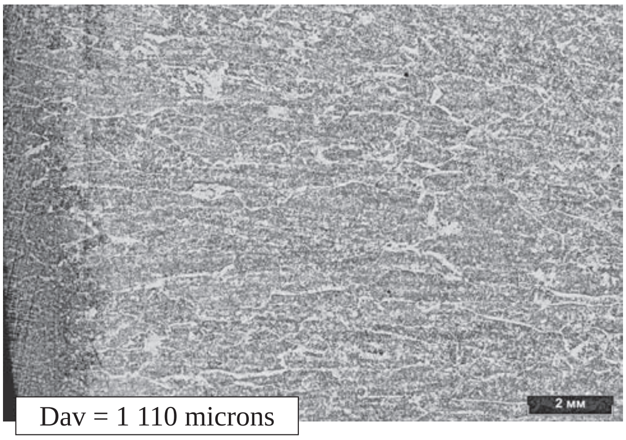

a)

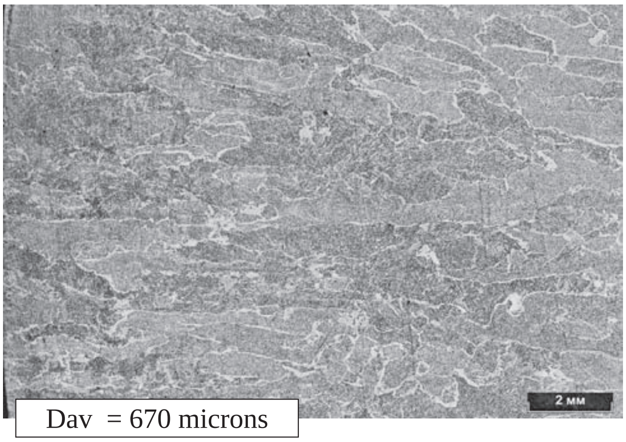

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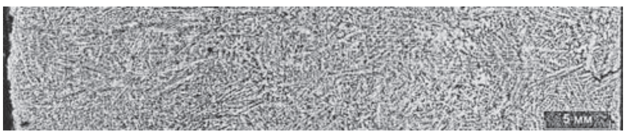
Figure 1 Macrostructure of cast metal
a) without adding conditioning agents,
b) with adding conditioning agent RZNTB in amount of 2,0 kg/t steel

with rare-earth metals leads to formation of dendrites of spherulitic type instead of dendriform ones. The Figure 2. shows image of dendritic strucutre of experimentally melted ingots. In case of modifying macrostructure across the whole cross-section of ingot, it consists of spherulitic dendrites with size of primary grain from 0,40 mm in transcrystallization zone to 1,2 mm in the middle. At the same time, the macrostructure of non-modified ingots represent mixture of dendriform and spherulitic dendrites, where dispersion of primary grain decrease from surface to core from 5 to 3-4 mm. The increase of dispersion of dendrite structure leads to more homogeneous distribution of alloying and doping elements by cross-section of ingot. This type of dendrite structure wil contribute to obtaining more homogeneous and dispersed structuresduring controlled rolling.



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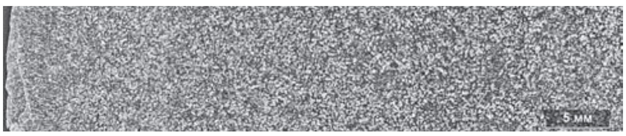

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Figure 2 Dendritic (a) and spherulitic (b) structure of cast metal: a) no conditioning agents added, b) with adding conditioning agent MM 0,2 kg/t

The impurity of steel with non-metallic inclusions was defined according to ASTM E 1245. It is found that modifying pipe steel with REM leads to significant decrease of its impurity with non-metallic inclusions: from 0,03 – 0,08 % for non-modified steel and up to 0,01 – 0,02 % for modified steel.

The results of electron micro probe analysis of non-metallic inclusions, which were found in modified metal, allowed to identify next types of inclusions: 1) globular compounds $(Ce,La)AlO_3$, $(Ce,La)Al_{11}O_{18}$ of micron, submicron and nanometric size; 2) sharply angular inclusions of $(Ce,La)_2O_3$; 3) compounds of Al_2O_3 - FeO system, also 4) titanium nitride TiN. The formation of these inclusions was proved by the results of thermodynamic simulation, except $(Ce,La)_2O_3$ particles, which are formed at non-equilibrium conditions of salvo input of modifiers.

Oxides of rare earth metals are often substrates for the precipitation of titanium nitride on them by heterogeneous mechanism resulting in formation of multiphase compounds such as (Ce, La) $Al_{11}O_{18}$ + TiN. In the process of plastic deformation inclusions are transformed to relatively large multiphase aggregates mainly consisting of inclusions of rare earth metal oxides and system FeO - Al_2O_3. It is found that the steel produced in vacuum is characterized by a uniform distribution of inclusions by volume of the metal. This is due to the fact that in vacuum melts modifier was added directly in a furnace, with the melt homogenization processes by chemical composition occurring more completely unlike open melts at which ligature was introduced to the flow during intermediate ladle pouring.

Using the software package Fact Sage we did thermodynamic modeling of the formation of non-metallic inclusions upon introduction of REM-containing ligatures into the liquid melt. Immediately upon entering of the modifier, compounds of the following type are formed as primary inclusions: $LaAl_{11}O_{18}$, $AlLaO_3$ and $AlCeO_3$. Next, during the cooling and crystallization secondary and tertiary inclusions are formed: Al_2O_3 and $CeAl_{11}O_{18}$. In other words, in view of high reactivity, lanthanum and cerium immediately after adding the ligature precipitate as non-metallic inclusions of the following type: $RAl_{11}O_{18}$, $RAlO_3$. This process is accompanied by the release of considerable heat, active spraying of molten metal and sparks-release.

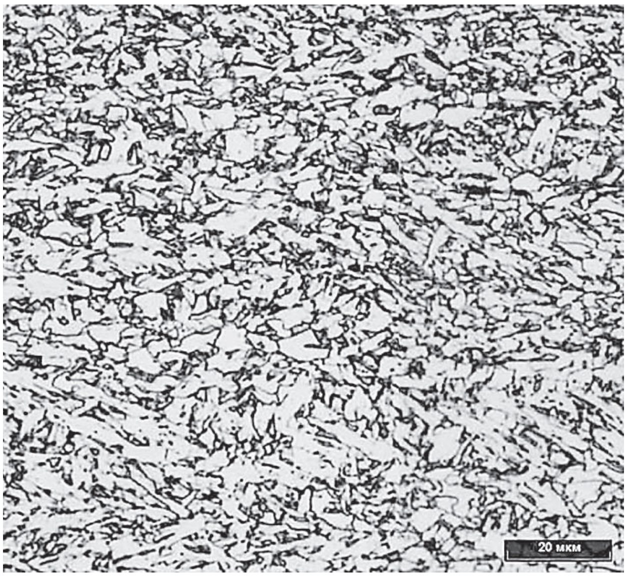
It should be noted that the most favorable morphology of nonmetallic inclusions is characteristic for ingots modified by mischmetal. In these ingots are found exclusively nanometric inclusions such as $RAl_{11}O_{18}$, whereas multi-phase TiN-containing inclusions reach relatively small size (up to 5 microns). In ingots modified by AKCeZh and RZNTB are found similar types of inclusions, but their dimensions are several microns whereas dimensions of multiphase conglomerates may reach several dozens of microns. In this regard, in terms of influence on the size and morphology of the inclusions formed, modifiers can be conventionally arranged in the following order in priority of use: MM→ RZNTB → AKCeZh.

CONCLUSIONS

Results of studying the microstructure of strained metal resulting from controlled rolling process simulation showed that the modified samples after deformation are characterized by fine-grained polygonized ferritic-bainitic structure with the actual ferrite grain equal to 13 and above. When rolling modified ingots, final structure of the sheet is characterized by higher dispersion (increase in grain number by ½), decrease in the volume fraction (by 2-10%) and the length of bainite zones of rack morphology (by 100 - 250 microns) thus providing morphologically similar highly dispersed structure. Figure 3 shows the panoramic images and fragments of microstructure of strained metal modified by REE and without modifiers added.

Furthermore, it was found that after hot strain the dendritic structure of the ingot persists acquiring banded nature and direction corresponding to the lines of plastic flow during rolling. This fact demonstrates the inheritance of chemical heterogeneity of the cast dendritic structure of a starting ingot. Use of modifiers provides better dispersion and uniformity of the resulting deformed dendritic structure (Figure 4).

In this regard, within this work we tested in a laboratory the technology of introducing modifying additives to molten steel both in open melting and vacuum melting which ensures rare earth metals recovery within 0,003 – 0,0052 %. It is found that modification of pipe steel grades by rare earth metals reduces metal contamination by nonmetallic inclusions 3-4 times, provides, under certain conditions, the formation of dispersed nonmetallic inclusions up to nanometric dimensions, and increases the uniformity and dispersion of the cast and strained structure.



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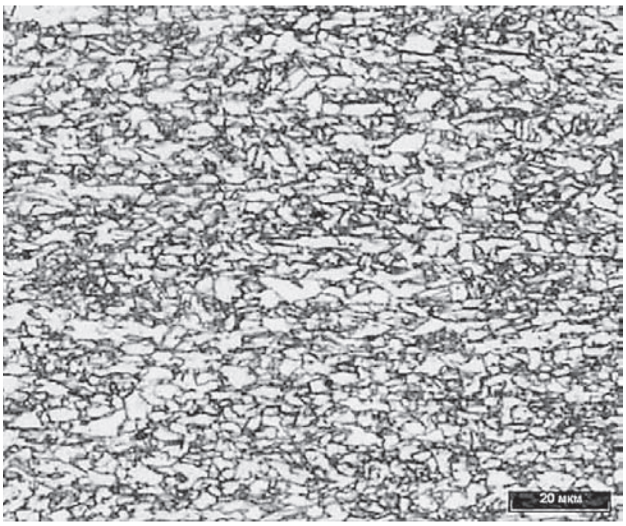

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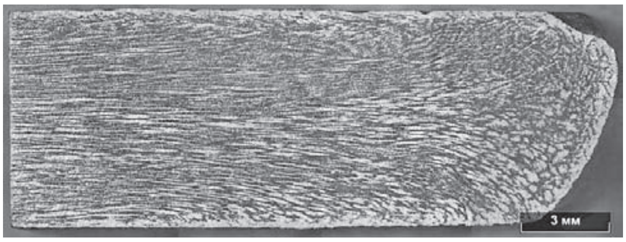
Figure 3 Microstructure of the strip after controlled rolling: a) no modifiers added,b) modified by RZNTB 2,0 kg/t



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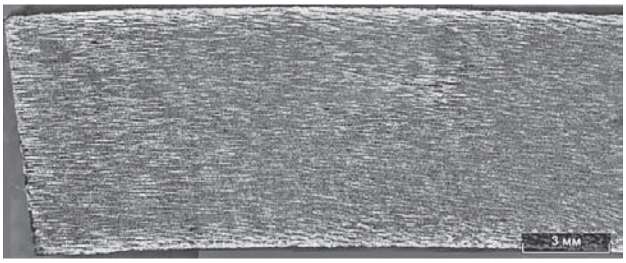

b)

Figure 4 Dendritic structure of the strip after controlled rolling: a) no modifiers added; b) modified by AKCeZh 2,3 kg/t

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Note: The responsible for England language is Nataliya Drag, Karaganda Kazakhstan