

## Research of Influence Modification of Natural Concentrate on Quality Metal

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**Abstract.** Questions of increase of mechanical, technological and service properties of metal at minimum cost to produce it are relevant for the metallurgical enterprises.

Modification of complex steel alloys containing reactive elements is one of the effective ways to improve the quality of steel. At the same time the direct costs for the use of modifiers are 0.2–0.3%, which little effect on the cost of production.

The paper presents the results of the application of natural concentrates as a modifier steel. The effects on the metal quality changes due to the impact of the modification concentrates demonstrate the effectiveness of their application. As a result of modification decreased the content of nonmetallic inclusions and grain size. Reduction of impurity modified metal of was the cause more high plastic properties, especially, impact strength at ordinary and low temperatures of tests. Based on the experimental data evaluated hardening mechanisms that lead to a significant improvement of physic-mechanical properties of the metal workpiece after administration modifier.

### Introduction

Metal processing outside the furnaces aimed at reducing the concentration therein of harmful impurities, contamination by nonmetallic inclusions, improved mechanical properties and specific, level of which is revealed during the operation of fabricated metal products (heat resistance, fatigue strength, cold resistance, corrosion resistance, etc.). At the same time when using a secondary treatment not always successfully resolved issues related to the quality of the metal: the elimination of cracks in the bars and theaters, reducing chemical heterogeneity of rolled metal and its products and in the manufacture of steel pipes – ensuring high corrosion resistance and others.

Less contamination of the modified metal is a cause more high plastic properties, especially, impact strength at low temperatures and routine testing.

Significant role may be played modifiers reduce or eliminate the negative impact of located in a metal gas – nitrogen and hydrogen. In the case of high concentrations affects the casting sieve porosity, sinks, cracks and even flakes. To eliminate the defects caused by the nitrogen can be useful modifiers, which include those elements have strong nitride – titanium or zirconium. To neutralize the harmful effects associated with hydrogen, recommended rare earth-containing modifiers that promote the binding of hydrogen in lasting hydrides, thus preventing or slowing its isolation in the solid metal in the form of flakes. Due to this safety can be increased level of hydrogen concentrations, reduced



intensity and duration of degassing a process the liquid steel, as well as reduced heat treatment castings anti flakes up to complete elimination of the latter.

Results are determined by modifying primarily contents of active elements (Ca, Ti, and rare earth al.) both in the liquid metal (in the ladle, ingot mold, the mold) and in the finished steel. The magnitude of these concentrations depend on many factors – the steel grade, the extent of it deoxidation, place and method of modifier additives and the presence and composition of slag in the ladle, casting, duration, etc.

## Results and Discussion

Modification of steel natural concentrates or minerals in recent years attracted considerable interest in the metallurgists as a source of modifying of steel. Recently there has been a tendency to replace ordinary carbon steels to high-resource-efficient micro-alloyed steel in the world steel production. Which are used to dope the rare and expensive alloy elements such as vanadium, titanium, niobium, rare earth metals, barium, strontium, and others. But significant costs on the use of clean alloy elements or their alloys restrain the development directions of micro-alloying and modifying steels and alloys. Current solutions this problem is the use of natural mineral concentrates as the replacement of expensive pure elements as modifiers for micro-alloying steel. Such mineral concentrates are an excellent substitute for expensive alloying elements with microalloying steel and more available for use.

One such example of the use such concentrates is the use of ilmenite, zircon sands deposit Tugansk in the modification and microalloying steel and cast iron, the chemical composition shown in Table 1.

**Table 1.** The chemical composition of the concentrates

Components		Ilmenite	Zircon
TiO <sub>2</sub>	no less	60.0	4.0
ZrO <sub>2</sub>	no less	–	60.0
VO <sub>2</sub>	no less	3.0	–
Al <sub>2</sub> O <sub>3</sub>	no less	5.0	1.0
Fe <sub>2</sub> O <sub>3</sub>	no less	–	1.0
SiO <sub>2</sub>	no less	4.0	–
Humidity, %	no more	0.5	0.5

As a result of a number of studies on the influence of the given deposit concentrates on the changes in the structure and properties of the steel were obtained results presented in the works [1, 2]. As a result of the experimental heats was identified structural changes, in particular the number of non-metallic inclusions was reduced.

The modifying mixture loaded on the bottom of a pouring ladle 3 per kg inoculant per ton of steel. After holding of melt in furnace to made steel casting ladle modifier. After three minutes of exposure in a ladle with a modifier steel began to pour.

Research quality and properties of all metal blanks performed on the developed and concerted the enterprises-manufacturers programs and schemes in the expanded volume of receiving and acceptance and periodic tests. All testing and research were carried out by the standardized methods, which ensures the objectivity and comparability of the results, including the ability to compare the results of earlier conducted research and testing, including testing of serial production.

The test results in the volume of blanks acceptance tests after heat treatment for various models are shown in Table 2.

**Table 2.** The results of blanks test (heat treatment mode number 1)

No of templates	$\sigma_p$ , MPa	$\sigma_{0.2}$ , MPa	$\sigma_B$ , MPa	$\delta$ , %	$\psi$ , %	KCU <sup>+20°C</sup> MJ/m <sup>2</sup>	KCU <sub>-50°C</sub> MJ/m <sup>2</sup>	KCT <sub>-50°C</sub> MJ/m <sup>2</sup>	K <sub>1C</sub> <sub>-50°C</sub> H/mm <sup>3/2</sup>
1	1187	1295	1413	11.5	35.0	0.29	0.20	0.12	2815
2	1187	1324	1413	9.4	24.0	0.29	0.12	0.11	2384
3	1197	1295	1393	9.4	30.0	0.33	0.20	0.11	2433
4	1207	1334	1432	10.0	32.0	0.27	0.12	0.11	2570
5	1197	1324	1442	10.5	30.0	0.29	0.22	0.10	2286

From the above data it is evident that All Templates in all tested final heat treatment conditions meet the requirements of state standard V5192-78 laid down for the category strength of O-120, in terms of mechanical properties and crack resistance. To achieve the sustained and higher rates of mechanical properties, especially on indicators of contraction ratio and toughness at temperatures below freezing, were carried out more research and testing of quenching and tempered regimes.

Results of chemical composition of the metal blanks control are shown in Table 3. The results of monitoring the content of nonferrous metal impurities are shown in Table 4.

**Table 3.** The results of monitoring of the chemical composition of the metal blanks

No of templates	Content of elements, %									
	C	Mn	Si	P	S	Cr	Ni	Cu	Mo	V
1	0.42	0.26	0.25	0.012	0.003	1.04	3.42	0.22	0.57	0.16
2	0.40	0.31	0.28	0.006	0.009	1.10	3.38	0.17	0.57	0.16
3	0.39	0.30	0.32	0.009	0.007	1.05	3.39	0.21	0.58	0.15
4	0.40	0.30	0.26	0.005	0.004	1.09	3.40	0.24	0.59	0.13

**Table 4.** The results of monitoring the content of non-ferrous metal impurities in the material blanks

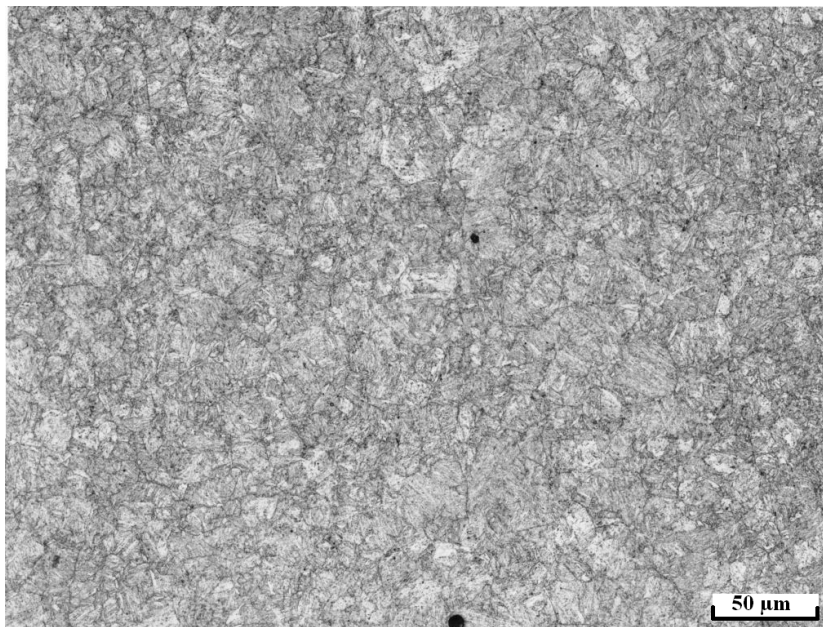
No of templates	Content of elements, %								
	Sn	As	Pb	Sb	Zr	Bi	Al	Ti	
1	0.009	0.012	< 0.001	0.003	0.022	0.002	< 0.005	0.020	
2	0.006	0.012	< 0.001	0.002	0.025	0.001	0.010	0.022	

As seen from the data on the chemical composition of the metal blanks fully complies the requirements of state standard V5192-78.

Control of the microstructure and fracture of metal, and the tensile test and impact toughness at + 20 °C - 50 °C were conducted directly at the manufacturing plants; test and crack resistance impact strength of on the with a crack samples at - 50 °C and a metal durability study conducted on samples prepared the enterprises-manufacturers blanks.

Control was carried out on metal macrostructure macro section prepared in accordance with state standard 10243-75. Etching performed in 50% hydrochloric acid solution at a temperature of 60 °C for 10–15 minutes. Fractures were made of the same samples, which held control of the macrostructure of metal. For this purpose, the samples were applied to the cuts macro sections the opposite side, and

then performed their destruction on the copra or press. Sample photo metal of the microstructure is shown in Figure 1.



**Figure 1.** Photography metal of the microstructure

Structure of metal is sorbitol. From the presented data show that the grain size metal parts billet meets the requirements of the Terms of Reference. Assorted metal over the cross section is not blank.

Control content gas (oxygen and nitrogen) in a metal was carried out using an automated analyzer Eltra ON900. To improve the accuracy of determining the gas content of the gas analysis procedure is conducted repeatedly for each sample and the results were subjected to statistical analysis. The results of monitoring the content gas (oxygen and nitrogen) in a metal blanks shown in Table 5.

**Table 5.** The results of monitoring the gas content in a metal blank

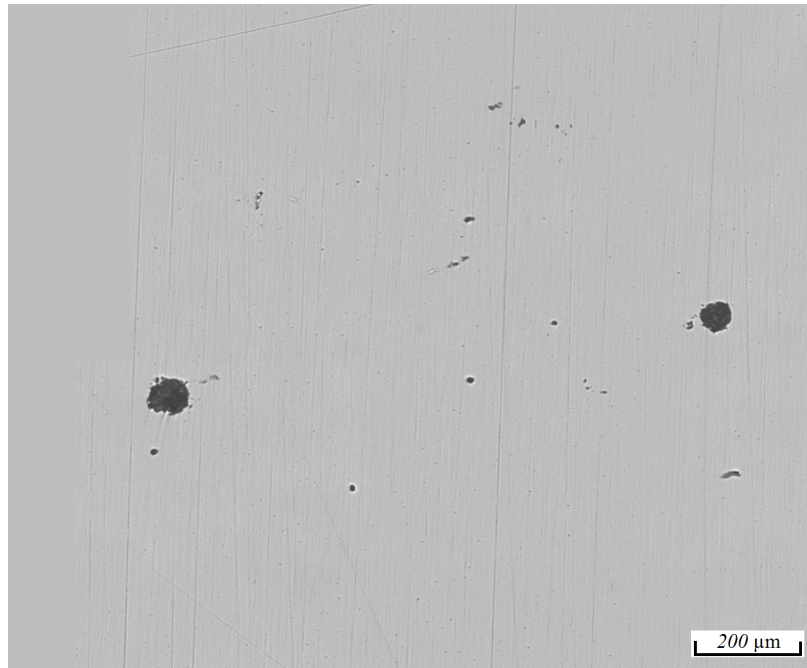
№№ of templates	Oxygen		Nitrogen	
	Concentration	Average deviation	Concentration	Average deviation
1	0.0058	0.0017	0.0062	0.0004
2	0.0088	0.0017	0.0069	0.0004
3	0.0068	0.0011	0.0068	0.0003

From the presented data show that the average content of gases in the metal blanks is quite high, but it fits into the limits set by the requirements of the Terms of Reference (no more than 0.008% of each).

Microsections for the research of non-metallic inclusions were made of halves of the samples after the tensile tests, the impact strength and crack resistance. Analysis of contamination of have become non-metallic inclusions was carried out on non-etched thin sections by ASTM E1245-03 standard and in accordance with state standard 1778-70 using appropriate Thixomet.Pro image analyzer modules.

Micro x-ray spectroscopic studies of the chemical composition of non-metallic inclusions were performed on a scanning electron microscope ZEISS SUPRA 55 VP. The microscope is equipped with a computer-controlled scanning electron beam and digital recording signals and images, X-ray

microanalyzer INCA WAVE and INCA X-MAX. Type of inclusions typical encountered in the metal blanks is shown in Figure 2.



**Figure 2.** Type of typical inclusions occurring in the blanks

As a result of research, it was found that the reason for the decline of properties blanks is large concentrations of nonmetallic inclusions onto the surface of the fracture. On average, the content of non-metallic inclusions in the metal blanks ranged up to 2.5 points, but some areas were (metal volumes), which was an increase in the content of some types of non-metallic inclusions to 4 points. The main types of inclusions non-deformable, ductile and fragile silicates.

Furnace processing with modifying powder of concentrates showed its process ability and allowed to get steel correspond the set requirements.

Experiments are carried out on improving industrial smelting of technology by using steel as refining and modifying elements titanium, vanadium, identified the following impact modifier, on the characteristics steel components. Experiments are carried out on improving industrial smelting of technology by using steel as refining and modifying elements titanium, vanadium, and et al. identified the following impact modifier, on the characteristics steel components.

Titanium improves the purity of steel by nonmetallic inclusions on oxides silicate fluxing effect renders it makes them more fusible that promotes coagulation of inclusions and the removal of the slag. The total pollution index of steel with a titanium additive to 0.11 % is in the range of 0.016–0.020. A further increase in the titanium content leads to a sharp drop in toughness and wear resistance and an increase in total pollution index to 0.029.

With increasing vanadium content in steel toughness is reduced, and the relative wear increases, this is associated with the processes of carbide-, nitride- and carbonitride formation, which contribute to improving the initial hardness of steel. However, in this case there is a risk of inclusions location carbides, nitrides and carbonitrides of at austenite grain boundaries, which can lead to embrittlement of the metal and reducing the toughness. Study of the microstructure of impact samples at the site of fracture showed that it is a finely dispersed austenite with vanadium carbides, located within and along the grain boundaries.

Zirconium, having a high affinity for oxygen, actively deoxidizes steel and its deoxidizing ability in conditions steelmaking processes above deoxidizing ability aluminum, whereby it prevents the

formation of harmful inclusions in the steel aluminous. The formed zirconium de oxidation products easily deformed and have a thermal linear expansion coefficient similar to those of the steel, and thus during heating and cooling of the metal they do not create a tension therein, unlike aluminous inclusions that cause micro cracks. Zirconium also reduces the coefficient of oxygen activity of the melt, thereby increasing the degree of assimilation of titanium them.

## Conclusion

On the basis conducted researches implemented steel smelting technology with the use of modifier deoxidizing complex mineral concentrates. In the process enhancing the properties of the castings obtained by grain refinement due to the formation in the melt and in the solid steel additional nucleation (vanadium and titanium nitrides), crystallite growth restriction (zirconium), of modifying the non-metallic inclusions (titanium, zirconium). Due to such possible to effectively manage the processes of both primary and secondary crystallization cast steel technology. In such a way one can effectively influence the processes of absorption by removing of harmful impurities and gases, changes in the character of crystallization and redeployment crystallizing phases and their quantities. Achieved by reducing the size of dendritic crystallites and austenite grains when introduced into the steel elements of the data is accompanied by an increase in the grain boundary surface, decreasing the specific border concentration of impurities.

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