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# INCREASING THE MECHANICAL PROPERTIES OF STEEL USING RARE EARTH METALS

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**Abstract**

The work is devoted to improving the mechanical properties of steel using rare earth metals. The thermodynamic analysis of the combination of rare earth metals with impurities and gases in steel is considered. It is shown that rare earth metals are strong deoxidizers and desulfurizers that neutralize the harmful effects of sulfur, phosphorus and non-ferrous metals.

**Keywords:** non-metallic inclusions, modification, rare earth metals.

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**Introduction**

Recently, in the manufacture of steel castings, much attention has been paid to the modification of liquid melts. During modification, the quality of castings is improved, which includes refinement of the grain structure, a decrease in the number of non-metallic inclusions and a change in their morphology, additional deoxidation and refining of steel.

Changing the grain structure, reducing the number of non-metallic inclusions and giving them a more favorable shape contribute to an increase in the plastic properties of the metal. In the process of modification, the technological properties of steel also change, the fluidity and crack resistance of castings increase, and the tendency of steel to form gas-shrinkage defects decreases. Modification of steel reduces segregation, thereby increasing the uniformity of distribution of carbon, sulfur and phosphorus in the casting. For the modification of steels, aluminum, magnesium, alkaline earth elements and rare earth metals (REM) are most often used. The use of rare-earth metals for processing steels in the form of master alloys reduces the vapor pressure of these elements, which makes it possible to significantly increase their solubility.

An increase in the properties of steel can be achieved by reducing the amount of non-metallic inclusions and neutralizing harmful impurities by using modification with cerium. At concentrations of practical interest, cerium should hardly dissolve in iron at the temperatures of steelmaking processes. The solubility of cerium in solid metals and alloys is very limited, since cerium atoms are relatively large in size, which hinders the formation of wide solubility regions in other metals in the solid state. So, 0.2% of cerium dissolves in iron. Many works provide data indicating that cerium is a surface-active element. The addition of cerium to liquid iron causes a decrease in its surface tension by 100–200 $J/m^2$, which should contribute to an increase in fluidity.

Currently, REMs are widely used in steel production, which have a high affinity for oxygen, sulfur, nitrogen, non-ferrous metals and other impurities. The effect of rare-earth metals is manifested both in a decrease in the content of these impurities in steel and in their transfer from active forms to passive ones, which contributes to the purification of grain boundaries and ensures the formation of a finely dispersed dendritic structure. Purifying steel from harmful impurities, REMs improve its casting properties, fluidity, feeding conditions and crack resistance of castings, and also reduce the anisotropy of the mechanical characteristics of steel. The high efficiency of the influence of REMs on the properties of steel is due to their favorable effect on the composition, type, shape, quantity and uniformity of distribution of the formed non-metallic shutdowns, a significant improvement in the macro and microstructure of the workpiece, a decrease in its physical and chemical

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heterogeneity, and the provision of increased density and dispersion of the crystal structure in all zones. cast billet, including small section.
Other researchers believe that the role of REM is to achieve such a total sulfur content in liquid steel, which is significantly lower than the values obtained using conventional desulfurizers, such as manganese, magnesium, and others.
Based on the foregoing, this work is devoted to the development of new technological methods for smelting and out-of-furnace processing, in particular, to improve the processes of refining in the ITP and modifying steel in a steel ladle. All types of REM compounds have a melting point higher than that of iron and a density slightly lower than that of steel, i.e. in liquid steel, the compounds formed must be in solid form, and their removal is difficult. All REMs form oxides of the $R_2O_3$ type with oxygen. Cerium and praseodymium can form $RO_2$ oxides, and some REM oxides of the RO type.
Thermodynamic analysis shows that rare-earth metals can form compounds with impurities and gases present in steel (sulfur, arsenic, tin, antimony, lead, oxygen, nitrogen, etc.), i.e. they are strong deoxidizers and desulfurizers, and, according to some researchers, neutralize the harmful effects of phosphorus and non-ferrous metals (Figure 1).

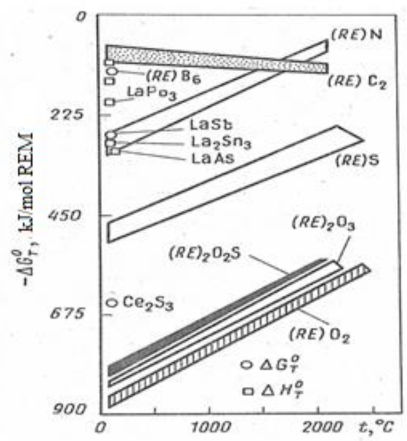


Figure 1 - Gibbs energy of formation of REM compounds

As can be seen from Figure 1, in order to form compounds with lower Gibbs energies, it is necessary to reduce the content of harmful impurities with high Gibbs energies in the melt. These data show that the values of the free energies of formation of REM oxides used in steelmaking are quite close.
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type with oxygen. Cerium and praseodymium can form $RO_2$ oxides, and some REM oxides of the RO type.

REMs have a significant affinity for nitrogen, commensurate with the affinity of such nitride-forming elements as titanium and zirconium. When introduced into a liquid metal, REMs primarily form strong bonds with sulfur and oxygen; even titanium and zirconium do not have such a high affinity for sulfur and oxygen as REM, and this allows them to actively participate in the formation of nitrides, especially at high temperatures. At temperatures of – 900...1100 °C, the change in ΔG0 of nitride formation in REM is large (about 225 kJ/mol REM), but the presence of free aluminum in steel (0.03...0.04%) exceeds tens of times (s taking into account the significant difference in atomic masses), the content of REM does not allow the latter to participate in the processes of nitride formation.

REM forms a number of compounds with phosphorus. This makes it possible to eliminate the negative effect of low-melting phosphorus-containing phases on the properties of corrosion-resistant and heat-resistant steels and can only be realized at high concentrations of REM in the metal. When introducing technologically acceptable quantities of REM (0.1...0.2%) from the point of view of successful pouring of metal into carbon and alloyed steels, the interaction of REM with phosphorus remains controversial.

REM bind impurities of non-ferrous metals into strong chemical compounds with high melting points and ensure the elimination of intergranular low-temperature and high-temperature brittleness.

In real solutions, the ability of participation of highly reactive elements with impurities dissolved in steel is determined by two factors: the activity of an impurity and an element in iron, determined by the equilibrium constant and the change in free energy associated with it as a result of their interaction.

With liquid iron, the deviation from ideal solutions is determined by the activity coefficient, which is calculated using the interaction parameters. However, for real conditions, it is necessary to take into account the influence of other steel components on the activity of REMs. The volume of research does not allow to fully reflect the state of the issue, however, the available data are of interest for additionally taking into account the effect of carbon and manganese, the content of which varies significantly for different steel grades.

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