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NEW CORROSION-RESISTANT COST-SAVING ALLOYED (NICKEL-FREE) TWO-PHASE STEELS WITH METASTABLE AUSTENITE

In the world practice, Cr-Ni steels of type 18/8 (10Cr18Ni(9…10)Ti, 08Cr22Ni6Mo2, etc.) are widely used as effective stainless (corrosion-resistant) steels. These steels are very expensive since they contain 9…11% Ni. Therefore, in many countries research and development are being carried out on low-nickel and nickel-free stainless steels capable of adequately replacing the above mentioned Cr-Ni stainless (corrosion-resistant) steels, retaining a sufficient set of mechanical properties and corrosion resistance.

With the objective of adequate replacement of expensive Fe-Cr-Ni-stainless (corrosion-resistant) steels with nickel-free steels, developed Fe-Cr-Mn steels for the ability to work in corrosive environments of low and medium aggressiveness.

To determine the optimal chemical composition of new nickel-free steels, the impact of chromium from ~14% to ~22% on the phase composition, microstructure, and mechanical properties was studied. An important feature and advantage of the developed Fe-Cr-Mn steels is the metastability of the austenitic phase, which undergoes a deformation induced martensite $\gamma \rightarrow \alpha'$ transformation that develops when testing the mechanical properties and operation DIMTT.

New nickel-free stainless steels, depending on the chromium content (from ~14 to ~22%), belong to different structural classes: austenite-martensite (10Cr14Mn6SiV), austenite-ferrite (10Cr18MnSiV), and ferrite-austenite (08Cr22Mn6SiV). After quenching at 1050 °C, the microstructure of 10Cr14Mn6SiV steel consists of austenite and martensite. With an increase in the chromium content from ~14% to ~18%, the martensite component disappears from the structure, and ferrite appears. The microstructure of 10Cr18Mn6SiV steel consists of ~46% ferrite in the form of closed regions and ~54% austenite. With an increase in chromium content to ~22%, the amount of ferrite increases to 68%, and austenite decreases to 32%. The mechanical properties of the investigated stainless steels after quenching at 1050 °C, tempering 200 °C are given in Table 1.

With an increase in the chromium content from 14 to 22%, the tensile strengths (from 1520 to 900 MPa) and the yield strength (from 920 to 500 MPa) and torsion and yield strength (from 1430 to 800 MPa and from 760 to 200 MPa, respectively) decrease in steel at continuous increase in plastic properties (δ – from 5% to 43%; ψ – from 6% to 65%; relative shear (g) – from 60% to 122%.

This is explained on the one hand by the disappearance of quenching martensite and an increase in the proportion of ductile ferrite. An additional and very significant factor in increasing strength and, at the same time, plasticity is the deformation metastability of austenite, which manifests itself in the development of γ→α′ DIMTT with the formation of deformation martensite (Δα′).

DIMTT causes, on the one hand, self-strengthening of steels, and on the other hand, relaxation of microstresses, it simultaneously increasing ductility and impact strength directly at testing of mechanical properties. The degree of the strengthening effect and increase of the ductility properties in steels is different and is determined by the kinetics of the γ→α′ DIMTT.

Table 1. Mechanical properties of the investigated stainless steels

Grade of steel	Ultimate strength ($\sigma_в$), MPa	Yield strength ($\sigma_т$), MPa	Relative elongation (δ), %	Relative duration (ψ), %	Impact strength, MJ/м^2	
					KCV	KCU
10Cr14Mn6SiV	1520	920	5	6	0,5	-
10Cr18Mn6SiV	1100	480	32	28	3,8	-
08Cr22Mn6SiV	900	500	43	65	3,3	-
10Cr8Ni9Ti (GOST7350-77)	530	230	38	55	-	2,5
AISI304 (ASTM A240)	510	205	43	-	-	-

The more deformation martensite (Δα′) is formed – the greater the self-strengthening effect ($\Delta\sigma = \sigma_в - \sigma_т$; $\Delta\tau = \tau_{пч} - \tau_{0.3}$), and the longer the DIMTT develops more smoothly in time - the greater the ductility properties (δ, ψ, g). It is noteworthy that in steel 08Cr22Mn6SiV the effect of superplasticity is manifested (g = 122%) when a strength high enough for this class of steels is reached ($\sigma_в$ = 900 MPa, $\tau_{пч}$ = 800 Pa). In standard Fe-Cr-Ni steels, for example 10Cr18Ni9Ti, (steel type 18/8) (AISI 304), under similar conditions for testing properties, this effect is not realized.

A comparison of the mechanical properties of the developed nickel-free corrosion-resistant steels and standard Fe-Cr-Ni steels (10Cr18Ni9Ti, (steel type 18/8) (AISI 304) (see Table) shows that the new nickel-free steels have a significantly higher set of strength properties with similar ductility indices.

In terms of complex of mechanical properties, the developed nickel-free stainless steels 10Cr18Mn6SiV and 08Cr22Mn6SiV are superior to the well-known widely used Fe-Cr-Ni steels (10Cr18Ni9Ti, AISI 304).