EROSION RESISTANCE OF Cr–Ni–Si METAL IN SURFACING IN DIFFERENT SHIELDING ENVIRONMENTS

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Pipeline stop valves during operation should possess the erosion resistance of sealing surfaces. For this purpose they are subjected to mechanized arc surfacing with producing of high-alloyed Cr–Ni–Si deposited metal. Further improvement of erosion resistance can be achieved by additional alloying of deposited metal using nitrogen. The paper presents the results of comparative tests of the deposited metal on tear resistance in surfacing using flux-cored wire in argon, carbon dioxide, nitrogen and mixture of nitrogen with carbon dioxide. The best indicators of erosion resistance belong to the deposited metal produced during surfacing in mixture of nitrogen and carbon dioxide. 2 Ref., 3 Tables, 1 Figure.

Keywords: *arc surfacing, mixture of shielding gases, stop valves of pipelines, sealing surfaces, flux-cored wire, Cr–Ni–Si deposited metal, erosion resistance*

For mechanized wear-resistant surfacing of sealing surfaces of the parts of pipeline stop valves under flux and in argon, flux-cored wires PP-AN133 (type 10Kh17N8S5G2T) and PP-AN157 (type 10Kh19N9S5M2RGT) are used. These materials are much cheaper as compared to the deficient cobalt stellites, which are finding wide spreading in industry instead of electrodes TsN-6L, TsN-12M. The deposited metal retains a sufficiently high resistance against corrosion and erosion wear and tears in the water-steam environment of high parameters and retains its characteristics during a long service life. The research and experience in application of these steels proves that the deposited coatings with a higher level of hardness show the higher tear resistance. However, their resistance against crack formation in this case falls, particularly abruptly at hardness of more than *HRC* 45 [1].

The hardness of surfacing Cr–Ni steels significantly depends on the presence of alloying elements, such as silicon and chromium in their composition, amount of ferrite phase and degree of its decay during heating. Therefore, a strict regulation of temperature and time modes of surfacing and heating of parts is necessary, including the mode of subsequent heat treatment. A slight deviation of chemical composition of the deposited metal as to chromium and, particularly, silicon, significantly reduces its service characteristics [1, 2]. As a result of dispersion hardening the sigma-phase is formed, which leads to embrittlement of deposited metal and formation of cracks in it. An important role belongs to the temperature-time conditions in surfacing of massive parts and to ageing of alloy at the long-term thermal loads at heat power plants with temperature of working environment of 450–600 °C, which generally reduces the service properties of the alloy [2].

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In order to evaluate the possibility of improving the service characteristics the research was carried out on the effect of nitrogen alloying on changes in physical and mechanical properties of alloys 10X17N8S5G2T and 10Kh9N9S5M2RGT depending on temperature of annealing, tear and erosion resistance. The surfacing was carried out in argon and N_2-containing atmosphere.

Mechanical properties. The tests of specimens on impact bending were carried out on pendulum impact testing machine KM-0.3 using the optoelectronic system of fracture energy registration. The full reserve of potential energy of the pendulum was 300 J. The losses for friction in the axis of pendulum in all the cases did not exceed 0.4 %. The tests were conducted on specimens of type 1 according to GOST 9454–78 with V-notch. The hardness of deposited specimens at the normal temperature was determined in TK-2 durometer at loading of 0.29 kg and 30 s holding. The factographic investigations of surface of specimens after fracture at impact toughness tests were performed in scanning electron microscope JSM-6390LV.

The investigations of mechanical properties of the N_2-containing deposited metal (Table 1) show that nitrogen increases the strength and impact toughness of the investigated alloys.

The study of fractograms of the fractured surface of specimens after test on impact toughness (the Figure) shows that the surfacing in atmos-

Table 1. Mechanical properties of Cr–Ni–Si deposited metal

Deposited metal	Shielding atmosphere	Heat treatment mode	σ_t, MPa	*KCV*, J/cm^2
10Kh17N8S5G2T	Ar	Initial state	88.2–92.5 / 90.3	5.2–5.6 / 5.5
		Tempering at 650 °C, 3 h	86.0–90.6 / 88.3	5.0–5.6 / 5.3
		Tempering at 850 °C, 3 h	66.8–77.2 / 72.0	2.8–4.6 / 3.7
		Ageing at 650 °C, 1000 h	62.4–68.3 / 65.4	0.25–1.10 / 0.67
10Kh17N9S5G2T	N_2 + 30 % CO_2	Initial state	94.2–115.0 / 104.6	10.6–12.4 / 11.5
		Tempering at 650 °C, 3 h	80.0–100.5 / 90.2	8.8–11.5 / 9.9
		Tempering at 850 °C, 3 h	68.2–78.4 / 73.0	5.6–6.4 / 6.0
		Ageing at 650 °C, 1000 h	63.8–67.9 / 65.6	2.3–3.8 / 3.5
10Kh9N9S5M2GRT	Ar	Initial state	86.0–99.2 / 92.6	3.5–5.2 / 4.4
		Tempering at 650 °C, 3 h	78.8–92.0 / 85.4	3.1–4.6 / 3.9
		Tempering at 850 °C, 3 h	79.8–94.0 / 86.9	2.6–4.2 / 3.4
		Ageing at 650 °C, 1000 h	71.2–84.6 / 77.9	3.1–4.6 / 3.9
10Kh19N9S5M2GTRT	N_2 + 30 % CO_2	Initial state	89.0–99.8 / 94.4	4.8–7.0 / 5.9
		Tempering at 650 °C, 3 h	79.4–94.0 / 86.7	4.1–6.3 / 5.2
		Ageing at 650 °C, 1000 h	71.2–85.4 / 78.3	3.1–4.6 / 3.9

phere N_2 + 70 % CO_2 leads to a significant increase in the fraction of tough component in the fracture as compared to argon (Figure *b*). At the same time, fracture of steel may be characterized as a tough cup-shaped fracture with some inclusions of areas of brittle cleavage.

In the metal deposited in mixture of N_2 + 30 % CO_2, the fraction of tough component is increased and the dispersion of structure remains at a sufficiently high level (Figure *c*), that provides the higher values of impact toughness.

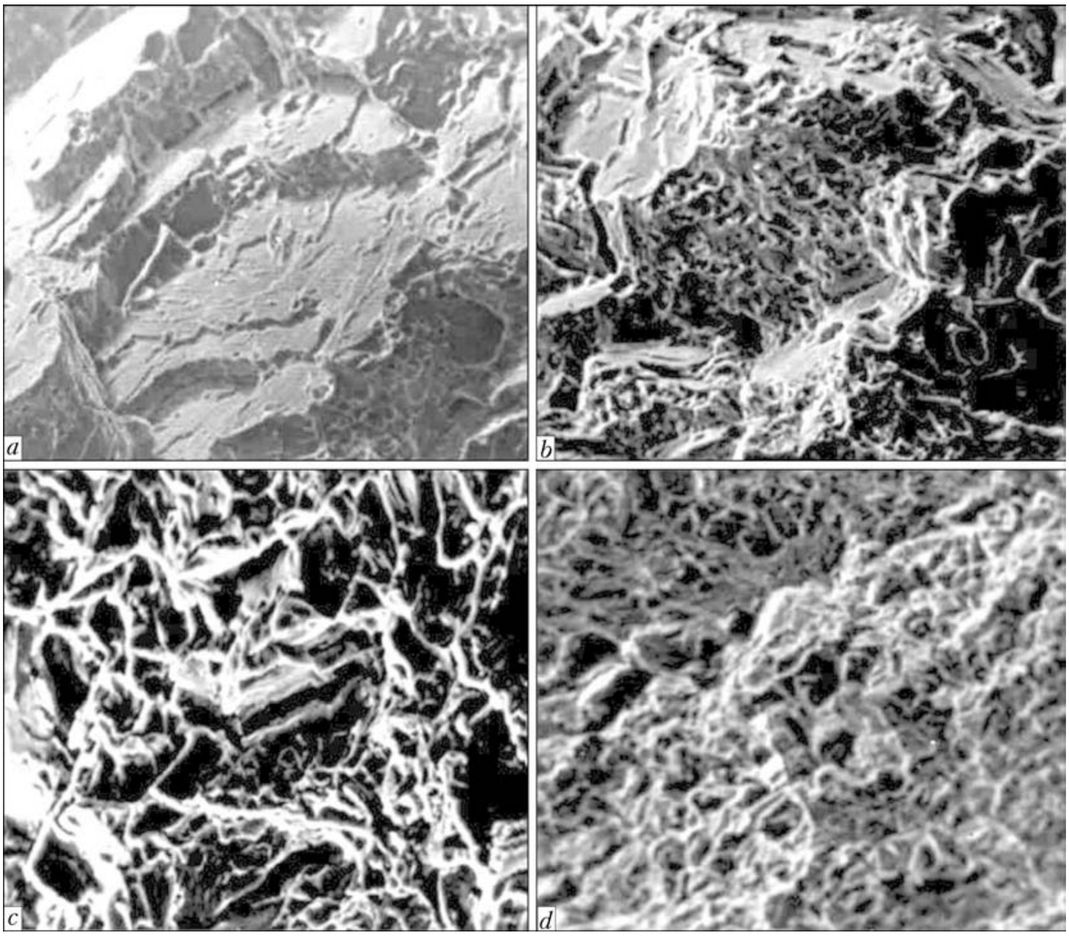
A further increase in percentage content of nitrogen in the mixture (over 70 %) results in growing tendency of the material to brittle fracture.

The metal deposited in atmosphere of 100 % N_2 with simultaneous strengthening the austenite leads to embrittlement. This is evidenced by appearance of cleavage sites with a distinct crystallographic orientation on the surface of fracture (Figure *d*).

Tests on tear resistance. In order to obtain the comparable data on service properties of surfacing consumables for sealing surfaces of stop valve gates, the complex experimental studies of alloys on the tendency to formation of tears and erosion under the parameters of environment and conditions close to the operating ones were carried.

The tests on tear resistance were conducted in the steam environment at 350 °C and specific pressure of 80–100 MPa at the specialized stand.

Alloys 10Kh17N8S5G2T and 10Kh19N9S5M2RGT were investigated, produced by surfacing using wires PP-AN133 and PP-AN157, respectively, in Ar, CO_2, N_2, and CO_2 + N_2. The investigation of materials on tear resistance was carried out by modeling the process of contact force action on sealing surfaces of the parts of gate valves. The minimum specific load, at which the tests were started, was 10 MPa. Then, the load was increased stepwise by 10 MPa up to a tear or reaching the preset value of specific pressure. After the test the area of contact (friction) of specimens and tear depth were determined.



Evolution of type of fracture (×580) in surfacing using flux-cored wire PP-AN133 and shielding atmosphere of Ar (*a*), N_2 + 70 % CO_2 (*b*), N_2 + 30 % CO_2 (*c*) and N_2 (*d*)

The measurements were carried out using microscope MIS-11. As a criterion of tear resistance the appearance of tear of 10 μm depth or more on the working (contact) surface of specimens was conditionally accepted. The specific loading, causing the tears of the preset value, was considered to be the maximum allowable one for the given material.

It follows from the presented data (Table 2) that all the pairs of specimens of alloy 10Kh17N8S5G2T, except of the specimens deposited in atmosphere of argon, have a sufficiently high tear resistance at specific pressures of 91.2–96.6 MPa, however, the best properties belong to the metal deposited using wire PP-AN133 in N_2 + 50 % CO_2 (96 MPa) and N_2 + 30 % CO_2 (96.6 MPa) atmosphere.

During testing of dissimilar pairs of specimens 10Kh17N8S5G2T + 10Kh19N9S5M2RGT the high tear-resistant properties were registered in the metal, deposited using corresponding wires in mixture of N_2 + 30 % CO_2.

The tear-resistant properties of similar pair of alloy 10Kh17N8S5G2T, alloyed by nitrogen, are not inferior to these properties during testing of above-mentioned dissimilar pairs. The improve-

Table 2. Tear-resistant properties of investigated alloys

Type of alloy of investigated pairs of specimens	Content of shielding gas, %	Hardness *HRC*	Specific loads causing tear of more than 10 μm, MPa
10Kh17N8S5G2T	100 Ar	36	57.7
	100 CO_2	32	71.2
	100 N_2	36	93
	N_2 + 50 CO_2	35	96
	CO_2 + 30 N_2	33	93
	N_2 + 30 CO_2	35	96.6
10Kh17N8S5G2T (down)	100 N_2	32/36	70
10Kh19N9S5M2RGT (top)	N_2 + 30 CO_2	35/38	77

Table 3. Erosion properties of steel 10Kh17N8S5G2T

Steel	Shielding gas content, %	Tests parameters			Test results		
		P, MPa	*T*, °C	*t*, h	Wear depth, μm	Wear rate, μm/h	CRES
10Kh17N8S5G2T	100 Ar	17.0	200	254	15.95	0.064	1.03
		18.5	180	196	15.32	0.052	0.88
		18.5	180	196	9.32	0.047	0.97
	N_2 + 50 CO_2	17.0	200	254	12.15	0.051	1.29
		18.5	180	196	7.21	0.033	1.39
	N_2 + 30 CO_2	17.0	200	254	13.06	0.053	1.24
		18.5	180	196	7.52	0.035	1.31
	CO_2 + 70 N_2	17.0	200	254	12.33	0.032	2.06
		18.5	180	196	6.15	0.051	1.40
		18.0	180	196	10.86	0.049	1.53
12Kh18N10T	–	17.0	200	254	16.80	0.066	1
		18.5	180	196	8.70	0.046	1

ment of tear-resistant properties of the deposited metal is associated with producing a more uniform structure in surfacing in N_2-containing environments. In the structure of the alloys, alloyed with nitrogen, the quantitative ratio of α- and γ-phases is changed in the direction of increasing the austenite. Alloy 10Kh17N8S5G2T, alloyed with nitrogen from gas phase, is characterized by formation of fine-dispersed carbonitride particles uniformly distributed in the austenitic matrix, causing the strengthening effect.

Tests on erosion resistance. The working environment was water (18 MPa, 210 °C), feeding the boilers of industrial heat power plant. Simultaneously several pairs of specimens were subjected to tests, where at least in three of them the specimens of test material were present. The speed of environment in gap of 0.3 × 3 mm^2 between the investigated upper and lower specimen of 12Kh18N10T steel was about 100 m/s. The parameters of environment were maintained and recorded during the experiment using the monitoring system, composition of environment was controlled by hemical sampling at the heat power plant and at the test stand.

The degree of cavitation-erosion fracture of the investigated specimens was determined by weighing them in analytical scales before and after the tests with accuracy of ±0.0001 g. Besides, the working surface of specimens in the slotted water flow was evaluated according to the average depth of wear. The measurements were carried out at nine spots of the investigated surface.

During each experiment alongside with the specimens of the investigated material the upper specimen of steel of type 12Kh18N10T was also installed as a one being investigated, whose level of erosion resistance was taken as a unit. The coefficient of relative erosion resistance (CRES) was calculated as the ratio of numerical values of erosion rate of the reference and investigated materials. The final indicators were determined as the simple average of relative erosion of tested pairs of specimens.

The average erosion rate was determined as the ratio of average depth of erosion fracture $\overline{h}$ per a unit of time τ — $i = \overline{h}/\tau$ μm/h. For comparative evaluation of resistance to erosion of the investigated surfacing consumables the tests at changing operating conditions were carried out. It follows from the given results (Table 3) that all the investigated variants of alloys, produced by surfacing using wire PP-AN133 in N_2-containing atmospheres, have a high erosion resistance.

The comparative characteristics showed that the best indicators of erosion resistance belong to the metal deposited using wire PP-AN133 in N_2 + 30 % CO_2 and N_2 + 50 % CO_2 environment.

The phase composition of the deposited metal considerably influences the erosion properties. With increase in the content of austenite fraction, alloyed with nitrogen, the erosion resistance of steel increases. Improving of erosion properties of the N_2-containing deposited metal is obviously connected also with the formation of fine-dispersed nitrides with the lattice coherent to the lattice of austenite and provides their strong engagement in it.

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