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Corrosion-mechanical behavior of welded joints of 17G1S-U steel in the terms simulating operational conditions

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The aim of the work – to study the corrosion-mechanical behavior of such welded joints in conditions that simulate operating conditions, in order to determine the most important factor that can lead to the destruction of the pipe.

MATERIALS AND METHODS

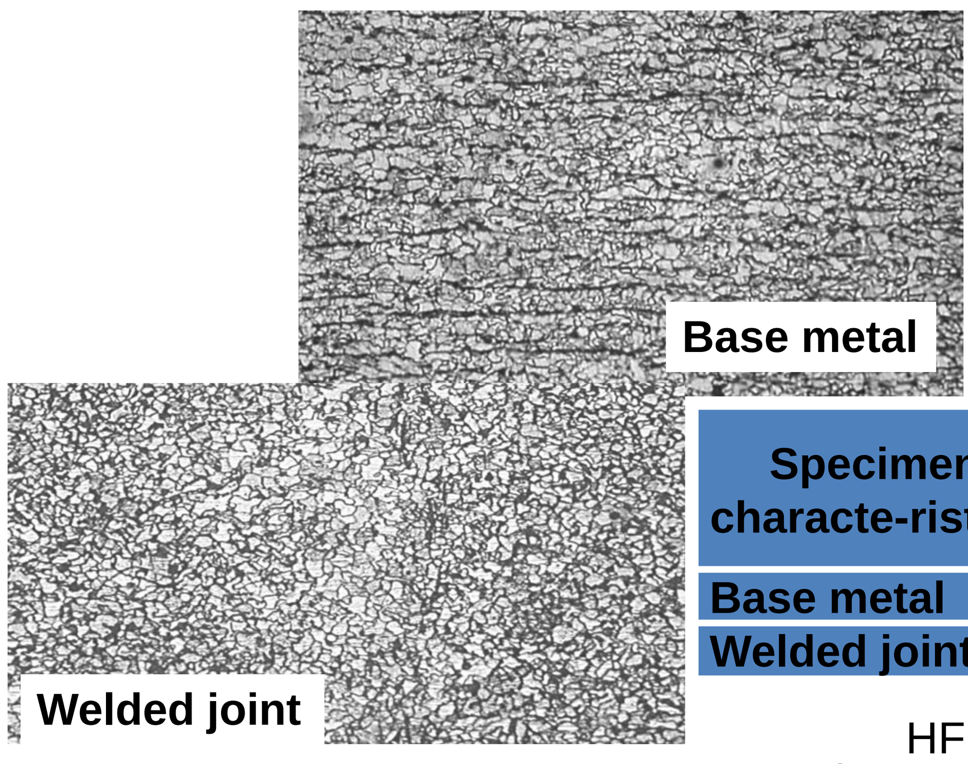
Specimens of welded joints made by high-frequency welding (HF), cut from a pipe with a size (530×10) mm made of steel 17G1S-U.

The corrosion and electrochemical tests were carried out in 3% NaCl, stress-corrosion cracking) in NS4 solution. The slow strain rate tests were carried out by stretching flat samples at a low speed of 10-6 s-1 up to failure.

Corrosion-mechanical tests of the base metal and HF weld in a two-phase medium (hydrocarbon-water solution) were performed for 400 and 1500 h. The size of the samples was (115×10×3) mm, the area of the weld ~(4.7-5.1)% of the area of the specimen. Specimens were tested at a constant deformation of $0.95\sigma_{0.2}$ of the base metal. A four-point bending scheme according to ISO 7539-2 (paragraph 3.4.1.4) was used for loading.

EXPERIMENTAL RESULTS

MICROSTRUCTURE



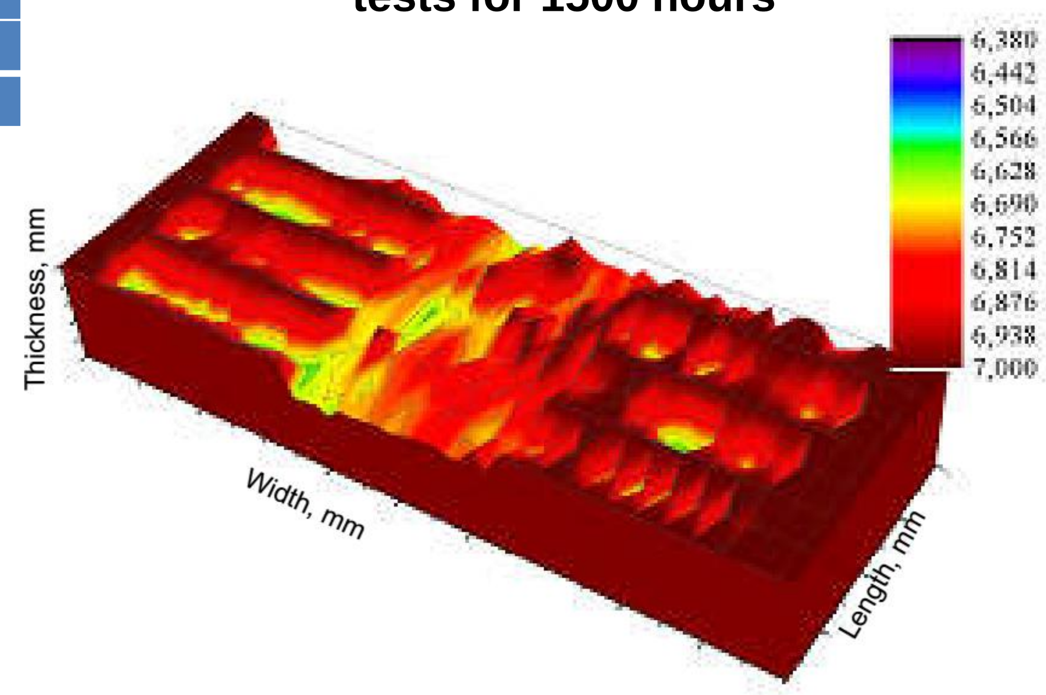
Chemical composition

Grade of steel specimen, random length	Mass fraction of elements, %									
	C	Mn	Si	S	P	Al	Ni	Ti	V	Nb
17G1S-U	0.12	1.23	0.49	0.016	0.013	0.01	0.03	0.005	0.03	0.021
GOST 5520	0.15-0.20	1.15-1.6	0.4-0.6	0.040	0.035	-	-	-	-	-

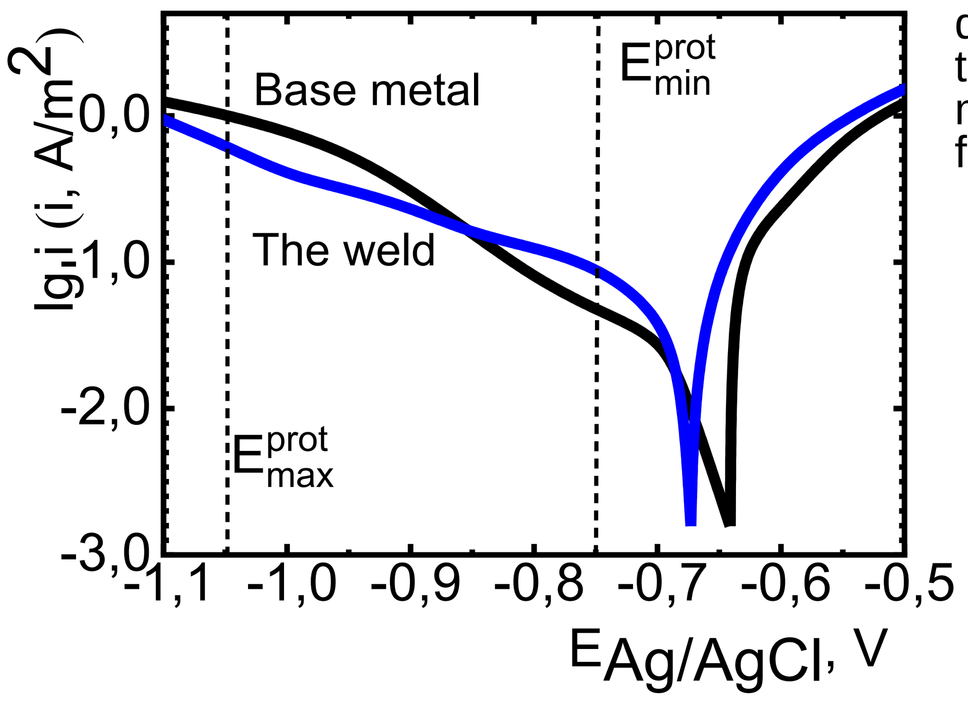
Mechanical properties

Specimen characte-ristics	σ_y, MPa	σ_t, MPa	δ_5, %	KCV^{-20}, J/cm^2	KCU^{-40}, J/sm^2
Base metal	400-430	560-580	29-33	138-289	**155-308**
Welded joint	-	**550-580**	-	**72-284**	**97-245**

Prophylogram of specimen of welded joint of 17G1S-U steel after corrosion-mechanical tests for 1500 hours



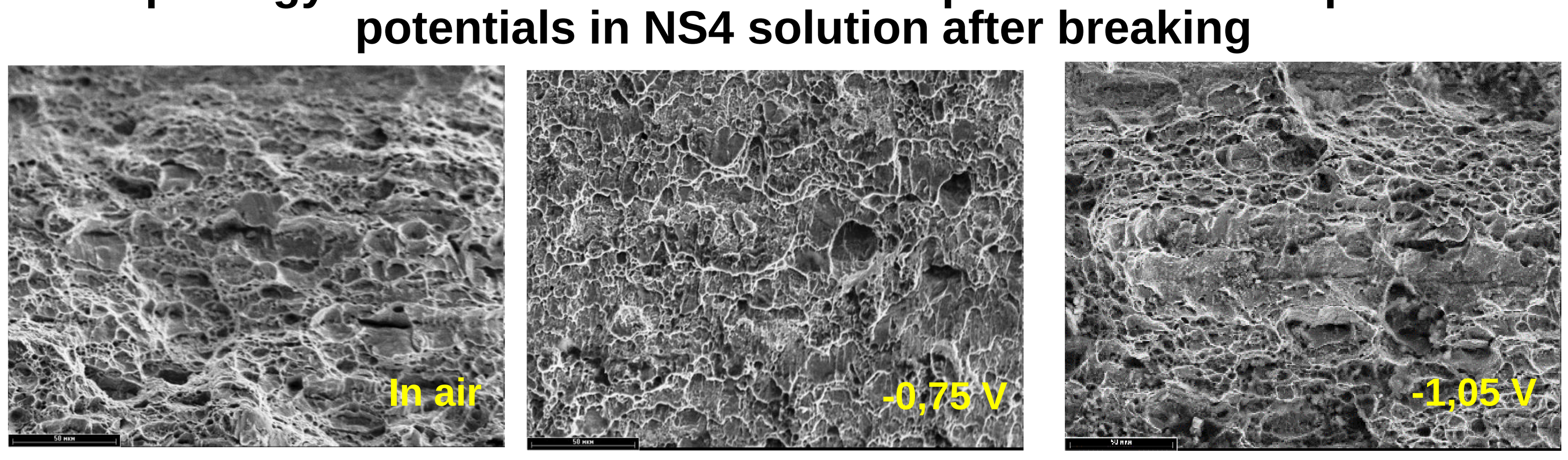
Polarization curves of base metal of 17G1S steel and weld, obtained by high frequency current welding, in 3 % NaCl. Potential scanning rate 0,5 mV/sec



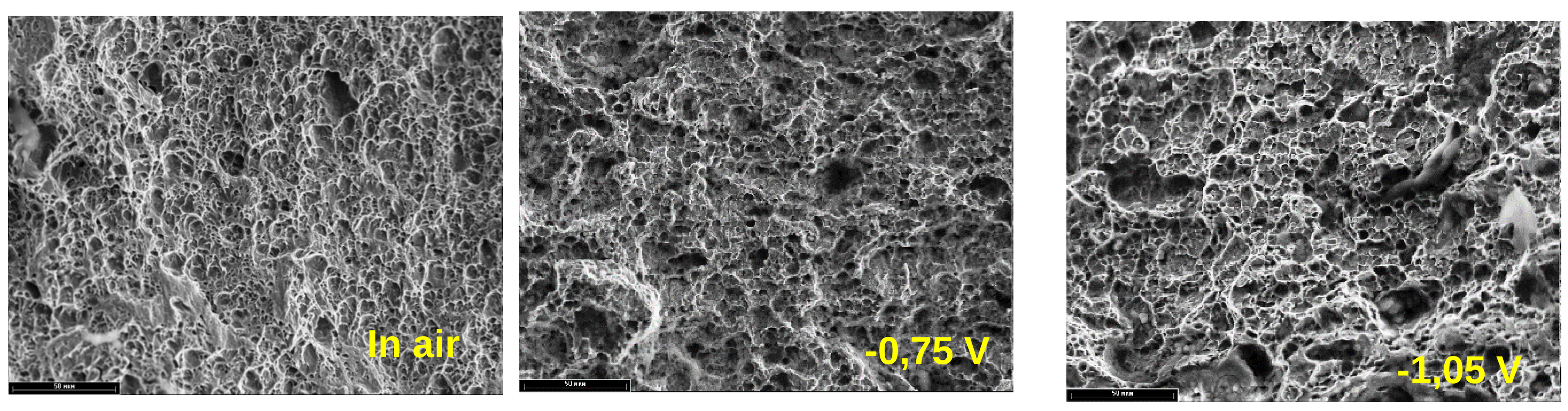
HF weld corrosion potentials are slightly more negative than 17G1C steels (-0.658 V for base metal and -0.666 V for HF weld). However, the potential difference between the base metal and the weld metal is 8 mV, figure 2, which according to GOST 9.502 is permissible.

The slopes of the anode curves of the base metal and weld metal are equal to 0.064 V, which indicates the diffusion control of corrosion. There is a difference in the electrochemical characteristics of the base metal and weld in the cathode region: the maximum diffusion current for HF weld near ~2.6 times more than the current on the base metal, the potentials of hydrogen evolution for HF weld and base metal steel 17G1S differ slightly, figure 2.

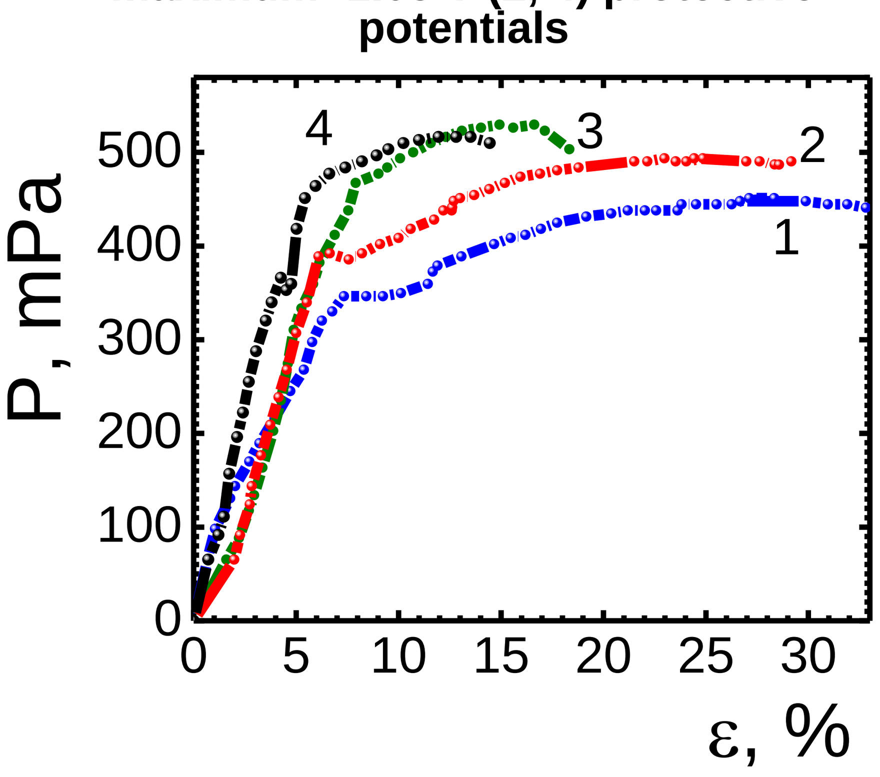
Morphology of fracture surfaces of samples in air and at protective potentials in NS4 solution after breaking



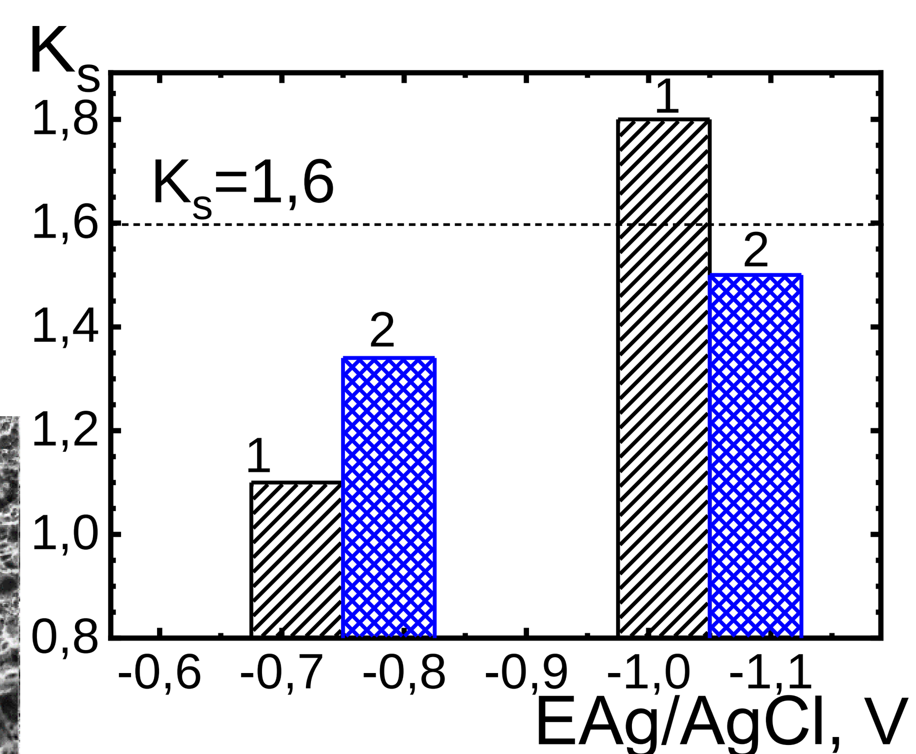
Welded joint



Breaking diagrams of the base metal (1, 2) and welded joint (3, 4) at the minimum -0.75 V (1, 3) and at the maximum -1.05 V (2, 4) protective potentials



Susceptibility to stress-corrosion cracking of steel 17G1S-U (1) and welded joint (2) in NS4 solution depending on the cathodic polarization potential



Evaluation of the susceptibility of pipe steel and welded joints to stress-corrosion cracking was performed according to the previously introduced coefficient K_S ($K_S = \psi_n/\psi_p$, where ψ_n and ψ_p is the relative narrowing of the samples in air and solution, respectively) and the criterion of susceptibility to corrosion cracking. (if $K_S \geq 1{,}6$, steel is susceptible to corrosion cracking).

It was established that at the maximum protective potential the susceptibility to stress-corrosion cracking of both the base metal and the welded joint increases, which is confirmed by the deterioration of plastic properties. For the welded joint, the change in the tendency to brittle fracture with the potential is less intense than for the base metal.

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CONCLUSION

It is established that the determinative factor in initiating of local corrosion of welded joints on the inner surface of the pipeline is thin-film corrosion in a two-phase medium (hydrocarbon-water), which is accelerated by deformation conditions. On the side of the outer cathodic-protected surface, the possible development of stress-corrosion cracking is dangerous. Maintaining the potential at the level of maximum protective contributes to the susceptibility to stress-corrosion cracking of both the base metal and the welded joint, due to the deterioration of the plastic properties of the metal during prolonged exposure to cathodic polarization. For the welded joint, the tendency to brittle fracture with a potential shift to the maximum protective is less intense than for the base metal. This is confirmed by the values of the coefficient of susceptibility to SCC.

The trouble-free operation of pipelines with HF welded joints in the conditions of cathodic protection will be defined by resistance against SCC of welded joints.