ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 9, Issue 1 , January 2022

Some Aspects of Resistance of Bimetallic Layered Compositions to the Effect of Aggressive Media

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ABSTRACT: The corrosion resistance of new synthesized bimetallic alloys of the MLC system with adaptation to hydrogen sulfide-containing hydrocarbons has been investigated. A high degree of resistance to aggressive media is shown in terms of corrosion resistance to continuous corrosion, hydrogen saturation and hydrogen embrittlement and sulfide cracking under pressure.

KEY WORDS: nonmetallic inclusions (NI), metal oxide, study of steel microstructure, aggressive environment.

I. INTRODUCTION

Specifically, the harsh operating conditions of oil and gas field equipment, largely due to the combined effect of mechanical stress, contact interaction and the influence of aggressive media, cause their corrosion-mechanical destruction and corrosion-mechanical premature wear [1,2]. In this aspect, the study of the use of multifunctional composite materials with specified technological and operational properties, which include bimetallic layered compositions (MLC), is undoubtedly relevant.

Currently, the possibility of using MLCs in the production of tools used in the conditions of percussion rotary perforating drilling of boreholes in medium abrasive rocks with a strength coefficient of $f \geq 10$ and other tools used in drilling operations, in the field, including in the equipment of the oil and gas complex, has been established [3].

During operation in environments containing hydrogen sulfide, the metal of the field equipment undergoes general corrosion and stress corrosion cracking caused by hydrogen saturation, and a decrease in the plastic properties of the metal in the process of electrochemical continuous corrosion [1,2,4]. Hydrogen sulfide stress cracking manifests itself in the rapid (after reaching the critical length) development of one crack directed perpendicular to the acting tensile stresses. This form of fracture is observed in steels with high strength, hardness and, accordingly, low ductility [1,2].

In this aspect, a qualified assessment of the corrosion resistance of bimetallic layered compositions (MLC) in hydrogen sulfide environments in order to determine the possibility of their application for the manufacture of wear-resistant parts for main, oil and gas field and production equipment resistant to hydrogen sulfide cracking is undoubtedly relevant.

II. LITERATURE SURVEY

Proceeding from this, the purpose of the research is to carry out a set of tests, including the assessment of changes in the mechanical properties of an alloy of the Cu-Ni-Mn system (MLC), under the influence of media.

For comparison, steel grade 17GS used for the manufacture of tubing and loop pipes, as well as parts operated at high temperatures, and steel 20 - for welded and non-welded structures were adopted. The chemical composition of the steels used in the comparative studies is presented in Tables 1 and 2.

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Table 3 shows the indicators of the mechanical strength of the steels used for comparison and the tested alloys.

Table 1 – Chemical composition of the MLC alloy

Alloy grade	Alloy chemical composition (masses %)					
MLC	Cu	Ni	Mn	Si	Mo	others
	4,1	basis	19,5	7,7	10,4	10,6%Cr

Chemical composition of alloys (masses %)													
C	Mn	Cu	Nb	Al	Ti	Si	P	N	V	Cr	Ni	S	Mo
Steel 17GS (GOST 19282, for the manufacture of tubing and loop pipes)													
0,16	1,27-1,4	0,017	-	-	-	0,4	0,02-0,035	-	-	0,16	0,018	0,019-0,04	-
Steel 20 (GOST 380, for welded and non-welded structures)													
0,17-0,24	0,35-0,65	0,25	-	-	-	0,17-0,37	0,035	-	-	0,25	0,25	0,03	-

Table 2 – Mechanical properties of steels and alloy

Temporary resistance break, σ_B, MPa (kgf /mm^2)	Fluidity limit σ_T, MPa (kgf/mm^2) not less	Relative elongation, δ_5(%), not less	Relative Constriction Ψ, %	Impact strength, KCU J/ cm^2	Brinell hardness, HB, not more
MLC					
480 (48)	360(37)	38	75	69 (7.0)	-
Steel 17GS					
450 (46)	325 (33)	21	-	59 (6,0)	-
Steel 20					
410 (42)	245 (25)	25	55	157	163

The study was based on the scheme of the effect of aggressive hydrogen sulfide-containing media on oil and gas steel (Figure 1).

III. EXPERIMENTAL RESULTS

The assessment of the resistance of the tested alloys to continuous corrosion was determined by the corrosion rate, characterized by the loss of mass per unit surface per unit mass and by the polarization resistance data, characterized by instantaneous (current) values of the corrosion rate in the corrosive environment NACE. The NACE test medium is a 5% aqueous solution of NaCl + 500 mg/l acetic acid with a hydrogen sulfide content of 2500 mg/l, pH = 3 [4.5].

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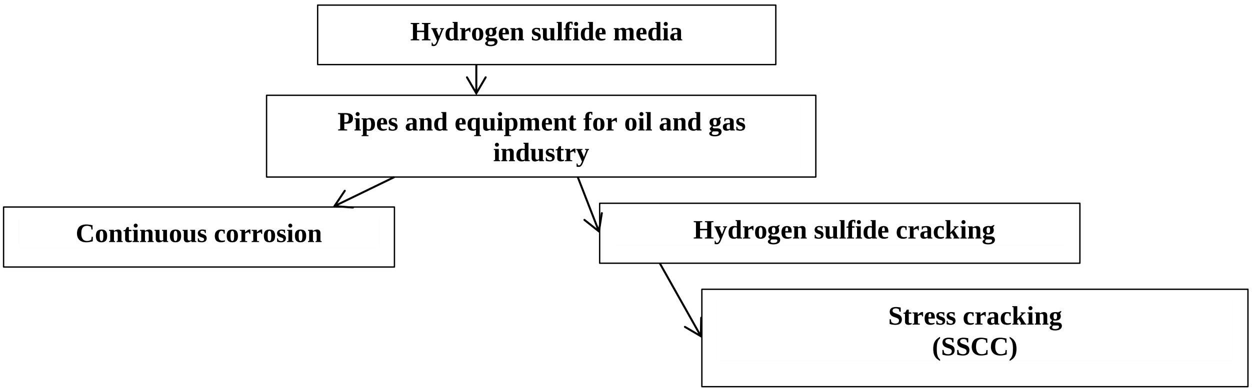

Figure 1 – Scheme of the effect of aggressive hydrogen sulfide-containing media on steel

The assessment of the resistance of MLC to stress corrosion cracking was determined by the resistance to hydrogen cracking by the degree of damage to the sample surface (blistering) and the given resistance to deformation at a constant rate in air after exposure in the NACE environment.

Measurements of stationary electrode potentials on the samples showed the minimum spread of values (Table 3). As can be seen from the data given in Table 4, during the first 1-2 min, the MSCs achieve the maximum absolute values of the electrode potential, after which the values of the potential are stabilized over time.

Table 3 – Results of electrode potentials determination

Steel	Electrode potential (on a scale AgCl)	
	φ, mV (within 2 min)	φ, mV (in 20 min)
17GS	670,5	690,1
Steel 20	660,3	665,2
MLC	670,1	670,9

Table 4 – Results of determining the tendency of MLC to hydrogen embrittlement

Steel	φ, mV	Polar activation current density			
		start	in 5 min	in 10 min	in 15 min
17GS	670,3	0,41	0,36	0,36	0,3017
Steel 20	662,0	0,24	0,29	0,32	0,45
MLC	670,2	0,36	014	0,12	0,11

From the data given in Table 4 it can be seen that the values of the cathode current density for MLC decreases with time, which is due to the non-tendency to hydrogen embrittlement, which cannot be said about the sample of Steel 20.

The results of measuring the MLC corrosion rate of the sample exposure time are shown in Table 5. It is obvious that after 3 days the MLC corrosion rate decreases by more than 20% and stabilizes over time with a low tendency to pitting and hydrogen embrittlement. Whereas, when the sample of Steel 20 is exposed from 1.5 to 5.0 h, the pitting index is 8.7 and 11.5.

Table 5 – Dependence of MLC pitting on exposure time

Exposure time, h	Corrosion rate, $g/m^2 \times h$	Pitting index (number of lesions per unit area)
0	0,53	19,5
0,5	0,22	10,3
1,0	0,20	6,2
2,0	0,18	4,2

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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3,0	0,17	3,8
5,0	0,15	3,5
10,0	0,20	3,1
24,0	0,22	3,3
72,0	0,21	3,0

Table 6 shows the results of determining the rate of general (continuous) corrosion by weight and depth indicators. The test time in the NACE environment was 72 h, the area of the samples was 2,5 cm^2.

Table 6 – Steel corrosion rate determining results

Steel	Corrosion rate for the period (h), ($g/m^2 \times h$) / (mm/y)	
	24 h	72 h
MLC	0,23/0,25	0,23/0,25
17GS	0,09/0,17	0,07/0,08
Steel 20	0,37/0,41	0,31/0,34

The time of testing let to identify the mechanisms of the process that occur in a hydrogen sulphide environment, which are responsible for general corrosion, hydrogen embrittlement, the formation of a sulphide layer on the surface and stabilization of the corrosion process.

During the first 32-60 h exposures of the MLC sample in the NACE environment, a sulfide layer is formed on the surface of the sample, which is characteristic of the Fe-NACE interaction system.

Visual inspection of the MLC samples surface after their exposure to an aggressive environment and removal of corrosion products revealed the absence of hydrogen embrittlement bubbles. The surface was affected by general corrosion with minor stains and pitting. The performed complex of weight and electrochemical studies of MSC samples showed acceptable steel purity in terms of chemical composition and non-metallic inclusions, sufficient for class C-2.

IV. CONCLUSION AND FUTURE WORK

A comparative assessment of the influence of a model aggressive environment on the MLC plastic properties and steels is carried out - comparison (degree of embrittlement) by the fatigue method (wire bending) [5]. Table 7 shows the comparative results for the degree of embrittlement of the tested steel samples in the NACE environment.

Table 7 – Effect of exposure time on the embrittlement degree

Steel	Exposure time, h	Embrittlement degree,%
MLC	96	17 -18
17GS	72	17-19
Steel 20	72	32-34

The assessment of the resistance of MLC steel to hydrogen sulfide cracking (SSCC) was carried out on the samples using the accelerated test method: hydrogen embrittlement was carried out in a NACE environment for 192 h at a temperature of 23-25 ° C. Then the samples were destroyed on a tensile testing machine by the method of slow deformation with a constant speed of grippers movement 2.0 × 10-8 m / s. The main criteria for assessing resistance to SSCC are the presence of cracks at the ends; relative narrowing; relative extension; temporary tensile strength; yield point.

Table 8 – Determination results of Resistance to Stress Corrosion Cracking of MLC Specimens

Steel	$\sigma_в$ (MPa)		$\sigma_т$ (MPa)		δ_5, %		Ψ,%		Δψ, %	δ_5, %	Presence of cracks
	orig.	final	orig.	final	orig.	final	orig.	final			
MLC	465	460	360	355	38,1	36,0	75	70,1	6,1	5,5	No
	466	460	365	354	38,2	36,2	74	71,0			No
	465	461	363	355	38,3	36,1	75	70,5			No
Average	465,6	460,3	362,6	354,6	38,2	36,1	74,6	70,5			No

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International Journal of Advanced Research in Science, Engineering and Technology
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From the data in Table 8, it is obvious that there were no significant changes in the strength and plasticity parameters of the MLC sample. This indicates the resistance of MLC to SSCC.

Thus, as a result of the studies carried out, it was found that the new synthesized bimetallic alloy MLC [2] in terms of corrosion resistance to continuous corrosion, hydrogen saturation and hydrogen sulfide cracking under pressure meet the requirements for steels of the C-2 resistance group, which are currently used. time for the manufacture of pipes with a diameter of 530 × 14mm and other metal equipment operated in aggressive environments.

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ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 9, Issue 1 , January 2022

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