EFFECT OF SILICON, MOLYBDENUM, AND COPPER ON THE PITTING CORROSION OF STEEL 00Kh18N20

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Stainless steels which have high corrosion resistance to pitting corrosion are of great interest for industry. It is well known that alloying stainless steels with molybdenum or silicon increases their resistance to pitting corrosion [1 — 4]. /133*

This article investigates several austenite steels with a 00Kh18N20 base alloyed with different amounts of molybdenum, silicon, and copper, and also steel 00Kh18N20S3M3D3B (EP 667). The amount of chromium in the alloys changes from 17.3 to 17.49%, nickel — from 19.5 to 20.0%; molybdenum — from 1.0 to 5.0%; silicon — from 0.94 to 4.00%; copper — from 1.5 to 5.1%; carbon — from 0.003 to 0.06%.

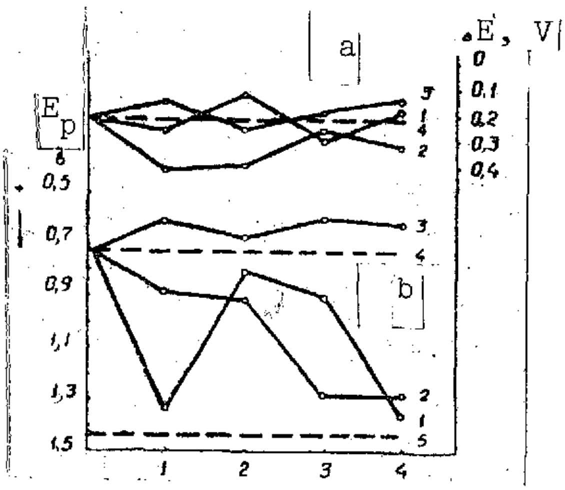
A new corrosion-resistant steel of the austenite class (EP 667), developed in the AN GSSR Institute of Metallurgy, has great resistance in several corrosive media (hot solutions of sulfuric acid — up to 80° C, etc.), and has been put into production as hydroxylamine sulfate. It is of interest to analyze the behavior of this steel in a medium containing chlorine ions.

*Numbers in the margin indicate pagination of original foreign text.

The steels were tested in a tempered state (tempering in water from a temperature of 1100° C). A study of the microstructure of steels of the 00Kh18N20 type with differing contents of silicon, molybdenum, and copper showed that, in the tempered state, all of the steels have a polyhedral austenetic structure. No separation of other phases was observed.

The pitting formation potential (E_p) of the steels studied was used to establish the pitting tendency; this was determined from the potentiokinetic and potentiostatic curves and the method of Brennert [5].

The potentiokinetic curves were recorded at a rate of 32 volts per hour in 0.1 N NaCl at 25° in a potentiostat of the Central Laboratory of Automation (TsLA). The cylindrical samples of the steels were placed in an epoxy resin. The working surface of the sample represented a base of a cylinder with a 2.0 mm diameter. Before recording the curve, the samples were cleaned with No. 28 emery paper, washed with a solution of soda, and then with distilled water, and dried with filter paper. The pitting formation potential was assumed to be the potential for the beginning of a current increase on the curve. For steel with 1% silicon in the 0.7 — 1.3 volt potential region, periodic fluctuations of the current were observed, which were apparently due to the formation and repassivation of pitting. The potential corresponding to a sharp current increase was used as the pitting formation potential on anode polarized curves obtained by potentiokinetic and potentiostatic methods. The pitting formation potentials obtained /134 by the potentiokinetic method are shown in Figure 1 for all of the steels studied.



% of alloying element

Figure 1. Influence of alloying elements in 00Khl8N20 steel on the pitting increase rate (ΔE) (a) and the pitting formation potential (b).

1- % silicon; 2- % molybdenum; 3- % copper; 4- 00Khl8N20 steel; 5- EP 667 steel.

It was found that, with an increase in the content of molybdenum, the potential of the 00Khl8N20 steel pitting formation was displaced in a positive direction. This means that, when molybdenum is introduced into 00Khl8N20 steel, its tendency toward pitting is decreased.

The introduction of copper into 00Khl8N20 steel displaces its pitting formation potential in the negative direction, i.e., its tendency toward pitting is increased.

In 00Khl8N20 steel alloyed with silicon, there is a more complex dependence of the pitting formation potential on the amount of silicon in the steel. The largest positive pitting formation potential is observed in steel with 1% silicon, and the smallest — in steel with 2% silicon. With a further increase in the silicon up to 4%, the pitting formation potential is again displaced in the positive direction.

Combined alloying of steel with 3% silicon, 3% molybdenum, and 3% copper, i.e., the composition of steel corresponding to EP 667, gives a pitting formation potential of + 1.44 volts, which is more positive than for 00Khl8N20 steel alloyed with 3.0% molybdenum or 3.0% silicon. Consequently, there is no negative influence of copper with combined alloying.

The positive role of combined alloying with molybdenum and silicon of steel 18 — 8 is well known from [1, 2]. The decreased tendency toward pitting corrosion with the combined alloying with silicon, molybdenum, and copper was observed first.

In order to study the influence of alloying elements on the pitting increase rate, on the potentiokinetic curves we noted the potential at i = 100 μA, arbitrarily calling it the potential of stable pitting increase (E_i). The difference $\Delta E = E_i - E_p$ characterizes the resistance of steel to the pitting expansion (increase in the area): the greater is ΔE, the lower is the pitting development rate, and vice versa.

The value of ΔE increases stably when there is an increase in the amount of molybdenum or silicon in the steel, which characterizes a decrease in the pitting increase rate for these steels. When there is an increase in the copper content in the steels, the pitting increase rate does not change (Figure 1). /135

The pitting formation potentials in steels with silicon were determined by recording the potentiostatic curves using the method of Brennert [5]. The potentiostatic curves were recorded in 0.1 N NaCl at 25° C for cylindrical samples with a diameter of 2 mm, which were submerged in a solution to a depth of 3 mm without insulation. The current was recorded every 15 minutes after measuring the potential with intervals of 50 mV.

When the method of Brennert was used [5], we made an automatic recording of the potentials, which excluded the possibility of errors in determining the pitting formation potential. Figure 2 gives data on determining the pitting formation potential of the steels obtained by different methods.

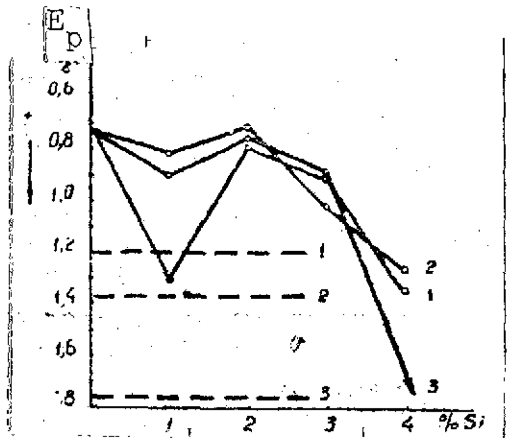


Figure 2. Pitting formation potential of steel 00Kh18N20 alloyed with silicon (solid lines) and steel EP 667 (dashed lines) determined by different methods:

1- potentiokinetic; 2- potentiostatic; 3- method of Brennert.

The results of these experiments show that the changes in the pitting formation potential as a function of the alloying component content are identical for the methods used. In 00Kh1N20 steel with 4% silicon, when the method of Brennert was used, the pitting formation potential did not reach +1.70 — 1.77 V.

Comparative 120 hour corrosion tests of silicon steels were performed in a 0.5 N solution of $FeCl_3$ at 25° C. The number of pittings per unit of area was used to determine the tendency of the steels toward pitting corrosion. The area of the samples was 8 cm^2. The table gives the average values obtained with two parallel samples. When the number of pittings were calculated, pittings on the end surfaces, which develop as a rule in the cracks and other defects, were omitted.

Steel	00Kh18N20					EP 667
	0% Si	1% Si	2% Si	3% Si	4% Si.	
Number of visually apparent pittings per 1 cm^2	0.62	0.06	3.2	1.3	0.06	0.05

Steel with 2% silicon had the greatest tendency toward pitting. A decrease in the tendency toward pitting was observed in steels with 1 and 4% silicon. The results obtained confirm the data of the electrochemical tests.

The experiments performed show that, for steel with 1% silicon, an anomaly is actually observed — steel with 1% silicon is less inclined toward pitting corrosion than steel with 2% silicon. Further studies are necessary to explain this interesting fact.

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*Translator's Note: This is a misprint in foreign text.

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