THE CORROSION RESISTANCE OF CARBURIZED STAINLESS STEELS

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Machine parts subject to friction in a humid atmosphere are manufactured from carburized stainless steels Kh13, 1Kh17N2, 1Kh16N2AM (ÉP479), and 1Kh12N2VMF (ÉI961).

The corrosion resistance of stainless steel is impaired by carburizing, although it remains fairly high in water tests after polishing to a certain depth.

This work was undertaken to determine the optimal heat treatment for reliable operation of machine parts subject to friction under conditions of varying temperature and humidity. We tested rods from commercial heats used for carburizing of martensitic and martensitic–ferritic stainless steels – 1Kh13, 1Kh12N2VMF, 1Kh17N2, and 1Kh16N2AM – and ferritic steel Kh17 for comparison.

The preliminary heat treatment for all steels was quenching from 950°C in oil and tempering at 680°C for 2 h, after which cylindrical samples 10 mm in diameter and 40 mm long were prepared. All samples were carburized simultaneously to a depth of 1.0 mm under optimal conditions at 950°C for 15 h and then quenched from 980°C, subjected to cold treatment at –70°C for 2 h, and tempered at 250°C for 2 h.

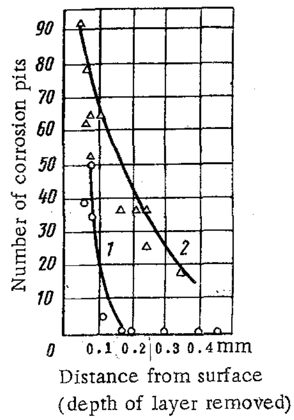

Fig. 1

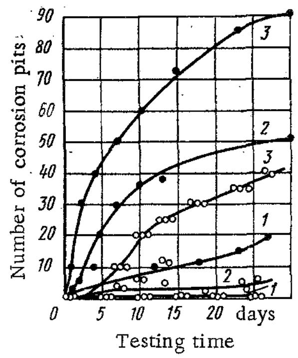

Fig. 2

Fig. 1. Corrosion resistance of carburized steels 1Kh16N2AM (ÉP479) (1) and 1Kh12N2VMF (ÉI961) in relation to depth of layer removed after testing in tropical chamber for 500 h.

Fig. 2. Effect of quenching temperature before carburizing on the corrosion resistance of steel 1Kh16N2AM in water (white points) and in 0.01% NaCl (black points). 1) 950°C; 2) 1040°C; 3) 1100°C.

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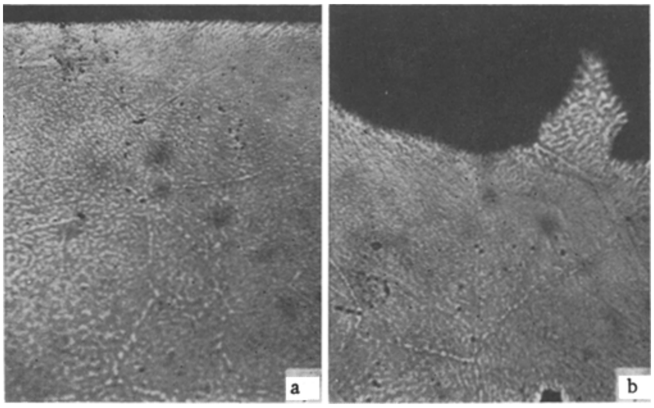

Fig. 3. Carburized layer on steel ÉP479 after corrosion tests in water for 30 days (×500). a) Preliminary quenching from 950°C; b) 1100°C.

After heat treatment, the samples were polished to a depth of 0.18-0.20 mm. The surface finish was ∇8-∇9. The tests were made in distilled water and in a tropical chamber under cyclic conditions: 1) 8 h at 50 ± 3°C, relative humidity 98-100%; 2) 12 h at 22 ± 7°C, 98-100%; 3) 4 h at 22 ± 7°C, 40-60%.

The samples were tested for 30 days in water and 20 days in the tropical chamber. The corrosion resistance was determined from the weight loss and from the number of corrosion pits on the sample (S = 8 cm^2). The corrosion products were removed in boiling 1% ammonium tricitrate (current density 0.3 A/cm^2, stainless steel cathode). The results showed that carburized steels 1Kh12N2VMF and 1Kh13 are not corrosion resistant after polishing to a depth of 0.18-0.20 mm. After polishing to the same depth, carburized steels 1Kh16N2AM, 1Kh17N2, and Kh17 were corrosion resistant in water and in the tropical chamber.

The results of the corrosion tests agree with electrochemical data on the potentials in 0.01% NaCl. The potentials are more negative for steels 1Kh12N2VMF and 1Kh13. The potentials of carburized steels 1Kh16N2AM, 1Kh17N2, and Kh17 are positive. With increasing testing times the potentials usually shift to negative. The corrosion resistance is highest for carburized steels 1Kh16N2AM, 1Kh17N2, and Kh17.

Ferritic steel Kh17 is not used for carburized parts due to its very low strength. Cracks often occur in carburized parts of steel 1Kh17N2 due to ferritic banding. Steel 1Kh16N2AM contains considerably less δ ferrite; at the present time this is the best material for carburized machine parts subject to friction in a humid atmosphere, and this steel was therefore subjected to further testing.

The corrosion resistance of carburized stainless steels in water improves with increasing depth of the layer removed in polishing. To determine the thickness of the nonresistant zone of carburized steel 1Kh16N2AM in the more severe test under tropical conditions we investigated samples polished to different depths. Carburized samples of steel 1Kh12N2VMF polished to a depth of 0.05, 0.1, 0.15, 0.2, 0.3, and 0.35 mm were tested at the same time. The number of corrosion pits decreases sharply with increasing thickness of the layer removed (Fig. 1). At a depth of 0.1 mm the carburized surface of steel 1Kh16N2AM is quite resistant in the tropical chamber, while samples of steel 1Kh12N2VMF showed a large number of corrosion pits (as many as 20 on a surface 8 cm^2) even after polishing to a depth of 0.35 mm.

We investigated the effect of the preliminary heat treatment on the corrosion resistance of carburized steel 1Kh16N2AM. The tests were made in distilled water and in 0.01% NaCl for 30 days. The test pieces were subjected to the following heat treatment before carburizing: tempering at 680°C for 5 h, quenching from 950, 1040, and 1100°C, and tempering at 680°C for 2 h. The prepared samples were carburized under optimal conditons (950°C for 15 h) to a depth of 1 mm and heat treated under the conditions given (depth of polishing 0.15 mm).

After tempering at 680°C and quenching from 950°C there were no corrosion pits after tests in water. The samples quenched from 1040°C before carburizing showed pitting corrosion after 10 days, while the samples quenched from 1100°C showed pitting corrosion on the fourth day. It was found in [1] that the increase in grain size with heating above 1040°C induces the formation of a coarse carbide network.

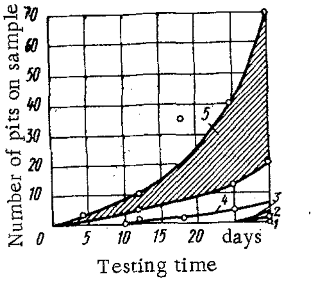

Fig. 4

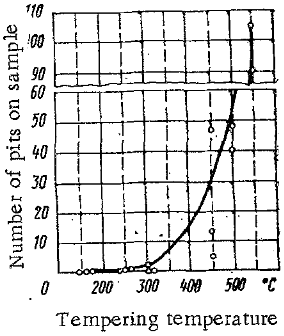

Fig. 5

Fig. 4. Effect of tempering temperature on the corrosion resistance of carburized steel 1Kh16N2AM in water. 1) 250°C; 2) 160°C; 3) 350°C; 4) 450°C; 5) 550°C.

Fig. 5. Effect of tempering temperature on the corrosion resistance of carburized steel 1Kh16N2AM in a tropical chamber.

The weight loss resulting from testing for 30 days in water and 0.01% NaCl, determined after removal of corrosion products, increased considerably with the preliminary quenching temperature. The weight loss increased about six times in water tests when the preliminary quenching temperature was raised from 950 to 1100°C. It can be seen in Fig. 2 that the corrosion rate varies with the preliminary heating temperature (it increases with the quenching temperature before carburizing). Evidently the lower corrosion resistance in this case is due to an increase of the grain size, which is inherited by the carburized layer.

Metallographic analysis revealed pitting corrosion in the carburized stainless steels tested in water and in 0.01% NaCl (Fig. 3).

Samples heat treated under optimal conditions (oil quenching from 950°C, tempering at 680°C for 2 h) were carburized to a depth of 1.0 mm and quenched from 800-1000°C, subjected to cold treatment at −70°C for 2 h, and tempered at 250°C for 2 h.

Raising the quenching temperature from 900 to 1100°C slightly improves the corrosion resistance of the carburized samples tested in water and in the tropical chamber. Lowering the quenching temperature to 850-800°C reduces the corrosion resistance.

It was found in [2] that the corrosion resistance of steel with 0.37% C and 14.5% Cr annealed at 300°C improves with an increase of quenching temperature from 925 to 1145°C, with only slight differences in the weight loss. Tempering at 400-650°C leads to the reverse relationship – the corrosion resistance is highest for samples quenched from lower temperatures. The effect of the tempering temperature on the corrosion resistance of carburized steel 1Kh16N2AM was determined on samples quenched from 980°C in oil after carburizing. All samples were subjected to cold treatment at −70°C for 2 h and tempered at 160-550°C after quenching. The tests were made in distilled water and in the tropical chamber after polishing to a depth of 0.2 mm, and the steady potential was determined in 0.01% NaCl for 24 h. Figure 4 shows the variation of the corrosion resistance in tests in distilled water for 30 days. The corrosion rate increases (the weight loss increases about ten times) when the tempering temperature is raised from 350 to 450-550°C.

The results of tests in the tropical chamber also showed that the number of corrosion pits on the samples increases sharply with the tempering temperature above 350°C (Fig. 5). Samples tempered at 160 and 250°C were not attacked in water or in the tropical chamber. Samples tempered at 350°C showed pitting corrosion in water on the 28th day. After tempering at 450, 500, and 550°C, intensive pitting corrosion occurred in both tests, as was confirmed by electrochemical measurements. To ensure satisfactory resistance in water, carburized steel 1Kh16N2AM must be polished to a depth of 0.15 mm when tempered at temperatures up to 300°C. The depth of polishing must be increased to 0.25 mm with increasing tempering temperatures to 500°C.

CONCLUSIONS

1. The corrosion resistance in water and in the tropical chamber is highest for carburized steels 1Kh17N2 and 1Kh16N2AM.

2. The corrosion resistance increases with increasing depth of polishing of the carburized steel.

3. Raising the quenching temperature before carburizing (above 950°C) lowers the corrosion resistance.

4. Raising the quenching temperature after carburizing from 950 to 1100°C has no effect on the corrosion resistance of steel 1Kh16N2AM; lowering the quenching temperature to 800-850°C lowers the corrosion resistance.

5. The corrosion resistance of the carburized steel is highest after tempering at 250°C for stress relief.

LITERATURE CITED

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