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EFFECT OF PLASMA HARDENING ON CHROMIUM STEEL CORROSION RESISTANCE

V. A. Korotkov

Plasma hardening by a standard UDGZ-200 unit makes it possible to provide not only a marked increase in steel 20Kh13 hardness and wear resistance, but also an improvement of corrosion resistance. Under experimental conditions, the corrosion resistance of steel 20Kh13 after hardening increased by a factor of 1.86, but decreased somewhat (by 15%) in the transition area to unhardened metal.
Keywords: *plasma hardening, corrosion resistance, hardness, wear resistance.*

The problem of wear resistance for machine components is important for providing guaranteed operation of equipment between repairs. It is well known that the occurrence during friction of surface activation facilitates a shift in steady-state potential into an unfavorable region and intensification of corrosion. This process in itself may be insignificant, but may considerably accelerate mechanical wear [1].

Treatment by a pulsed gas plasma of strengthened steels has a favorable effect on steel corrosion resistance in various corrosive media [2]. In this case, the intercrystalline nature of corrosive reaction shifts into frontal. A disadvantage of pulsed plasma hardening is that structural and phase modification occurs at a depth less than 20 μm, which is inadequate for operating conditions of a significant part of machine components and oil and gas equipment.

Ion bombardment in a propane atmosphere at a pressure of 80–150 Pa [3] facilitates an increase in the resistance of polished specimens of steel 12Kh18N10T to electrochemical corrosion in NaCl solution. However, for this a cell is required with a controlled atmosphere that imposes significant limitations on the prospects for industrial application of this technology.

Recently, there has been more extensive use of manual plasma hardening with a UDGZ-200 unit [4] with which at the surface of a component hardened strips are applied (~10 × 1 mm). This makes it possible to strengthen the surface where other forms of hardening are impossible to use or are difficult. The effect of plasma hardening on surface roughness is significant, which makes it possible to exclude polishing; also component tempering is not required (as with bulk hardening or HFC hardening). This considerably (by 30–40%) reduces the labor content and the cost of component preparation. The manual hardening process with a UDGZ-200 unit (in contrast to HFC hardening) is convenient for application to single and low series production, and in this case it is possible to automate or robotize. Wear resistance under dry friction conditions for corrosion-resistant chromium steel 20Kh13 as a result of plasma hardening in a UDGZ-200 unit increases by a factor of 150 [5].

The aim of this work is to study the effect of manual plasma hardening with a series standard UDGZ-200 unit on corrosion-resistant steel 20Kh13 distinguished by good wear resistance under dry friction conditions.

Materials, equipment, and research results. An economic and efficient method for evaluating resistance to corrosive breakdown is chemical and electrochemical etching [6]. For this, a specimen 30 × 50 × 500 mm in size of steel 20Kh13 was ground to Ra 0.8. By previously immersing a specimen in water to two-thirds of the specimen thickness, surface hardening was carried by the UDGZ-200 unit (according to recommendations of the unit certificate. A plasma arc was moved over the longitudinal axis of a specimen in a current of 200 A. A template was cut from the specimen with a size of 30 × 50 × 50 mm and a microsection was prepared in a transverse cut with polishing (Fig. 1) and the hardness was measured in a PMT-3M instrument (Fig. 2).

Nizhnii Tagil Branch, Ural Federal University, Nizhnii Tagil, Russia; e-mail: vk@udgz.ru. Translated from Khimicheskoe i Neftegazovoe Mashinostroenie, No. 9, pp. 45–46, September, 2017.

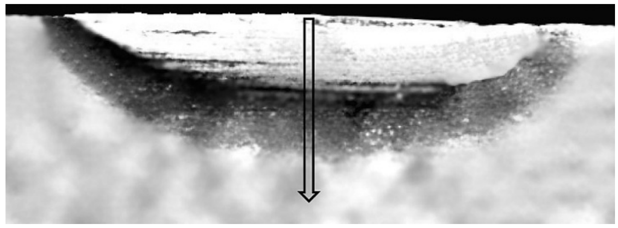

Fig. 1. Transverse microsection of template with hardened band (arrow indicates direction of microhardness measurement and roughness).

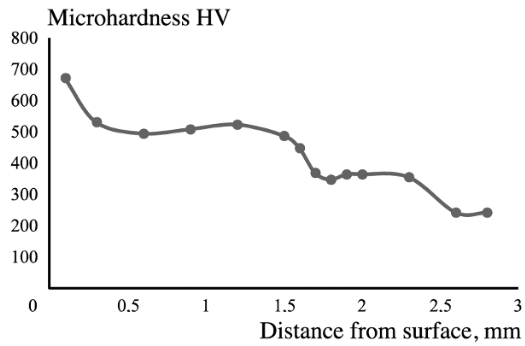

Fig. 2. Microhardness distribution through template microsection.

Unhardened areas of a microsection over both sides from the hardened strip at a distance of about 5 mm were covered with sticky tape in order to avoid electrochemical dissolution during etching. A Fronius Magic Cleaner 110B unit was used for etching.

The chemical reagent used was 20% H_2SO_4 solution in water in order to provide rapid corrosive action on a test surface. In the course of etching, the electrode holder with a plug was moved reciprocally over the microsection surface and as required reagent was fed by pressing a knob. Voltage at the electrodes in this case was ~7 V; treatment time was about 5 min; the number of double movements of the plug was 250.

Measurements with inside calipers show that the depth of etching of unhardened metal was about 150 μm. With the use of a TR-200 profilometer, the profile was determined for the etched surface and roughness was determined (Fig. 3).

Discussion of results. As a result of hardening steel 20Kh13 by a plasma arc, the microhardness increased close to the surface from 242 HV to 672 HV(see Fig. 2), and at a depth of 0.3–1.5 mm the microhardness is lower than at the surface, but also quite high, i.e., 531–487 HV, and there was total hardening. The greater microhardness value close to the surface may be explained by greater heating and as a consequence more enrichment of austenite with carbon and chromium. At a depth of 1.6–2.3 mm, microhardness decreases smoothly to the level of 448–355 HV, which is a consequence of incomplete austenitizing with decreasing heating as distance increases from the surface (correspondingly incomplete hardening). At a depth of about 2.4 mm, the metal is unhardened.

The depth of etching (see Fig. 3) corresponds to the value of microhardness (see Fig. 2). A section with the greatest microhardness (672 HV) close to the hardened surface (see Fig. 3) is hardly broken down by electrochemical action. Breakdown of a section of complete hardening (microhardness 550 HV) occurred at a depth of 70 μm (see Table 1), which is less by a factor of 1.86 than in a section of unhardened metal (130 μm). In a section of incomplete hardening (390 HV), breakdown by etching (150 μm) is more intense (by factor of 1.15 than in an unhardened section).

A reduction in etching depth for steel 20Kh13 as a result of plasma hardening points to an increase in its corrosion resistance. It is possible to explain this by a probable increase in chromium content in solid solution (as a result of dissolution

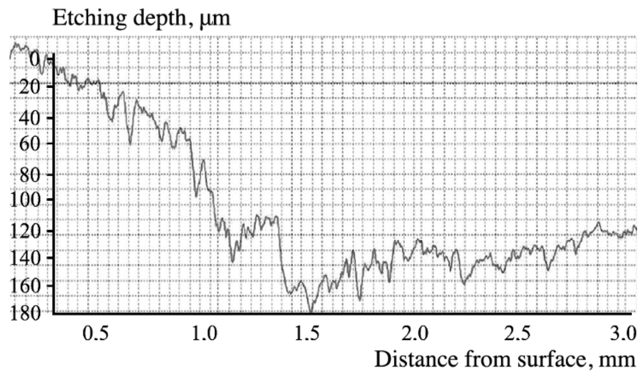

Fig. 3. Curve for microsection surface etching depth as a function of distance from the surface.

TABLE 1. Characteristics of Different Steel 20Kh13 Hardened Strip Zones (according to Figs. 2 and 3).

Parameter	Template section microsection		
	Complete hardening	Incomplete hardening	Unhardened metal
Distance from hardened surface, mm	0.2	1.6	2.8
Etching depth, μm	70	150	130
Microhardness HV	550	390	240
Roughness parameter Ra	3.6	3.0	2.0

of chromium carbide during heating). In a section of incomplete hardening, the process of carbide dissolution slows down in view of a reduction in heating temperature. In this case, there is possibly carbide coarsening, which is the most probable reason for some (by 15%) reduction in corrosion resistance.

An unexpected result is the greater roughness (Ra 3.6) of a hardened surface with respect to unhardened surface (Ra 2.0), whereas the corrosion resistance of a hardened surface is better than for an unhardened surface. Apparently, this is explained as follows. In an unhardened surface of a microsection (see Fig. 1), there are strips typical for a rolled product structure. Probably, with electrochemical etching of these strips in a hardened layer appeared more clearly, which is due to the high roughness of a hardened surface measured by the mobile profilograph feeler moving across a strip.

Conclusion. Plasma hardening with a standard UDGZ-200 unit (surface hardening method, available for extensive application) makes it possible to provide an increase in both hardness and wear resistance of steel 20Kh13, and also corrosion resistance.

Under conditions of electrochemical etching in 20% sulfuric acid solution, the depth of etching of hardened metal is less by a factor of 1.86 than for unhardened metal. In this case, in the zone of incomplete hardening between hardened and unhardened metal corrosion resistance is considerably reduced with respect to unhardened metal.

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