DOI 10.1007/s11041-022-00809-7
Metal Science and Heat Treatment, Vol. 64, Nos. 5 – 6, September, 2022 (Russian Original Nos. 5 – 6, May – June, 2022)

UDC 621.793.044:669.018.025

INVESTIGATING THE STRUCTURE AND PROPERTIES OF THE VK10KS HARD ALLOY AFTER ELECTRIC SPARK TREATMENT

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Translated from *Metallovedenie i Termicheskaya Obrabotka Metallov*, No. 6, pp. 36 – 39, June, 2022.

Original article submitted December 23, 2021.

The research investigated the structure and properties of the VK10KS hard alloy after electric spark treatment utilizing the VK6-OM alloy as an electrode in the Turbo and Norma 3 technological modes. We performed scanning electron microscopy and x-ray diffraction analysis to determine the wear resistance, nanohardness, and structure of the VK10KS alloy surface layers after electric spark processing. The study revealed a change in the phase composition of the alloy associated with the formation of ditungsten carbide W_2C, which contributed to an increase in the nanohardness of the surface layer with a thickness of 20 – 25 μm to 22,000 MPa. This change also improved the wear resistance of the alloy.

Keywords: roughness; surface hardness; microstructure; wear; hard alloy; x-ray diffraction analysis; scanning electron microscopy.

INTRODUCTION

High wear resistance is required for metal-cutting, rock-cutting, stamping, and drilling tools. At present, one of the effective ways to solve this problem is to use new types of coatings on hard alloys [1 – 5].

Until now, it has been possible to increase the service life of metalworking and medical tools, dies for cold working of metals made of structural and tool steels severalfold by applying a thin layer of coating to the surface of the product using electric spark treatment. The properties of such a coating depended on the material of the alloying electrodes. It can be assumed that there are other ways to improve the performance of the products under consideration. However, there is little information regarding this issue in the relevant literature.

This research aims to study the feasibility of hardening the VK10KS hard alloy surface by electric spark processing.

METHODS OF STUDY

Electric spark treatment of the VK10KS hard alloy surface was carried out on an UR-121 installation manufactured by the Instrument Factory of OJSC "Podolsk Concern."

The essence of this processing is as follows. During a spark discharge, the electrode is eroded, and the erosion products are transferred to the part where a surface layer is formed. This layer has a changed chemical composition and structure. The high discharge temperature (up to 10,000°C), its short duration (10^{-6} – 10^{-3} sec), and instantaneous cooling of the heated areas lead to superfast quenching after electric spark treatment. Besides, there is a drop transfer of alloying elements from the electrode to the treated surface followed by a subsequent diffusion of these elements in the layer [6].

We used the VK6-OM hard alloy as the electrode. Its chemical composition, physical, and mechanical properties correspond to All-Union State Standard (GOST) 3882–74. The method of forming a coating on a hard alloy was carried out as follows. A graphite layer was applied to the degreased surface of the VK10KS hard alloy to eliminate the formation of surface decarbonization and the embrittling η_1-phase (i.e. ditungsten carbide and cobalt Co_3W_3C) which are both unacceptable according to GOST 9391–85. Subsequently, the surface of the VK10KS hard alloy was treated with a VK6-OM electrode [6] in two technological modes: (*1*) in the Turbo mode at the rate of 1.0 min per 1 cm^2 of the treated surface; (*2*) in the Norma 3 mode at the rate of 0.55 min per 1 cm^2 + the Turbo mode at the rate of 1.0 min per 1 cm^2.

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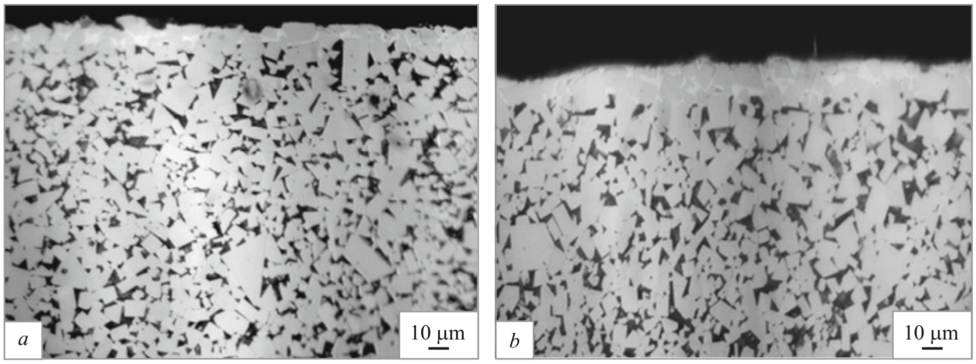

Fig. 1. The VK10KS alloy microstructure after electric spark treatment in modes *1* (*a*) and *2* (*b*).

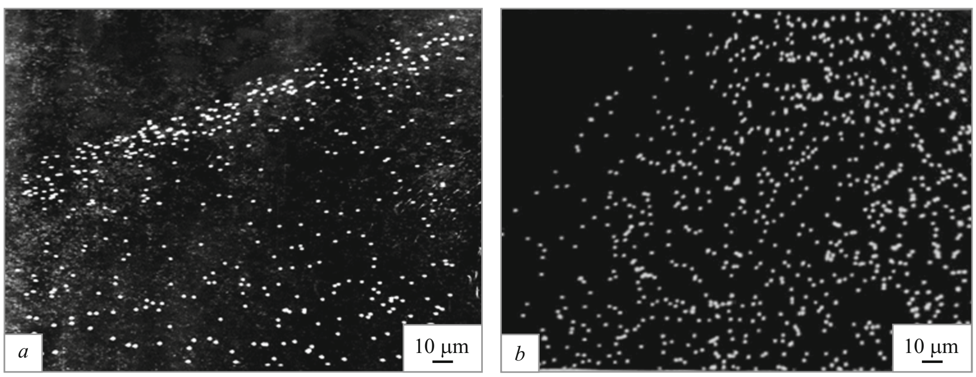

Fig. 2. The VK10KS alloy microstructure after electric spark treatment in mode *2* in the characteristic x-ray radiation of tungsten (*a*) and cobalt (*b*).

During electric spark processing according to mode *2*, it is advisable to apply a graphite layer between the layers to avoid decarbonization and the formation of the unacceptable η_1 phase [6].

The study of the structure after treatment in different modes was carried out using an OLIMPUS GX 50 optical microscope and a Philips SEM 515 scanning electron microscope.

Wear tests were performed on a PC-Operated High Temperature Tribometer. The wear of the samples was determined by measuring the depth and the track area after testing with a high precision profilometer "Micro Measure 3Dstation" with software.

RESULTS AND DISCUSSION

The metallographic investigation of the VK10KS alloy after electric spark treatment in these two modes (Fig. 1) revealed poorly etched layers of different thicknesses (10 – 25 μm) in both cases depending on the treatment time.

Using scanning electron microscopy, an increased content of tungsten and a reduced content of cobalt were identified in the surface layer (Fig. 2).

X-ray diffraction analysis showed that the electric spark processing of the hard alloy surface leads to a change in its phase composition (Fig. 3). In the initial state, two phases were found in the hard alloy: tungsten monocarbide WC and cobalt binder. After electric spark treatment, finely dispersed ditungsten carbide W_2C and carbide WC_{1-x} were additionally formed in the surface layer.

The authors of works [7 – 9] found that the formation of ditungsten carbide W_2C improves the service properties of the WC-based hard alloy since the hardness of W_2C carbide is higher than that of WC carbide.

It should be noted that the phase composition of the samples processed in two power modes is almost the same; the difference only consists in the thickness of the coatings. In this regard, all subsequent tests were conducted on samples processed according to mode *2*.

Additionally, changing the phase composition of the surface layer of the hard alloy causes an alteration in its nanohardness. Nanoindentation of the hard alloy after electric spark treatment (Fig. 4) revealed an increase in surface hardness to 22,000 MPa.

This paper presents the results of tribological tests as the arithmetic mean values of the wear profiles obtained on three samples with 10 measurements on each sample. Wear tracks were formed due to the action of a stationary diamond indenter with a load of 3 N applied to it on a sample rotating at a speed of 2.5 cm/sec. The total number of revolutions was

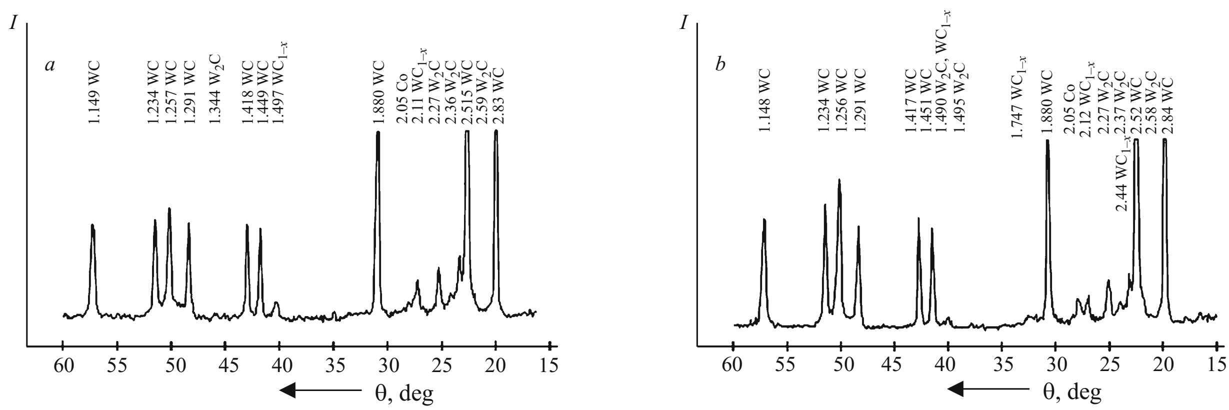

Fig. 3. Fragments of x-ray diffraction patterns of the VK10KS hard alloy after electric spark treatment in modes *1* (*a*) and *2* (*b*).

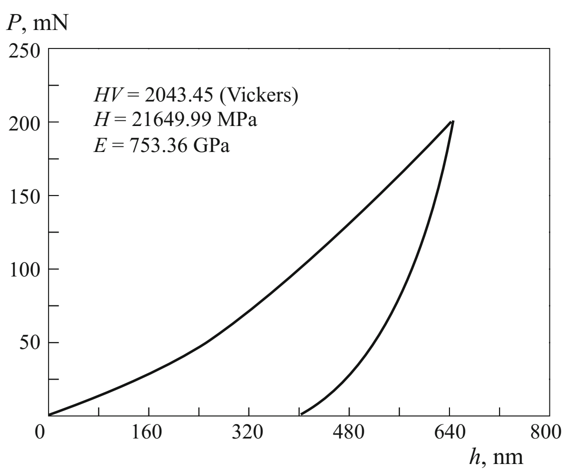

Fig. 4. Load – unload curves of nanoindentation of the VK10KS alloy after electric spark treatment (*h* is the indentation depth).

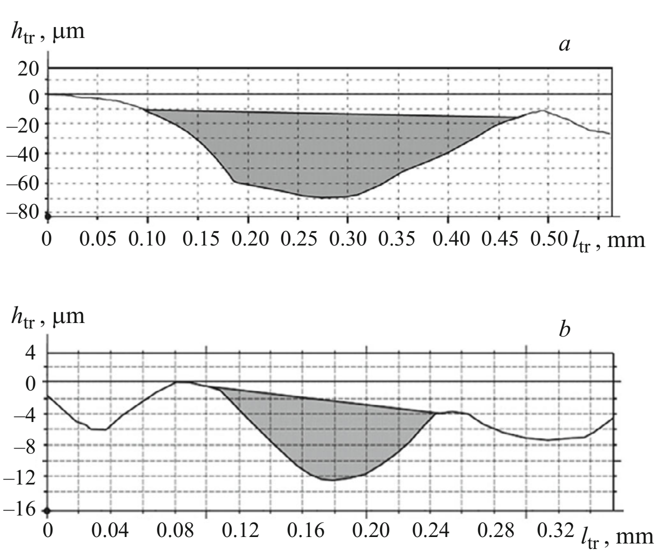

Fig. 5. Wear profiles and track cross-section areas (highlighted in gray) of the VK10KS alloy: *a*) sample in the sintered (initial) state; *b*) sample after electric spark treatment; h_{tr} and l_{tr} are the height and length of the track, respectively.

4000. For comparison, similar tests were performed on the initial samples.

Wear resistance tests have shown that the maximum track depth for alloys after electric spark processing is 10.8 μm while for the original sample it is 58 μm (Fig. 5). The wear track area of the treated alloys is 941 μm^2, while that of the untreated alloy is 12921 μm^2.

It is known that electric spark treatment of steels and alloys is accompanied by an increase in their surface roughness [10]. Therefore, this research examined the microgeometry of hardened VK10KS alloy samples using the profilometry technique and a Micro Measure 3D station profilometer. The results of the tests are presented in Table 1. The measurements were carried out on five samples. It has been established that the hardening of the VK10KS hard alloy surface by the method of electric spark processing slightly worsens the microgeometry of the surface. At the same time, it keeps it within the technical requirements with the recommended surface roughness (R_a 2.5).

The profilometric investigation of the samples (Table 1) has shown that a large increase in roughness occurs after electric spark treatment in mode *1* (Turbo). The use of a double processing mode (Norma 3 + Turbo) contributes to obtaining a lower roughness than after a single Turbo mode. Therefore, it is advisable to harden the VK10KS surface in a double mode. In this regard, the modes of a hardened layer 20 μm thick were experimentally selected (Table 2). The main criteria for selecting such a layer should be the minimum processing time and low roughness.

TABLE 1. Surface Roughness of Coatings

Treatment	R_a
Mode *1* Turbo	1.92
Mode *2* (20% Norma 3 + 80% Turbo)	2.15
Initial state	1.32

Note. 20% and 80% — the ratio of treatment durations.

TABLE 2. Coating Roughness after Electric Spark Treatment in Different Modes

Treatment		Processing time, min	R_a
Turbo	Norma 3		
40%	60%	1.55 (0.55 Norma 3 + 1.0 Turbo)	1.83
50%	50%	1.40 (0.4 Norma 3 + 1.0 Turbo)	1.87
60%	40%	1.20 (0.2 Norma 3 + 1.0 Turbo)	1.90
80%	20%	1.10 (0.2 Norma 3 + 0.9 Turbo)	2.15

Note. After all processing options, the thickness of the changed layer is 20 μm.

Electric spark processing can be used not only for surface hardening, but also for the restoration work of hard alloys after operation. This will extend the service life of products equipped with these alloys as well as save scarce materials (tungsten and cobalt) [11].

CONCLUSIONS

The results of the research enable us to conclude that using the proposed method of electric spark treatment to coat the surface of the VK10KS hard alloy makes it possible to obtain a hard-alloy plate with a gradient structure. It consists of a viscous core (VK10KS) and a hard surface layer (VK6-OM). The viscous core acts as a damper which dampens shock loads well and can withstand significant bending stresses. The surface layer has higher hardness and wear resistance than the core.

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