COMPLEX ION-PLASMA SURFACE TREATMENT OF DIE STEEL*

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The paper presents the evolution patterns of the tribological and mechanical properties of nitrided layers and nitride coatings on the surface of Cr12MoV die steel, created by the methods of ion-plasma nitriding, plasma-assisted electric arc depositing, and a combination of these methods, and also determines the optimal and efficient modes of ion-plasma treatment of die steel, which increase its wear resistance and hardness.

As a material for the study we used Cr12MoV die steel (1.45–1.65 wt.% C; 11–12.5 wt.% Cr; 0.4–0.6 wt.% Mo; 0.15–0.3 wt.% V). The samples were subjected to three types of ion-plasma treatment: 1 – nitriding; 2 – deposition of coatings, 3 – combined treatment, including nitriding and subsequent deposition of coatings. Die steel was nitrided in glow discharge plasma with a hollow cathode. High purity nitrogen and a mixture of $Ar+N_2$ gases were used as the working gas. Determination of the effect of nitrogen content in the nitrogen-argon gas mixture on the properties of the nitrided layer was carried out at the same pressure of 1 Pa for the following values of the nitrogen content in the working mixture: 100, 50, 25 and 10 %. The temperature of the samples during nitriding was 520 °C, the nitriding time was 3 h. The coatings were deposited using a plasma-assisted electric arc method on a modernized NNV 6.6-I1 device. To generate a metal plasma flow, two arc evaporators with cylindrical cathodes 80 mm in diameter made of Ti grade VT1-0 and Cr (99.8 %) were used. The source of gas plasma with a hot and hollow cathode "PINK" was used for heating steel samples and their preliminary cleaning, as well as for additional gas ionization and assistance in the deposition of coatings. All coatings were deposited at a substrate bias voltage (–) of 150 V, a substrate temperature of 390–400 °C in a nitrogen-argon gas mixture (90 % (N_2) and 10 % (Ar)) at a pressure of 0.6 Pa. Single-layer coatings of the (Ti, Cr)N system were deposited, in which the Cr content was varied by changing the current of the chromium electric arc evaporator (40, 60, 80, 100 A). Multi-layer CrN/TiN coatings, in which the thickness of each layer and the number of layers (500 nm for 8 layers, 250 nm for 16 layers, and 125 nm for 32 layers) were varied, were deposited at electric arc evaporator currents of 80 A (Ti) and 90 A (Cr). During combined treatment, nitriding was carried out in two modes: 1 – N_2 gas at a pressure of 1 Pa (samples had a "white" nitride layer) and 2 – a mixture of gases 50 % N_2 and 50 % Ar at a total pressure of 0.25 Pa (samples without nitride layer). The constant parameters in the nitriding processes were: substrate bias voltage (–) 600 V, substrate temperature 520 °C, and nitriding time 3 h. Before coating deposition, the nitrided samples were polished. The deposition of coatings on polished, nitrided samples was carried out by a plasma-assisted electric arc method using the best deposition modes in terms of tribological properties, namely, deposition of a CrN coating, a single-layer TiCrN (80/80) coating, and 32-layer CrN/TiN coating. Tribotechnical tests were carried out on a Tribotechnic tribometer under dry friction conditions with reciprocating movement of the sample relative to a counterbody in the form of an Al_2O_3 ball 6 mm in diameter. Nitriding of Cr12MoV steel in glow discharge plasma makes it possible to increase the wear resistance of the material by two orders of magnitude. The lowest wear coefficient was observed for the composition of the gas mixture N_2 (10 %) + Ar (90 %), in which there is no "white" nitride layer. The nitride layer, the main phase of which is ε-$Fe_{2-3}N$, is very brittle and during wear it breaks down and begins to act as an abrasive. It has been established that single-layer TiCrN coatings have a rather low coefficient of friction, on the order of 0.13-0.14. The most wear-resistant TiCrN coating is formed at electric arc evaporator currents of 80 A (Ti) and 80 A (Cr) and has a wear coefficient of 3.8×10^{-7} mm^3/N*m, because in this coating, the main phase is (Ti, Cr)N, a phase with a face-centered cubic lattice of the NaCl type. It is shown that changing the architecture of multilayer coatings by reducing the thickness of the layers makes it possible to smoothly reduce the wear coefficient and friction coefficient to the values of 6.8×10^{-7} mm^3/N*m and 0.28, respectively, characteristic of 32-layer CrN/TiN coating. With combined treatment, coatings deposited on steel in the initial state and after nitriding (with and without a nitride layer) have similar values of the wear coefficient. However, the results of the scratch test unequivocally show that the coatings on the nitrided layer have a significantly higher resistance to destruction, and combined processing is most appropriate in cases where high loads are applied to the surface of the stamping tool.

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