ANNOTATION

dissertation for the degree of Philosophy Doctor (PhD)
6D072300- Technical Physics

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Electrolytic-plasma nitriding of the high-speed steels surface layers

Work actuality. As you know, one of the most important problems of modern engineering is to provide maximum resistance to wear metal-working tools. Durability of the tool depends largely from the surface's properties. Recently, due to the application of protective coatings and surface hardening, high-speed steels is more used and manufactured, thereby reducing the costs of expensive hard alloys. To increase the tool life of high-speed steels processes of chemical and thermal processing are widely used, in particular nitriding. Nitriding in plasma electrolyte is the most promising resource-saving method, which allows to intensifying the saturation process. In this regard, the improvement of traditional methods and the development of the new ways of electrolyte-plasma nitriding to improve the wear-resistance of high speed steels and the structural and phase states responsible for the tribological characteristics of nitrided layers, it is actual problem.

The object of study is the electrolyte-plasma nitriding technology and R6M5, R9 and R18 instrumental high-speed steels, after subjecting to the standard thermal processing for these steels.

The aim of the work is to develop a resource-saving method for electrolyte-plasma nitriding of high-speed steels and to study the effect of electrolyte-plasma nitriding on the structural and phase states and the tribological properties of the surface layers of high-speed steels.

To achieve the aim in the dissertation following **objectives** were solved:

- Explore the features of the formation of low-temperature plasma and the formation of modified layers in high-speed steels during electrolytic-plasma nitriding in the carbamide-based electrolyte;
- Develop a method for the cathode electrolytic-plasma nitriding of high-speed steels in the carbamide-based electrolyte, which will improve the tribological properties of the surface of steel;
- Determine experimentally the relationship between the parameters of the nitriding and structural-phase state of the nitrided layer of high-speed steels;
- Investigate the effect of electrolyte-plasma nitriding on the microhardness, red hardness and wear-resistance of the surface of R6M5, R9 and R18 high-speed steels;
- Establish correlations between the features of the structure and phase composition of the nitrided layer with the tribological properties of nitrided high-speed steel;
- Develop a hardening process of cutting tools made from high-speed steels by electrolyte-plasma nitriding in the carbamide-based electrolyte.

Research methods. In this work, to study the structural and phase states of the nitrided layer following the classical methods of experimental research were applied: metallographic analysis, scanning and transmission electron microscopy, X-Ray analysis. Tribological and mechanical properties of the nitrided layer were by measuring the microhardness and red hardness, wear-resistance determined by "ball-on-disk" and "pin-on-disk" tests, and by the scratch test, and tests for abrasion.

Scientific novelty of the work: firstly systematic experimental data's of electrolytic-plasma nitriding effect on the structure, phase composition and tribological properties of the surface layer of high-speed steels are obtained. To improve durability, a new high-speed steel nitriding method is developing, it's including surface saturation with nitrogen by electrolyte-plasma influence in the electrolyte from an aqueous solution containing 20% carbamide and 10% sodium carbonate in the two-stage electrolyte-plasma heating at a cathode mode. It is found that after electrolyte-plasma nitriding of the high-speed steels at 550°C, a modified surface layer is formed consisting of a nitrided α'-phase with fragmented substructure, excess γ'-phase particles and fine chromium nitride, which is durable and firm.

The main provisions for the defense:

1. Resource-saving method of the electrolytic-plasma nitriding of high-speed steels at the cathode mode, which is surface intensive saturation to nitrogen by carbamide-based electrolyte influence in the low temperature plasma. Thus the process of diffusion saturation intensifies by low-temperature plasma. Preparation of low-temperature plasma at voltages of 180-200 V, provides a reduction in energy intensity of the process. The use of carbamide-based electrolyte makes modification environmentally safe. In general, the developed method allows obtaining a modified surface layer with high tribological characteristics.

2. The regularities changes in structural and phase states of the modified surface layer of high-speed steel, depending on the nitriding temperature. The modified layer is formed after electrolyte-plasma nitriding at 450°C, composed of α'-phase ($Fe_{\alpha\,(N)}$) and carbides, γ'-phase (Fe_4N) particles is formed in the modified layer during nitriding temperature increasing from 450°C to 500°C, and fine particles of chromium nitride (CrN) is formed at 550°C nitriding temperature.

3. Installed basic mechanisms to ensure high wear-resistance of the surface layer of high-speed steels, nitrided by electrolytic-plasma method.

Scientific and practical significance of the research. The obtained results of theoretical and experimental studies provide new, deeper understanding of the modified surface layer formation process in alloy steels during electrolytic-plasma nitriding, its structure, composition and properties. In addition, the laws governing the formation of modified layers in high-speed steels during electrolyte-plasma nitriding identified in this work can be used by researchers in selecting modes of electrolytic-plasma processing of alloy steels, as well as the analysis of the structural transformations of high-speed steels.

This work is of practical importance, because the developed method for electrolytic-plasma nitriding provides a modified surface layer on the high-speed steels with high physical and mechanical properties. Implementation of the developed method, increasing the tools durability (resource), in mechanical engineering

provides techno-economic and ecological effect through the use of simple equipment, not expensive and environmentally sound electrolyte based on urea, reducing the duration of saturation process, improve the productivity and reduce the environmental load environment.

Publications. Main scientific results of the dissertation were published in 21 publications, including 4 scientific journals recommended by the Committee for control in the field of education and science MES RK, in 3 international scientific journals included in the Scopus database, 10 in materials of international conferences, including 6 in the materials of foreign conferences. As well as the results of the dissertation received 3 innovative patents for inventions and one utility model patent.

The structure and scope of the dissertation. The work consists of an introduction, five chapters, conclusion and list of references. It is stated on 144 pages, contains from 74 drawings, 14 tables and a list of references with 202 sources.