FORMATION OF WEAR-RESISTANT VACUUM-PLASMA COATINGS TO INCREASE THE DURABILITY OF AGRICULTURAL MACHINERY PARTS

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Abstract: *This paper examines the formation of wear-resistant vacuum-plasma coatings to increase the durability of agricultural machinery components. The influence of process gas composition and pressure, surface temperature, and ion energy on the phase composition, structure, and morphology of multicomponent coatings is analyzed. It is shown that regulating the plasma flow and process environment parameters allows for the formation of a protective layer and its performance characteristics to be controlled. The findings can be used to select the composition and application modes of coatings for components subject to intense wear.*

Key words: *agro-industrial complex, agricultural machinery, vacuum-plasma coatings, PVD, wear resistance, protective coatings, multicomponent systems, process gas, structure, nitrides.*

The reliability of agricultural machinery is largely determined by the longevity of its components, which are subject to abrasive wear, impact loads, contamination, and variable operating conditions. One promising method for increasing service life is the application of vacuum-plasma multicomponent coatings, which form a hard protective layer without significantly altering the component's dimensions. The effectiveness of this process is determined by the condensation conditions of a highly ionized plasma flow.

The aim of this work is to develop theoretical understanding of the mechanisms underlying the structure formation of multicomponent vacuum-plasma coatings in the

presence of a process gas. Coatings of the following types are considered: (Ti,Al)N, (Ti,Si)N, (Al,Si)N, Al2O3, and ZrO2+Y2O3. Nitrogen, oxygen-argon, and nitrogen-acetylene mixtures can be used as process media.

Gas components interact with plasma flow particles in the condensation zone, altering the phase composition and structure of the layer. Therefore, gas composition and pressure are important tools for controlling the coating properties.

When forming nitride coatings, increasing the partial pressure of nitrogen promotes an increase in the nitrogen content in the layer and more intense metal-nitrogen reactions, which is theoretically associated with increased coating hardness. However, excessive pressure increases reduce the mean free path of particles and alters the conditions for plasma material transfer to the surface. Therefore, the process conditions must ensure a compromise between the participation of the reaction gas in phase formation and the efficient delivery of a high-energy flux.

The coating structure is formed under the influence of surface temperature and ion energy. Vacuum condensates are characterized by conical and columnar structures. In multicomponent systems, the redistribution of components at the growth front is of additional importance.

Changes in interfacial conditions affect the mobility of adsorbed atoms and can lead to the formation of interlayers and a striated structure. Thus, the chemical composition, process gas pressure, surface temperature, and ion energy collectively determine the final morphology of the protective layer.

For the agro-industrial complex, the practical value of the approach discussed lies in the ability to scientifically substantiate the selection of protective coating application modes for agricultural machinery parts.

Managing the structure of a multi-component coating allows for targeted increases in the hardness and wear resistance of working surfaces. The resulting principles can serve as a theoretical basis for further selection of the composition and process parameters of wear-resistant coatings to extend the service life of agricultural machinery parts and components.

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