Rzeszow University of Technology Rzeszow, 2026

The Faculty of Mechanical Engineering and Aeronautics

Abstract of doctorate thesis

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Abstract The doctoral dissertation concerns the tailoring of the tribological properties of technological tooling made of tool steels through the application of thermochemical treatment processes and hard coatings. The research included boride layers produced using paste and powder boriding methods, plasma-nitrided layers, TiN coatings deposited by chemical vapour deposition (CVD), and hybrid DUPLEX systems incorporating TiAlN coatings deposited by physical vapour deposition (PVD). The experimental investigations were conducted on laboratory specimens as well as on actual technological tooling, specifically sizing dies, which enabled the assessment of the applicability of the investigated technologies under semi-industrial conditions. The research programme included the analysis of microstructure and chemical composition using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS), phase identification by X-ray diffraction (XRD), microhardness measurements, and the assessment of tribological behaviour and coating adhesion using scratch testing. The research programme also included an assessment of the effects of the chemical composition of the steel and technological process parameters on the formation and properties of the resulting surface layers. The investigations of boride layers demonstrated a significant influence of the steel grade and boriding method on their microstructure, phase composition, and thickness. Depending on the process conditions, single-phase Fe_2B and two-phase FeB–Fe_2B layers were obtained. The analysis of boride layer growth kinetics revealed differences in the growth rates as a function of the chemical composition of the steel. The feasibility of performing the boriding process using a mixture of fresh and once-used EKABOR II powder was also demonstrated. However, the results obtained do not provide a sufficient basis for the quantitative determination of the effect of powder reuse on the growth kinetics of the boride layers. Plasma nitriding enabled the formation of diffusion layers characterized by a gradient distribution of microhardness, without the formation of a distinct and continuous compound layer. The results of the microstructural, phase composition, and microhardness profile analyses indicated that the obtained diffusion layer may serve as

a substrate for hard PVD coatings. In DUPLEX systems, the application of plasma nitriding as a preparatory treatment prior to PVD coating deposition resulted in a multilayer structure in which the diffusion layer provides mechanical support for the outer coating, while the PVD coating primarily governs the surface and tribological properties. Investigations performed on actual technological tooling confirmed the technical feasibility of applying such a technological sequence to components with 10 geometries representative of industrial tooling. At the same time, the results indicate the potential of DUPLEX systems for tooling applications; however, their unequivocal superiority in terms of service life requires further direct comparative investigations conducted under identical operating conditions. The obtained results confirmed that the microstructure, phase composition, and functional properties of the investigated layers and coatings depend on the applied surface engineering technology, the chemical composition of the substrate, and the process parameters. The research enabled the identification of relationships between the manufacturing conditions, surface layer structure, and resulting properties. The results also confirmed the possibility of tailoring the functional properties of technological tooling through the appropriate selection of surface engineering technologies.

Keywords: tribology, boriding, plasma nitriding, CVD coatings, DUPLEX systems, tool steel.