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A Comparative Study of the Tribological Behavior of Bilayer Coatings for Machine Protection

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Abstract : During their lifetime, industrial machines are often subjected to chemical, mechanical and thermal extreme conditions. In some cases, the loss of efficiency comes from the degradation of the surface as a result of its exposition to abrasive environments that can cause wear. This is a common problem to be solved in industries of diverse nature such as food, paper or concrete industries, among others. For this reason, a good selection of the material is of high importance. In the machine design context, stainless steels such as AISI 304 and 316 are widely used. However, the severity of the external conditions can require additional protection for the steel and sometimes coating solutions are demanded in order to extend the lifespan of these materials. Therefore, the development of effective coatings with high wear resistance is of utmost technological relevance. In this research, bilayer coatings made of Titanium-Tantalum, Titanium-Niobium, Titanium-Hafnium, and Titanium-Zirconium have been developed using magnetron sputtering configuration by PVD (Physical Vapor Deposition) technology. Their tribological behavior has been measured and evaluated under different environmental conditions. Two kinds of steels were used as substrates: AISI 304, AISI 316. For the comparison with these materials, titanium alloy substrate was also employed. Regarding the characterization, wear rate and friction coefficient were evaluated by a tribo-tester, using a pin-on-ball configuration with different lubricants such as tomato sauce, wine, olive oil, wet compost, a mix of sand and concrete with water and NaCl to approximate the results to real extreme conditions. In addition, topographical images of the wear tracks were obtained in order to get more insight of the wear behavior and scanning electron microscope (SEM) images were taken to evaluate the adhesion and quality of the coating. The characterization was completed with the measurement of nanoindentation hardness and elastic modulus. Concerning the results, thicknesses of the samples varied from 100 nm (Ti-Zr layer) to 1.4 µm (Ti-Hf layer) and SEM images confirmed that the addition of the Ti layer improved the adhesion of the coatings. Moreover, results have pointed out that these coatings have increased the wear resistance in comparison with the original substrates under environments of different severity. Furthermore, nanoindentation hardness results showed an improvement of the elastic strain to failure and a high modulus of elasticity (approximately 200 GPa). As a conclusion, Ti-Ta, Ti-Zr, Ti-Nb, and Ti-Hf are very promising and effective coatings in terms of tribological behavior, improving considerably the wear resistance and friction coefficient of typically used machine materials.

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