Chapter 10
Investigation on the Wear Resistance of Ni-B-TiO2 Composite Coatings for Dry Crushing Application

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ABSTRACT

To achieve a more important service life of hammers, used in crushing process, a Ni-B-TiO2 composite coating was electrodeposited on heat treated AISI P20 using conventional and novel methods. The prepared coatings underwent different tribological tests to quantify the coating that offers the best resistance against wear. For this reason, abrasive wear tests such as pin-on-disk test and multi-pass scratch test were performed to evaluate the abrasive wear resistance of the coatings under a round counterbody (alumina ball) and a sharper contrerbody (sphero-conical indenter), respectively. In addition, the impact-sliding test was also performed to assess the impact resistance of the composite coatings. The obtained results showed that the novel method promotes the best mechanical and tribological properties of the elaborated Ni-B-TiO2 composite coating. This is attributed to the fact of adding TiO2 sol into Ni-B electrolyte which enhances the dispersive strength of the formed TiO2 nanoparticles, contrary to adding solid TiO2 nanoparticles into the electroplating bath.

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INTRODUCTION

The wear represents a serious issue in many industries in various fields, especially the one using crusher machines (food industries, mineral industries, automotive and aerospace companies). Different components of crushers are exposed to severe erosion. For example, in the olive oil extraction industry, the hammers of the crusher, made of 304L stainless steel, underwent premature damage in three weeks. Based on expert study, the researchers have found that the wear phenomenon originated from the acidity and the continuous impact of olive sides on hammers, leading mainly to a corrosive and erosive wear (Ben Saada & Elleuch, 2015; Bahri et al., 2015) respectively. Furthermore, during the coke process in steel manufacturing, the repetitive impact of coke particles provokes a serious wear of hammers. The latter are made of austenitic manganese steel and have lost a weight of 5Kg within only 8.5 hours (Kallel et al., 2017). To reduce this damage, multiple attempts and solutions have been proposed and studied. Some industries have chosen to change either the material or the design of the hammer while others decided to keep the base material of the hammer, focusing their studies on enhancing its mechanical properties. This could be done by strengthening its working surfaces through a heat treatment technique or by a coating deposition process.

Metal alloy coatings were intensively elaborated to confer on the surface of a sample some required properties such as decorative aspects, corrosion protection and engineering properties. In some cases, this coating does not satisfy the properties in question, which is why composite metallic coatings are performed to enhance the performance of pure films. This includes higher physical properties (thermal and electrical conductivity), better corrosion resistance and particularly significant mechanical properties. The combination between ceramic particles (Al_2O_3, TiO_2, ZrO_2 SiC, WC, etc.) and a metal or polymer matrix favors a synergy impact on the surface of the target material. In this respect, the use of composite coatings has progressively interested academics and professionals in medical, engineering and industrial applications.

Furthermore, many researchers have proven that introducing particles, especially nano-particles, in a metallic matrix enhances the mechanical properties, the wear performance and the self-lubricating characteristics of the target material (Shen et al., 2013). As tribology science is interested in interacting surfaces in relative contact, nanoparticles act as a lubricant to release the contact between the surfaces in relative motion. This, in turn, favors a higher wear resistance of the material. For instance, in automotive applications such piston rings and cylinder nanoparticles prove their central role in raising the lubricant behavior by the formation of tribofilms, which consequently reduces friction and wear (Singh et al., 2018). It has been reported that the beneficial effects of nanoparticles on metallic matrices are attributed to three important reasons. First, the nanoparticles can prevent the migration as well as dislocation of the grain boundaries. Second, introducing nanoparticles in a metallic coating decreases its porosity, leading to a more compact and dense structure with less cracks. Third, the crystalline size of the metallic coating can be refined thanks to the code-position of nanoparticles (Singh et al., 2018).

As regards this work, mineral industries suffer from wear occurring in various machines and more particularly in hammer crushers. In this context, an industry operating on crushing mineral rocks encountered premature wear in hammers of barite rock crusher (Kallel et al., 2017). Therefore, the dysfunction of the crusher causes a larger downtime in the industry, resulting in an important financial loss. The brittleness of the hammer material (High chromium cast iron ‘HCCI’) and the sharpness of the barite rocks are responsible for the hammer premature wear according to an expert study. As a matter of fact,

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