Optimization of Friction and Wear Properties of Electroless Ni-P-Al2O3 Composite Coatings

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ABSTRACT

Electroless Ni-P coatings with hard Al2O3 composite particles are developed on mild steel specimens. The coating parameters viz. source of nickel ions, concentration of reducing agent and concentration of Al2O3 particles are used as coating parameters to minimize wear rate (wear depth in µm) and friction coefficient. As annealing temperature strongly affects hardness and wear resistance of coating, it is considered as fourth parameter. In the present study wear depth and friction coefficient are used as response variables. To convert multiple responses into single performance index, Weighted Principal Component Analysis (WPCA) is used. Taguchi L27 OA with four process parameters at three levels is used to conduct the experiments. ANOVA is used to find out the significance of each coating parameters and their interactions. Annealing temperature is found to be the most significant factor followed by concentration of composite particles. The surface morphology, composition and phase structure analysis are done with the help of SEM, EDAX and XRD respectively.

Keywords: Electroless Coating, Friction, Ni–P–Al2O3, Optimization, Wear, Weighted Principal Component Analysis (WPCA)

INTRODUCTION

In industries machine components, tools and other equipments are mostly related to sliding and rolling type of motion in between them. In such situations the components or tools may be failed due to lower hardness and wear resistance. Hence it is essential to improve the hardness, wear resistance and frictional resistance of said components to increase their life. In present days coating plays vital role in surface engineering techniques, as these are well suitable for excellent wear resistance, frictional resistance, erosion, corrosion resistance and higher hardness instead of protecting the base metal from environmental changes. Electroless coating or autocatalytic coating is defined as the deposition of a metallic coating by a controlled chemical reduction that is catalyzed by the metal or alloy being deposited. Unlike electroplating, it is not necessary to pass an electric current through the solution to form a deposit. The main advantages of these coatings are, these are having uniform and smooth thickness irrespective of complicate

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shape and sharp edges of base metal and it can be possible to coat nonferrous or electrically non conductive material. This process depends on the existence of a reducing agent, which reacts with metallic ions to deposit metal. When the substrate is dipped in the electroless bath, it develops potential. Due to this negative and positive ions are attracted towards the surface of the specimen and release the energy charge transfer process. Electroless bath consist of source of metallic ions, source of reducing agent, complexing agent, wetting agent, stabilizer, and pH controlling agent. The electroless Ni-P coating having more than 7% phosphorus has an excellent corrosion resistance. Therefore these coatings are used in industries which have corrosive environment like as mining, chemical, textile, oil and gas etc. Similarly the composite coating made by using hard/soft particles are having higher hardness, corrosion resistance, wear resistance and frictional resistance, hence these are widely used in variety of industries like as chemical, automobile, textile, mechanical and aerospace etc. (Balaraju et al., 2003). Basically electroless coating are classified into four group viz., alloy and poly alloy coatings, composite coatings, nano coatings and pure nickel and black coatings (Sudagar et al., 2013).

Electroless nickel composite coatings are formed by incorporating fine inert soft/hard particles into electroless nickel coatings. In these coatings second phase particles are appropriately wrapped by Ni-P layer during metal deposition process. Soft particles like as PTFE, MoS₂, HBN, and graphite are strongly recommended for composite coatings which are having higher corrosion resistance and lubricity. Whereas hard particles SiC, WC, Al₂O₃, Si₃N₄, CeO₂, TiO₂, ZrO₂, and diamond etc. are recommended to increase the hardness, wear resistance, corrosion resistance, and frictional resistance (Sharma and Singh, 2013). In fact the properties of electroless nickel composite coating are depending on amount of hard/soft particles embedded in the coating. To obtain excellent properties of composite coatings, the second phase particles must be uniformly distributed during deposition process otherwise due to non-uniform distribution of particles numerous defects are formed owing to segregation and agglomeration of composite or nano particles in the electroless bath (Sahoo and Das, 2011). After heat treatment at 400°C or more for one hour, the mechanical and tribological properties of composite coatings are improved impressively (Apachitei et al., 2001). Compare to various hard particles available for composite coating, Al₂O₃ is the most important due to its high elastic modulus, strength retention at high temperature, and high wear resistance (Abdel Aal et al., 2007). By and large, the existence or availability of composite particles in the electroless Ni–P composite coatings depends on impingement of particles and their holding time on the on the surface of the coating (Balaraju et al., 2006). Alirezaei et al. (2004) have found that the deposition rate, deposition percentage of particles, roughness and hardness of Ni–P–Al₂O₃ composite coatings depend on the concentration of alumina particles in the electroless bath and also confirmed that hardness and average roughness are increased with Al₂O₃ particles content.

Ramesh et al. (2010) have performed experiments by using pin-on-disc tribotester to know the tribological performance of Ni-P-Si₃N₄ composite coating and result show that composite coating had minimum wear rate and lower friction coefficient over a load range of 20-100N and sliding velocity in the range of 0.31-1.57 m/s. Ramalho and Miranda (2005) have found that wear resistance of Ni-P-PTFE composite coating increased significantly in the presence of PTFE particles in the Ni-P matrix. Similarly Chen and Hon (2002) have observed significant improvement in wear resistance of Ni-P-SiC composite coating due to incorporation of SiC particles into electroless Ni-P interlayer. Chen et al. (2006) have notice that Ni-P-MWNTs composited coating revealed lower wear rate and friction coefficient compared to Ni-P-SiC composite coating. Apachitei et al. (2002) have found that phosphorus content and heat treatment strongly influenced the structure and abrasive property of the alloy and composite coatings and also concluded that due interac-
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