Taguchi -Grey Based Optimization of Friction and Wear of Electroless Ni-P Coatings in Acidic Environment

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ABSTRACT

The present study describes the synthesis of electroless Ni-P (nickel-phosphorous) coatings on mild steel substrate and optimization of the coating process parameters for minimum friction and wear in acidic (1M H₂SO₄) solution using Taguchi based grey relation analysis. The study is carried out using different combinations of four coating process parameters, namely, concentration of nickel source, concentration of reducing agent, deposition temperature and annealing temperature with three levels each. The tribological tests are conducted with a pin-on-disk tribometer. Analysis of variance reveals that annealing temperature has the maximum contribution in controlling the friction and wear characteristics of Ni-P coating. The coating is characterized using scanning electron microscopy, energy dispersive X-ray and XRD analysis, respectively. It is found that Ni-P coating is amorphous in as-deposited condition but gradually turns crystalline with heat treatment. Moreover the wear mechanism is found to be abrasive in nature.

Keywords: Acidic Environment, Electroless Ni-P Coating, Optimization, Taguchi-Grey, Tribological Characteristics

INTRODUCTION

Most of the engineering components undergo rubbing action due to which wear takes place on the surface of the components and become useless after a certain period. Life and performance of these engineering components can be extended by applying hard coatings over the surface of the components. Among the various metallic coating method based on aqueous solutions, most of metals are electroplated since electroplating is technically straightforward and cheap than electroless deposition. Though, the importance of electroless deposition in industrial application can’t be denied mainly for copper, nickel, and some nickel based alloys. The electroless plating deposition was introduced by Brenner and Riddell (1946, 1950). Electroless
Ni-P (EN) coating is an autocatalytic deposition of a Ni-P alloy from an aqueous solution onto a substrate without the application of electric current. It has got the ability to deposit uniformly on uneven surfaces or geometries. It provides a deposit that follows all the contours of the substrate without building up at the edges and corners (Riedel, 1991). EN coatings have found extensive use in surface engineering due to their excellent mechanical, physical, electrical, corrosion and tribological properties (Sahoo & Das, 2011; Sudagar, Lian & Sha, 2013; Agarwala & Agarwala, 2003). Electroless nickel coatings are used in different areas such as aerospace, aviation, automotives, oil and gas processing, food processing, microelectronics, radio electronics, computer engineering, chemical processing, textiles, machinery, mining and metallization of plastic etc (Sahoo, 2008). The mechanical and tribological properties of EN coatings can further be improved by the incorporation of hard particles, heat treatment (Ashassi-Sorkhabi & Rafizadeh, 2004; Keong, Sha & Malinov, 2002) and dry lubricants (Straffelini, Colombo & Molinari, 1999; Zhao, Liu, Muller-Steinhagen & Liu, 2002; Huang, Zeng, Annergren & Liu, 2003). The properties and microstructures of EN coatings depend on the amount of phosphorous alloyed in the deposit (Hur, Jeong & Lee, 1990). EN coating provides natural lubricity due to the presence of phosphorous content and it is further improved by annealing (Ramalho & Miranda, 2005; Novak, Vojtech & Vitu, 2010). Heating the coating at 400°C for 1 h, results in highest hardness (Staia, Castillo, Puchi, Lewis & Hintermann, 1996; Wang, Gao, Xu & Xue, 2006). As harder materials generally encounter lesser wear, heat treated EN coatings are found to be more wear resistant than the as deposited ones. EN coating is also found to be good anti-corrosive properties due to the present of phosphorous content (Bai, Chuang & Hu, 2003; Nava, Davalos, Martinez-Hernandez, Manriquez, Meas, Ortega-Borges, Perez-Bueno & Trejo, 2013). Anti-corrosive properties of EN coating increase with increase in phosphorous content (Bigdeli & Allahkaram, 2009). In present day, EN coatings are widely used for corrosion protection application in a variety of environments viz. marine applications, mining industry, mineral processing, chemical industry, petrochemical industry, slurry handling and chlor-alkali industry etc. They act as barrier coatings, protecting the substrate by sealing it off from the corrosive environments, rather than by sacrificial action. However, only EN coating with high P coating is found to offer excellent protection against corrosion (Sankara Narayanan, Baskaran, Krishnaveni & Parthiban, 2006; Gawrilov, 1979). Due to the dynamics involved, these machineries would require protection against both wear and corrosion simultaneously as they undergo tribo-chemical interactions. Wide application of EN coating was used as corrosion resistance materials in acidic environment (Parkinson, 1997; Mallory & Hajdu, 1990), especially in chemical and petrochemical industries.

The present studies consider friction and wear characteristic of the EN coating in 1M H₂SO₄ solution and optimization of coating process parameter for minimum friction and wear based on taguchi methodology coupled with grey relational analysis. The microstructure, composition, phase structure and wear behaviour are studied with the help of scanning electron microscopy, energy dispersed X-ray analysis and X-ray diffraction analysis.

TAGUCHI METHOD AND GREY RELATION THEORY

Taguchi introduced the Taguchi technique and since then it has been widely used in the engineering domain to get the desired performance characteristics by optimizing the design parameters. Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments. The greatest advantage of this method is the saving of effort in conducting experiments; saving experimental time, reducing the cost, and discovering significant factors quickly. Now, Taguchi method arrives at optimality by the use of robust parameter design. Robust parameter
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