Tribological Behavior of Electroless Ni-P, Ni-P-W and Ni-P-Cu Coatings: A Comparison

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ABSTRACT

The present paper considers the comparative study of tribological characteristics of various electroless alloy coatings viz. Ni-P, Ni-P-W and Ni-P-Cu. The tribological behavior of these coatings depends on various parameters like load, speed, lubricant, chemical compositions and heat treatment temperature to a great extent. One of the main effects of heat treatment on these coatings is phosphide precipitation, which makes them suitable for anti-wear applications. The property of binary Ni-P can be further improved by depositing third particles electrolessly. The phase structure of the coatings depends on the amount of phosphorous and heat treatment temperature. The tribological behavior of heat treated samples reveals that Ni-P-W deposit shows higher coefficient of friction and lowest wear among these three types coatings. Very high tungsten concentration retard the phosphide precipitation, thus low concentration of tungsten and low heat treatment temperature produce better coating. In case of Ni-P-Cu, medium concentration of copper and medium heat treatment temperature produces better coating.

KEYWORDS
Electroless, Friction, Ni-P, Ni-P-Cu, Ni-P-W, Wear

INTRODUCTION

Since the inception of EN coatings, the properties and structures of such coatings have received considerable research attention. Nickel–phosphorus (Ni–P) and Ni–P–X (X–hard particles) coatings produced by electroless technique tend to be extensively used as wear resistant materials (Sahoo & Das, 2011; 2015; Gadhari & Sahoo, 2016; 2015; 2014; Panja & Sahoo; 2015; 2014a; 2014b; Kundu, Das & Sahoo, 2014; Sudagar, Lian & Sha, 2013). The electroless Ni–P based composite coatings possess better wear resistance than Ni–P alloy coatings (Balaraju & Seshadri, 1999). However, due to the complexity of the structure, wide variety of wear apparatus, loading conditions, environment during the wear tests, substrate and counter face material used, consolidation of the vast knowledge on wear of electroless coatings is difficult. The friction and wear behaviour of electroless composite coatings has yet to receive adequate attention from research community to fully exploit the potential it contains. It is, in general, observed that the friction coefficient of EN coating decreases with increase in load. The friction study of EN coating concluded that coatings with high phosphorus content
have higher friction coefficient than comparing to medium or low phosphorus electroless coatings (Taheri, Oguocha & Yannacopoulos, 2001). The friction coefficient was found to be within the range of 0.15–0.35 when tested under the 15-60N loading conditions and the friction coefficient of electroless coatings having 6–7% phosphorous content when tested under low loads was found to be as high as 0.7 (Staia, Castillo, Puchi, Lewis & Hintermann, 1996). It has been experimentally observed that regardless of phosphorus content, the composite coatings are more wear resistant, than basic Ni–P alloy as a consequence of high hardness of the co-deposited particles. Balaraju and Seshadri (1999) developed electroless Ni–P coating by an acidic hypophosphite-based bath to produce 10–12% P in the electroless nickel coating. The wear resistance of the samples, in as-deposited and heat-treated (at 400°C for 1 h) conditions are assessed using a disc-on-disc method under un-lubricated sliding conditions for 30min. The counter disc, of diameter 35mm, was made from heat-treated high-carbon, high-aluminium steel having 60 HRC hardness value. Forces of magnitude 20, 40 and 60N have been used against the test disc specimen which was rotated at 1000 rpm. Substantially low specific wear rate of electroless Ni–P in heat-treated condition is observed when compared to that with as coated samples, which is considered to be due to very low mutual solubility of nickel phosphide and iron thus presenting a relatively incompatible surface. The effect of temperature on wear of as-deposited electroless Ni–P coating under lubricated reciprocating sliding conditions are investigated using the ball-on-block test method (Yugang & Tandon, 1996). The studies reveal that the temperature increase from 25 to 100°C reduced the lubricated wear coatings, especially at higher loads. The wear mechanism also changes as temperature rises to 100°C. Higher sulphur and phosphorus contents on the wear track at high temperature reduce friction and wear of the electroless coating. Sahoo and Pal (2007) studied the impact of tribological testing parameters on Ni-P coating and observed that all the three test parameters i.e., load, speed and time have significant influence on friction and wear behavior at the confidence level of 99% within the specific test range. The interaction of load and time is also significant at the confidence level of 99%.

The incorporation of additional metal elements into the electroless deposits can be an important means of enhancing the range of chemical, mechanical, physical, magnetic, and other properties attainable. A number of alloys can readily be deposited by combining metals that are independently deposited electrolessly from similar baths; an example being nickel and cobalt from alkaline hypophosphite solutions. Also, and more importantly, certain metals that cannot themselves be deposited by the autocatalytic mechanism can be induced to co-deposit with an electrolessly depositing metal. Several ternary alloy coatings such as Ni-Cu-P (Abdel Aal & Shehata Aly, 2009; Liu & Zhao, 2004), Ni-Fe-P (Wang, 2004), Ni-Zn-P (Ranganatha, Venkatesha & Vathsala, 2010), Ni-W-P (Balaraju, Anandan & Rajam, 2005; Balaraju & Rajam, 2005; Roy & Sahoo, 2013), Ni-Co-P (Abdel Aal, Shaaban & Abdel Hamid, 2008) has been studied by researchers. This present work aims at comparative study of the tribological characteristics of electroless binary Ni-P, ternary Ni-P-W and Ni-P-Cu alloy coatings.

**EXPERIMENTATION**

Square shaped Mild steel specimen of size 20mm × 20mm × 8mm is used as specimen for the deposition of coatings. This particular dimension of the substrate is chosen in accordance with its counterpart in the multi tribotester apparatus where the sample has to be fitted for tribological testing. Shaping parting and milling operation is performed sequentially to prepare the specimens from the raw material. Finally surface grinding process is employed to make the surface of the blocks smooth enough because the tribological characteristics of a surface may depend on its surface roughness. Now, as electroless nickel coatings generally follow the surface profile of the substrate, the prepared substrates in the present study should have similar surface roughness. Hence, all the substrates before coating are subjected to roughness evaluations (center line average values, Ra) and the substrates which showed as little as about 0.1% variation in roughness are selected for electroless coatings. The
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