Tribological Performance Analysis of Electroless Nickel Coated Mild Steel: A Comparative Experimental Study

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Abstract. In the pursuit of sustainable materials, electroless Nickel coating has emerged as a breakthrough in the development of novel materials with excellent tribological properties. In the present work, NiP and NiB coating has been performed over mild steel specimens for an hour. The tribological character for various loads of NiP and NiB-coated mild steel was determined through tribological tests. The wear behavior of both NiP and NiB-coated mild steel has been analyzed. The NiB-coated mild steel was found to show less coefficient of friction and wear rate than NiP-coated mild steel.

1 Introduction

The electroless deposition was first identified in nineteenth century and there are three basic subcategories of electroless coatings: alloy coatings, composite coatings, and metallic coatings [1]. The ability to provide a durable, wear- and corrosion-resistant surface has made electroless nickel one of the most popular electroless coatings [2]. By using an autocatalytic reduction of metallic ions in a solution containing a reducing agent such as sodium hypophosphite, sodium borohydride, amino boranes, etc., nickel with B or P elements is deposited on a substrate in an electroless nickel coating [3]. Electroless nickel coatings' chemical, physical, and mechanical characteristics are greatly influenced by the type of reducing agents used. Sodium borohydride or amino boranes are employed as reducing agents to produce NiB coatings as opposed to sodium hypophosphite, which is used to deposit NiP coatings. Due to their excellent corrosion resistance, NiP coatings are well suited for corrosion protection applications, whereas NiB coatings have higher wear resistance, greater adhesion, and lower corrosion resistance.[3]

NiP coating is an even coating of nickel-phosphorus alloy that is chemically deposited on the surface of a solid substrate, such as metal. The substrate is submerged in a water solution that contains nickel salt and a phosphorus-containing reducing agent, such as hypophosphite salt, during the procedure. The percentage of phosphorus in the alloy affects its metallurgical characteristics. Low-phosphorus-coatings contain up to 4% P contents. Their hardness reaches up to 60 on the Rock Well C scale. Medium-phosphorus - coatings, the most common type, are defined as those with 4 to 10% P, although the range depends on the application: up to 4–7% for decorative applications, 6–9% for industrial applications, and 4–10% for

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electronics [4, 5]. High-phosphorus-coatings have 10–14% P. They are preferred for parts that will be exposed to highly corrosive acidic environments such as oil drilling and coal mining. Their hardness may score up to 600 on the Vickers test. NiB Coating is a method of metal coating that can deposit a nickel-boron alloy layer on the surface of a solid surface, such as metal [6,7]. The substrate is submerged in a water solution that includes nickel salt and a reducing agent that contains boron, such as sodium borohydride or alkylamine boron. Boron-containing reducing agents, like sodium borohydride or dimethylamine borane, are often used for electroless coating of Ni-B alloy deposits. Sodium borohydride has a substantially better reduction efficiency than sodium hypophosphite and dimethyl amine borane. In the electrical industry, electroless Ni-B coatings can take the place of gold since they are more wear-resistant than tool steel and hard chromium coatings [8]. In the present work, tribological properties like coefficient of friction and wear was measured for a number of samples coated with NiP and NiB coating in electroless coating methods.

2 Experimental procedure

A mild steel pin sample of diameter 6mm and length 30mm, was used as the substrate material for the preparation of electroless NiP coating. The electroless NiP coating is accomplished through a number of processes. First the beaker and magnetic bar was washed with distilled water. 200ml distilled water in a beaker was taken and the magnetic bar was put inside. The beaker was placed on a heater and the associated platform was set to rotate in the range of 450 – 600 rpm. After adding every substance, the solution was heated up to 82 degree Celsius and stirred at 450 rpm. The coating process was continued for 1 hr time. Solution pH was maintained between 4.5-5.5. The various components of NiP solution are depicted in Table 1. Similarly NiB coating was accomplished step by step. The pH value of the solution was maintained between 12-14.

Pin-on disc wear testing equipment (Fig. 2) is used to examine the friction and wear properties of the EN-coated specimens. The coated cylindrical samples are subjected to dry, non-lubricated wear testing at room temperature. Using a load cell and a linear variable differential transformer, the pin-on-disc machine automatically measures the friction force and pin vertical displacement. The disc is rotated by a variable-speed motor that is positioned in a way that prevents vibration from affecting the test. The normal loads placed on the disc through the pin in the current work are 15 N, 20 N, and 25 N, respectively. The disc's track
diameter is set to 50mm, 60mm, and 70mm, and its spinning speed is set to 50RPM, 60RPM, and 70RPM, respectively.

Fig. 2. Pin-On-Disc Tribometer setup

3 Result and discussion

Fig. 3 and 4 demonstrates the variation of Sample weight loss which is calculated from initial and final weight of the samples before and after tribo test as measured by a precision weight machine. The value of the coefficient of friction recorded from the data acquisition system of the Pin-On-Disc tribometer, has been also compared. The coefficient of friction is increasing as the load and disc rotation speed increase for both NiP and NiB-coated mild steel as shown in Figure 5 and Figure 6. Wear is increasing as the load and rpm increase for both NiP and Ni-B-coated mild steel as seen in figure 7 and 8. The wear rate shows a decreasing trend as the load and rpm increase for both Ni-P and Ni-B-coated mild steel as reported in many literatures (6, 9, 10). The wear rate value for NiP and NiB-coated mild steel is given below. A Comparison has been drawn between the behaviour of Ni-P and Ni-B-coated mild steels as shown in Figure 9, 10. It can be observed that the value of wear at constant rpm with the variable of the load is higher for NiP than NiB-coated mild steel. It is clear from Figure 11, Figure 12 that the value of the coefficient of friction at constant rpm with a variable load is higher for NiP than NiB-coated mild steel.

![Graph](image.png)

**Fig. 3.** Weight loss for Ni-P coated mild steel

**Fig. 4.** Weight loss for Ni-B coated mild steel
Fig. 5. Load vs Co-efficient of friction for Ni-P

Fig. 6. Load vs Co-efficient of friction for Ni-B

Fig. 7. Wear rate vs Load for Ni-P.

Fig. 8. Wear rate vs Load for Ni-B.

Fig. 9. Wear vs load at 50rpm.

Fig. 10. Wear vs load at 70rpm.

Fig. 11. COF vs load at 50rpm

Fig. 12. COF vs load at 70rpm
4 Conclusion

In this work comparison of tribological properties of NiP and NiB-coated mild steel is done. The weight loss of NiP-coated mild steel is higher than NiB-coated mild steel. The value of wear is also higher for NiP than NiB-coated mild steel. From Pin-On-Disc tribometer in the dry sliding test also showed that the value of friction for NiP is higher than NiB-coated mild steel. With increasing load, the value of the wear rate also increases in general. However, sometimes exceptions are also seen as the friction and wear rate depend upon surface roughness. In adhesive wear sometimes increasing the load, the surface become smoother so that the wear rate decreases with increasing load. Due to friction, heat is generated and this stimulates the tribe-oxide film formation which contributes in decreasing wear with increasing load. Such coated materials can significantly contribute in sustainable products and construction in the long run.

5 References