STM JOURNALS

International Journal of
Electro-Mechanics and
Material Behavior

Volume 1, Issue 1, 2023
January—June
DOI (Journal): 10.37591/IJEMB

https://journals.stmjournals.com/ijemb

Review IJEMB

Electroless Duplex Nickel Coating and Tribological Characterization Under Elevated Temperature

Rajarshi Chakraborty[1,*], Arka Bhattarcharjee[2], Sourav Dey[3],
Subhadip Maity[4], Amrita Pradhan[5]

Abstract

Electroless Ni-P (EN) coatings had previously demonstrated their ability to improve the tribological properties of the underlying substantial. This is due to its high hardness, fatigue strength, and chemical resistance. Nevertheless, the EN coverings' effectiveness at high temperatures, as well as their heat resistance, have yet to be evaluated. The current work investigates the tribological properties, namely friction and wear, of EN coatings at increased temperatures (100°C, 200°C, and 300°C), by altering the interfacial testing constraints, namely normal load and sliding speed. Study findings of the tribological properties of the coatings are conducted for heat-treated and as-deposited specimens. The acquired results are contrasted with the results obtained from the coating's ambient temperature (AT) testing. For all treatment temperatures, the friction factor (COF) as well as wear of the EN coating are observed to rise under greater load. Yet, when slide speed varies, all COF and attrition rates exhibit a reversal pattern. The as-deposited specimens have a lower rate of wear, especially at maximum temperatures, which could be attributed to the in-situ thermal processing obtained throughout the experiment.

Keywords: Friction, wear, electroless Ni-P, elevated temperature, coating, friction coefficient

INTRODUCTION

Brenner and Riddell invented electroplating because of a biochemical interaction among a reduction agent in liquid and metal atoms. Because of their superior physical, electric, chemical, corrosive, roughness, frictional, and hardwearing qualities, Electroless Ni-P (EN) coatings have a broad spectrum of uses in industry. Electroless Ni-P (EN) coatings are created by autocatalytically depositing a Ni-P blend from such an aqueous phase onto a surface without the assistance of an electric charge. The electroplating baths are normally made up of an aqueous solution of metallic ions, polyfunctional reagents, reductases, and other stabilizers, all of which operate at certain levels of metal ions, temperatures, and pH spectra. Electroplated nickel coverings are extremely homogeneous. and match the surface characteristics of the substrates instead of simply covering the spaces between surface deformations [1, 2]. As a result, the sharpness of the covering does not differ much from the smoothness of the substrates overall. The discharge rate, characteristics of plated elements, and mechanical integrity of deposits are mostly determined by plate bath fragments like the kind and amounts of the reduction phase, preservative, pH, and heating rate, among others. Each optimum condition plays a

***Author for Correspondence**
Rajarshi Chakraborty
E-mail: rajarshi.chakraborty@gkcem.ac.in

[1]Assistant Professor, Department of Mechanical Engineering, Greater Kolkata College of Engineering and Management, Baruipur, West Bengal, India
[2-5]Student, Department of Mechanical Engineering, Greater Kolkata College of Engineering and Management, Baruipur, West Bengal, India

Received Date: June 23, 2023
Accepted Date: July 07, 2023
Published Date: July 22, 2023

Citation: Rajarshi Chakraborty, Arka Bhattarcharjee, Sourav Dey, Subhadip Maity, Amrita Pradhan. Electroless Duplex Nickel Coating and Tribological Characterization Under Elevated Temperature. International Journal of Electro-Mechanics and Material Behavior. 2023; 1(1): 12–17p.

unique function inside the deposition and is wholly accountable for the effectiveness and crystalline nature of EN deposition. Heating also has a considerable impact on deposition, with decreased bath loading resulting in much greater accumulation [3].

Thermal treatment has a significant impact on the depth, toughness, and shape of the deposit. The commonly accepted ideal heat utilization for electroplating nickel-phosphorus coating is 400 degrees Celsius for one hour. The harder it becomes is attributable to nickel crystallization as well as the precipitation of tiny Ni3P nanoparticles. High thermal processing temperatures and periods result in a gradual hardness drop that may be attributed to nickel grain refinement and perovskite coalescence [4, 5]. Several optimization strategies are being developed to select the best way for better utilization of electroless plating. Incorporating multiple metal ions into electroplating formations may serve as a critical method of expanding the spectrum of biochemical, physical, electromagnetic, and other characteristics that can be obtained. To increase qualities such as toughness, higher viscosity, anti-sticking, and anti-wear, numerous hard and soft granules have been included in the electroplated matrix [6]. Electroplating Ni-P-based lubricant composites often incorporate co-deposited solid lubricants like WS2, MOS2, PTFE, and graphite and have a lower frictional force than electroplating Ni-P coating. Likewise, the coating of wear-based composite typically contains co-deposited subdivisions like WC, Sic, Al_2O_3, B4C, and diamonds, and all these coverings offer higher hardness as well as durability than conventional coatings [7].

Although there have indeed been several studies on EN coatings, especially their interfacial qualities, there have been few investigations on their tribological features at increased temperatures. The current study is a step in that path. A thorough review of the high heat wear and frictional characteristics of EN coating is described here. The tribological properties of both as-deposited and heat-treated films are examined. The load and sliding speed are changed to find out the precise patterns of friction and wear at elevated heat.

EXPERIMENTAL WORKS

Coating Development

The foundation for the creation of EN coatings is cylindrically shaped steel with a diameter of 7 mm and a length of 40 mm. Since EN coating follows the surfaces of a foundation and frictional properties are dependent on surface quality, all platforms are honed to a surface quality of around 0.60 Ra. The substrates are first cleaned with water and detergent. The solvent is then used to remove any leftover organic components. Lastly, methanol is used to clean the substrates. Prior to spraying, the surfaces undergo a one-minute cleaning process with a 50% HCl solution to eliminate iron and other protective oxide deposits. Next, the cleared surfaces are deactivated in gold chloride at 55 degrees Celsius before being deposited in an electroplating solution. Its pH in the electroplating resolution is monitored by means of a pH monitoring device and preserved during the surface coating. The coating is left on for a total of four hours to create a significant droplet size, which would be required for the tribological testing.

Tribological Test

The tribological properties of EN samples are examined in a pin-on-disc style tester in drying, non-oiled circumstances, and at temperatures fluctuating from 100 to 300°C. The pin is accurately loaded using a stepping actuator and charge cell setup. A servomotor transmission is used to apply continuous power to the discs. The revolving counting disc is inferentially warmed to the appropriate temperature, and the test is carried out in a sealed room. A voltage-controlled impedance transducer is used to quantify wear in terms of movement. The wearing relocation sensor enables precise observation of the pin's motion, which corresponds to sample wearing and counters facing area wearing.

RESULT AND DISCUSSIONS

As-Deposited Condition

The influence of sliding speed as well as applied load upon that frictional characteristic of the as-deposited Ni-P coating is investigated at different operational temperatures. The tests are set up incrementally, adjusting one component at a time. Figures 1(a) and (b) illustrate the COF of as-deposited films because of load as well as sliding speed at various operating temperatures. Overall, COF rises with increasing load, which is caused by a rise in contact points; as a result, a stronger force is needed to break them. Several scholars have already made repeated discoveries. In addition to the AT test, the rise in COF is greater for load increases of 20–40% and significantly associated with increases of 40–60% [8].

Yet, for a given load, COF falls as operational temperature increases. This reduced roughness may be owing to the production of in-situ oxides on descending friction at maximum temperatures. The oxide film is soft and has shear rate characteristics, which results in reduced contact. COF shows a steadily rising trend over time with load applied in AT testing. The slide examinations are carried out with a consistent force of 10 N. Except for at, AT an increment in sliding speed causes a decrease in COF. In addition to the maximum sliding speed, the COF shown by the covering at AT is lower than that exhibited at extremely high temperatures. As a result, both slide speed and working temperature have a considerable influence on the COF of the EN coating. So, based just on sliding speed, the contact points vary quickly as the fresh sites contact one another and previous interactions dissolve. The greater the area of contact, the greater the frictional forces at interaction. At higher temperatures, the covering undergoes real-time heat processing and thereby hardens. When hardness increases, the true contact region produced decreases, resulting in a decrease in friction. The declining tendency of COF with sliding speed might be related to a change in shear, which can impact the material characteristics [9].

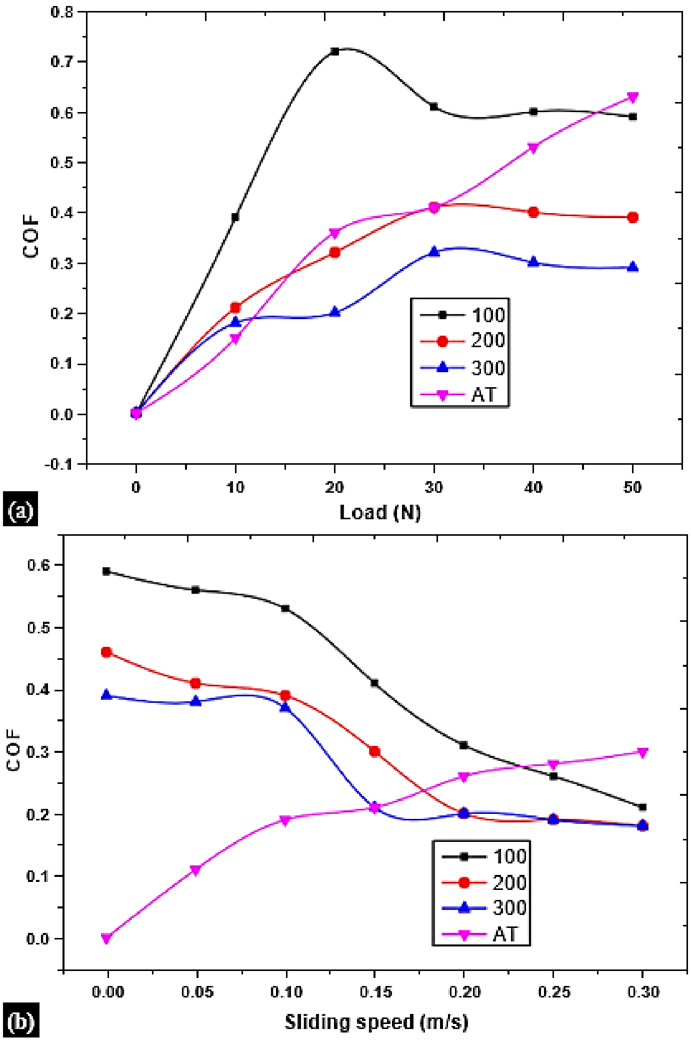

Figure 1. Frictional Rate of Ni-P coating (a) applied force; (b) speed.

Heat-treated Specimens

Heat-treated specimens are examined in the same way as as-deposited coatings. The COF of the materials evaluated at varying temperatures, pressures, and velocities is shown in Figure 2 (a) and 2(b), respectively. This fluctuation in coat resistance with duration at ambient and extreme heat. The high-temperature application samples exhibited a distinctly better frictional performance than the as-deposited coating, as shown in Figure 2 (a). COF rises as weight increases but drops above 20 N. With a temperature of 100°C, the decrease is significant. Moreover, the AT test exhibits a comparable tendency to the high thermal testing, which would be substantially different from the as-deposited coating. Figure 3 depicts the resistance characteristic of heat-treated coverings at increased temperatures for various sliding speeds. The impact of sliding speed and elevated heat on COF is like that of as-deposited coverings [10].

WEAR BEHAVIOR

As-Deposited Condition

Under increased temperatures, the wearing performance of the EN coating is examined by altering the testing parameters, namely the standard load as well as speed and sliding distance. The impacts of each factor on coat degradation are studied here. Wear is expressed by the weight-to-length covered ratio, allowing the influence of sliding velocity on wearing to be fully recognized. Figures 3 demonstrate the influence of speed and load on wear at a specific temperature for as-deposited EN coating. In Figure 3, the sliding speed is set to 0.220 m/s, while in Figure 3, the load is set to 10 N. According to Figure 3, the wear rate rises as the ultimate load increases.

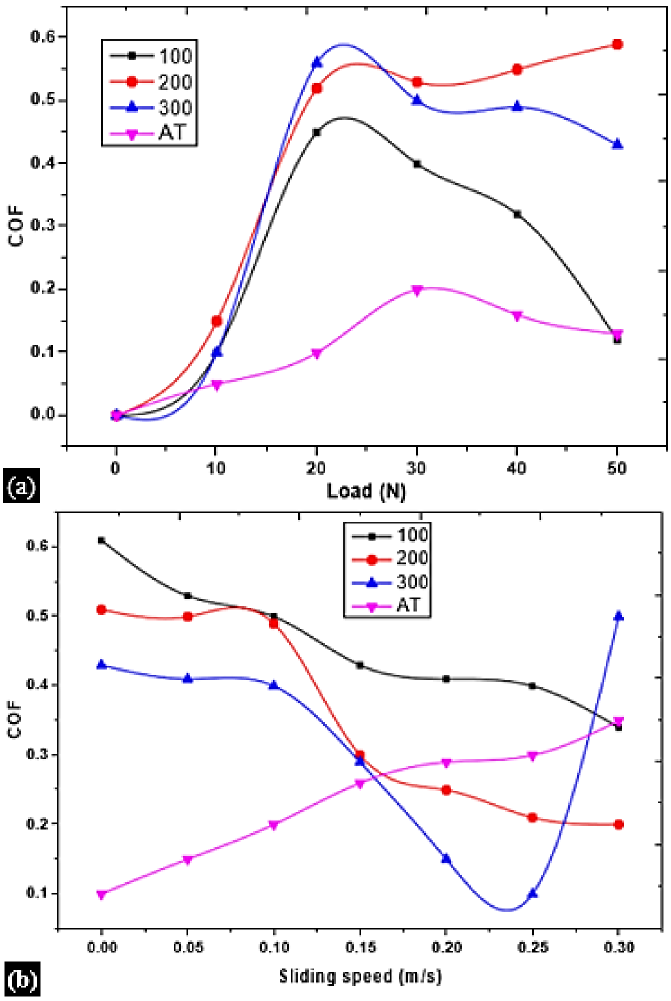

Figure 2. Frictional rate of heat-treated Ni-P coating (a) applied force, (b) speed.

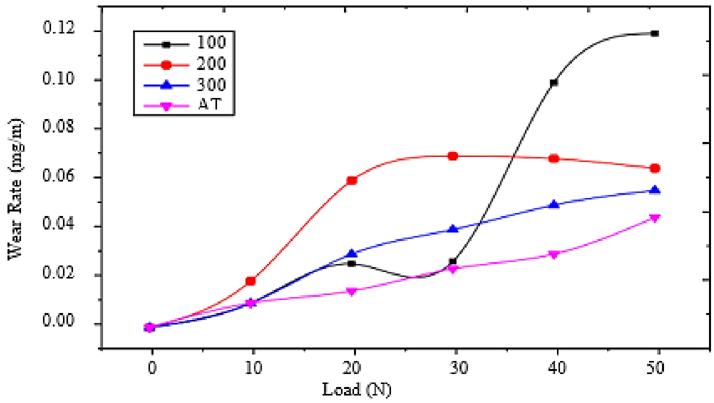

Figure 3. Wearing rate of Ni-P with respect to load.

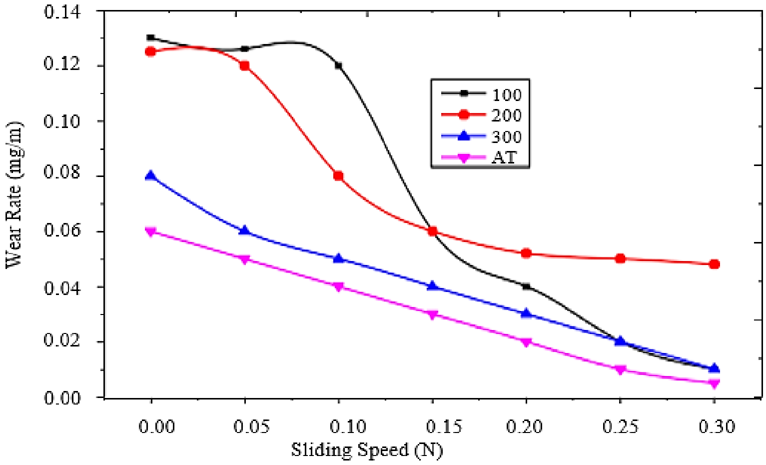

Figure 4. Wearing rate of Ni-P with respect to sliding Speed.

Numerous investigators have presented comparable findings for covers tested at AT. During AT, degradation is observed to rise by about three times throughout the output impedance range of 10–50 N in the ongoing investigation. In elevated temperature circumstances, within the identical load range, overall wear increases nearly tenfold (300°C plot). Yet, among the rising temperatures, 300°C settings have the lowest wear rates. The phase transformation temperatures of EN coating are already known to be approximately 225°C. As a result, the increased wear endurance seen at 300°C may be attributed to an improvement in surface roughness caused by heat processing at the specified temperature. This can also be verified by the toughness statistics of the specimens before and after testing [11].

Heat-treated Conditions

Figure 4 shows the impact of load as well as sliding motion mostly on the wear rate for a heat-treated EN coating at extreme temperatures. Like the situation of as-deposited specimens, increasing the load leads to increased wear at any cryogenic temperature. Among high heat testing, 300°C produces less wear, while it is much reduced at AT. Similarly, increasing the slide speed reduces the wear loss of the thermally processed covering. Yet, as contrasted to the AT experiment, the wearing rate increases under high thermal circumstances [12, 13].

CONCLUSION

EN coverings are created in laboratories using accessible chemicals and therefore are discovered to be rich in phosphorus. The coatings have a traditional columnar architecture with no surface defects. By adjusting the load applied and sliding speed both, heat-treated surfaces were tested for wear as well as friction under varied temperature controls. The COF of the as-deposited coating is observed to rise with increasing load at all temperatures and decrease according to increasing impact speed. The findings of the increased temperature testing, notably at 300°C, show a lower COF compared to the other temperatures.

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