# DRY SLIDING WEAR BEHAVIOUR OF ELECTRODEPOSITED NANO COATING AT ROOM TEMPERATURE

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**Article History: Received:10/02/2023 Revised: 12/02/2023 Accepted:20/02/2023**

**Abstract**
Electrodeposition is the proven technology in enhancing the surface properties in light of improving the life of substrate material. The nano hard particles of $Al_2O_3$ embedded in the Ni matrix are proved to increase in corrosion and wear resistance. The present work concentrates on the electrodeposition of Ni-α-$Al_2O_3$ nano composite coating on Al6061 substrate. In order to achieve the better adhesive strength zincating (electroless) process is carried out on the substrate material. Further work is carried out to study the influence of wear parameters viz., normal load, sliding speed, and sliding distance on the wear rate. The experimentation is carried out for 20 set of trails taken by central composite design (RSM) which is considered by response surface methodology (RSM). The three wear parameters mentioned above are considered as the parameters and are taken in five levels which are calculated by the value of α varied between the limits -1.682 to +1.682. The ANOVA and regression analysis reveals that the normal load is the most influencing factor followed by distance and the speed. The morphology of coating and worn-out surfaces also shows that uniform distribution of nano $Al_2O_3$ particles and their presence has resulted in increased wear resistance. Normal load applied and interaction effect of load with speed is found to be more influencing on wear rate.

**Keywords:** Ni-α-$Al_2O_3$ nano composite coating, RSM, Wear resistance, optimization

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**DOI: 10.53555/ecb/2023.12.Si13.218**

## 1 Introduction

The use of micro/nano particles in the conventional coating made a revolutionary contribution in the field of surface engineering. The incorporation of nano particles in the Ni coating has identified for its higher corrosion and wear resistance with better mechanical properties [1,2]. Though there are various types of coating methods electro co-deposition stands popular for its flexibility in any complex geometry of the substrate can be coated and for better economy. The functional property processed by the Ni composite coating with nano particles has gained major attention for the better wear resistance. In light of increasing wear resistance different nano particles are used viz., SiC [2], $B_4C$[3], $ZrO_2$[4], $CeO_2$ [5] and $Al_2O_3$ [6] in the Ni matrix to enhance the coating properties. Thus, the use of Ni-$Al_2O_3$ composite coating on the substrate material has sown the remarkable increase in wear resistance. Though there is enough work on the nano particle composite coating is carried out still it is restricted to an extent due to difficulty in coating nano size particles into the matrix. The present work is carried out on the enhancement in wear resistance of Ni-α-$Al_2O_3$ composite coating on Al6061 substrate material. Further work is extended in optimizing wear parameters on wear resistance of composite coating.

## 2 Experimental procedure

The presents have considered Al6061 alloy as the substrate material due to its applications in the field of Aircraft fittings, camera lens mounts, couplings, fittings and equipment, fitting and connectors, embellishing or equipment, pivot pins magneto parts, brake cylinders, pressure driven cylinders, machine fittings valves and valve parts, bicycle outlines. It processes high strength to low weight ratio and highly resistant to corrosion. The chemical composition of Al6061 material is given in the Tab. 1.

The Al6061 is been termed as the pin for the dry sliding wear tests and this pin is prepared as per ASTM G-99, that is of 10mm diameter and 30mm length.

**Table 1:** Chemical composition of Al6061 alloy (wt. %)

| Elements | Mg | Si | Fe | Cu | Ti | Cr | Zn | Mn | Be | V | Al |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wt. % | 0.92 | 0.28 | 0.28 | 0.22 | 0.1 | 0.07 | 0.06 | 0.04 | 0.03 | 0.01 | 97.537 |

The electro co-deposition is carried out considering the substrate material as cathode whereas Ni is connected to anode terminal in the DC power rectifier. The electrolyte set up is shown in the Fig.1. The nano $Al_2O_3$ particles are reinforced in the electrolyte solution and agitated at 250rpm using magnetic stirrer to avoid agglomeration of particles in the solution. The electrolyte bath is prepared as per watts bath standard [7]. The substrate is grinded, polishes and agitated in the acetone then in sodium hydroxide (NaOH). Initially the substrate is subjected to double layer of zincating in order to prevent formation of oxide layer and provide good adhesive strength of coating with the base material [8]. The process parameters maintained during the electro co-deposition process are: bath temperature; 40°C, current density; 1.75A/$dm^2$, percentage of $Al_2O_3$ nano particles; 4.5g/L, pH value; 3-4 adjusted by using NaOH.

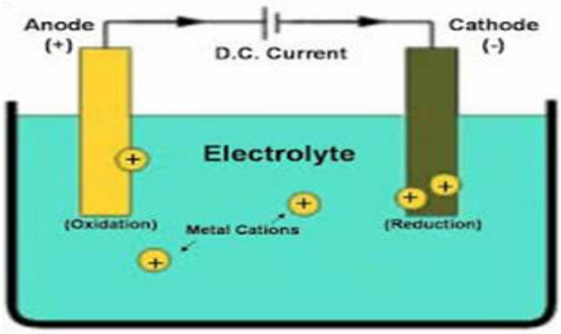


**Figure 1.** Electro co-deposition set up

Further work is carried out in order study the influence of wear parameters viz., normal load, sliding speed, and sliding distance on the wear rate. The experiments are designed by central composite design (CCD) method by considering 3 parameters in 5 levels. The details of the experimental design in terms of coded values are shown in the Tab. 2.

**Table 2.** Design parameters and respective levels.

| **Factors** | **Symbols coded** | **Encoded values of coded levels** | | | | |
|---|---|---|---|---|---|---|
| | | **-1.682** | **-1** | **0** | **1** | **1.682** |
| Load, N | $X_1$ | 10 | 18 | 30 | 41 | 50 |
| Sliding distance, m | $X_2$ | 500 | 702 | 1000 | 1297 | 1500 |
| Sliding Speed, rpm | $X_3$ | 200 | 321 | 500 | 678 | 800 |

**3. Results and discussions**

The morphology study is carried out using scanning electron micrograph (SEM) of Ni-$Al_2O_3$ coated surface. The Fig. 2 (a) shows the coating of Ni on the Al6061 substrate material. The Fig. 2 (b) shows the distribution of nano particles on the surface which plays a major role in deciding the characteristics of the composite coating.

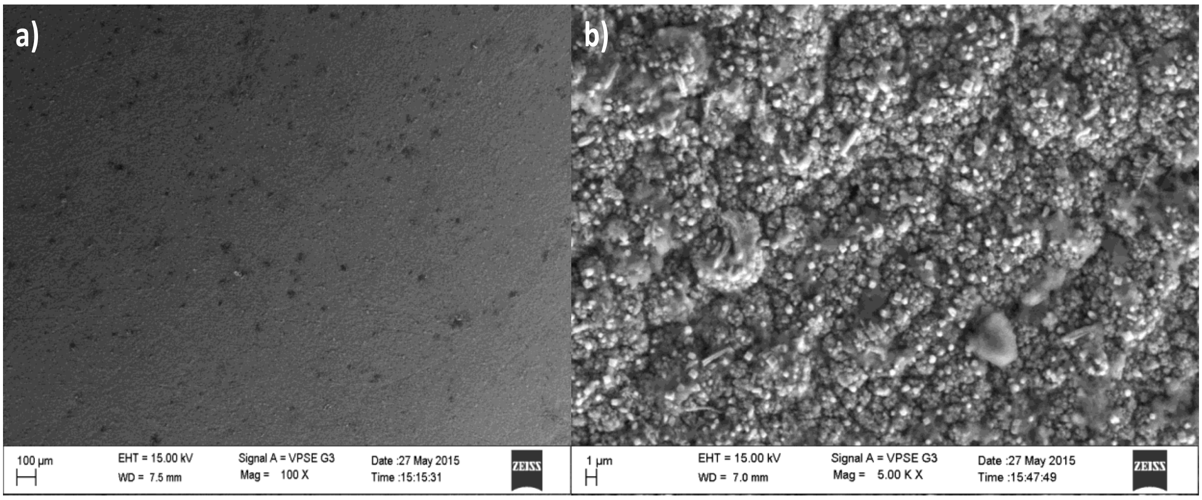


**Figure 2.** (a) Ni coating (b) Ni-$Al_2O_3$ composite coating

The normal probability plot shown in the Fig. 3(a) shows variation of response to the corresponding experiments lies well within the zone. This indicates that the model is significant and errors are distributed normally. The 95% significance factors are considered for the design. The normal load applied on to the pin is most significance on wear rate followed by sliding speed and sliding distance.

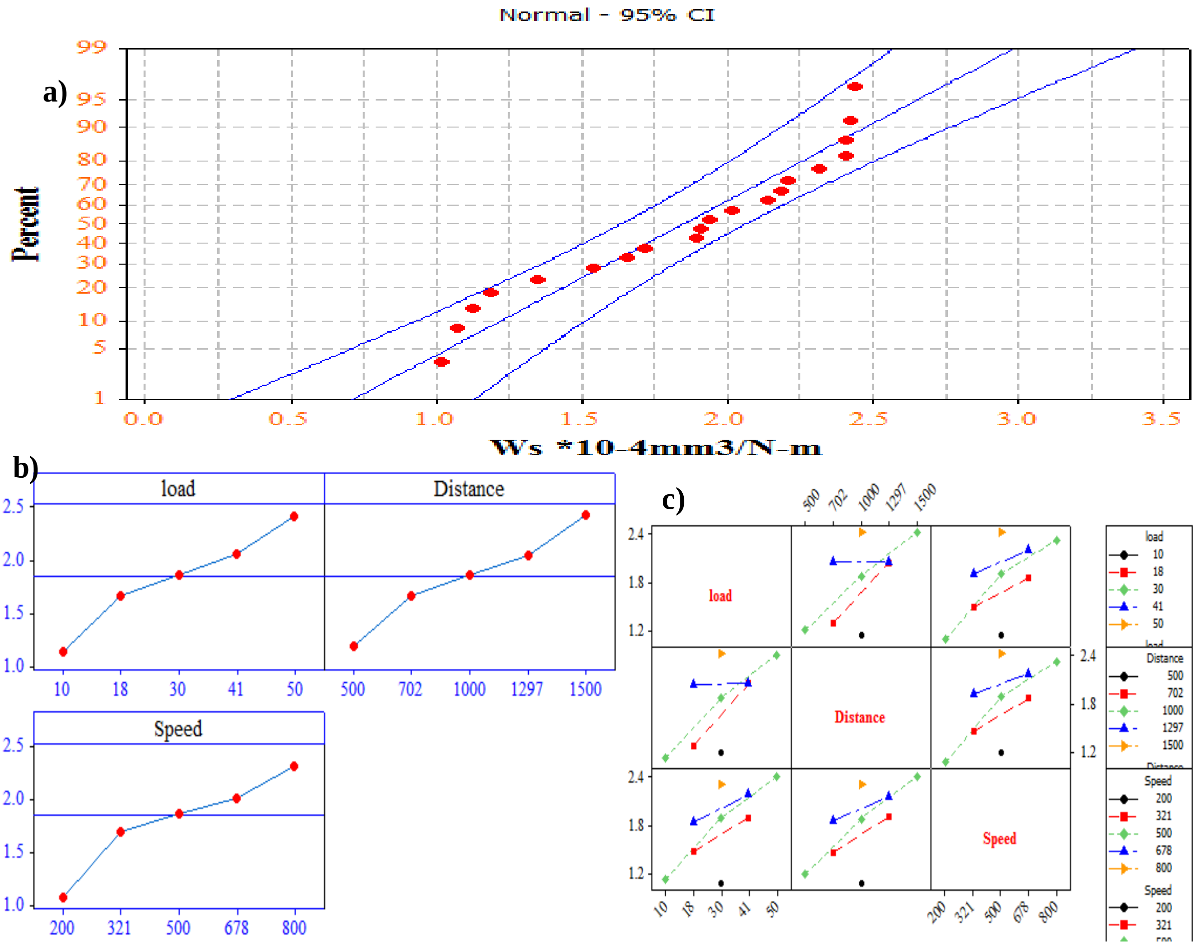


**Figure 3.** (a) Normal probability plot (b) Main effect plot (c) Interaction plot.

It is evident from the Fig. 3(a) shows the main effect plot where similar trend for of influence of load, distance, and speed on the wear rate is observed. The interaction plot indicates (Fig. 3(c)) that the interaction effect of load and speed is more influencing and interaction effect of distance with speed is found to be minimum on the wear rate. The least wear resistance is observed is $1.02*10^{-4}$ $mm^3$/N-m at the load, sliding distance and sliding speed of 18N, 702m, and 321 rpm respectively. The extreme wear rate is observed at higher load in all conditions of speed and distances. The maximum wear rate is also proving to be same which is shown by the 3-D plots in Fig. 4 (a)-(c). The higher wear rate is found at the 30N, 1000m and 500rpm and the value is found to be $2.440 *10^{-4}$ $mm^3$/N-m.

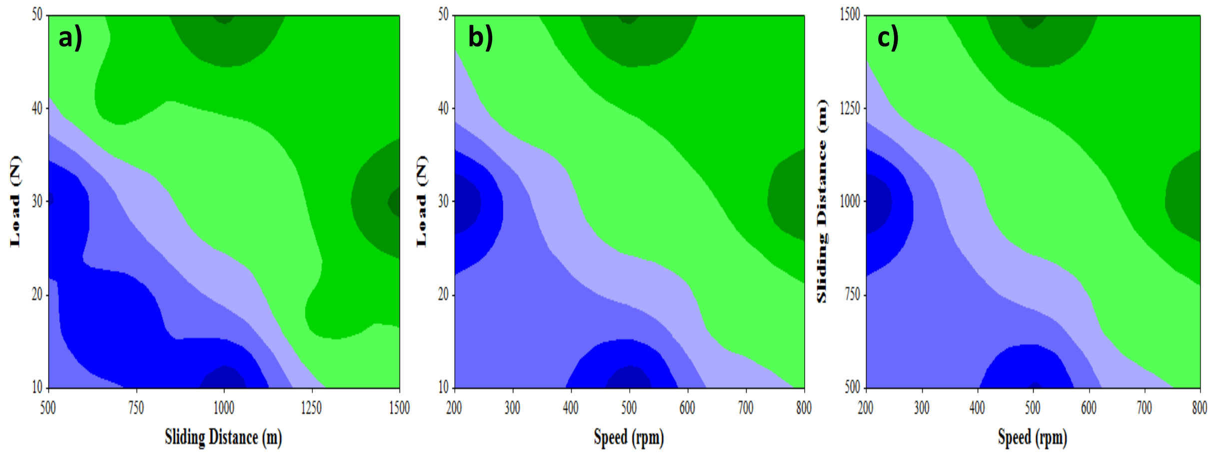


**Figure 4.** 3-D plots for interaction effect of Load, speed and sliding distance.

## 4. Conclusion

The present work concentrates on the electrodeposition of Ni-α-$Al_2O_3$ nano composite coating on Al6061 substrate material. Further work is carried out on optimization of wear parameters on specific wear rate of the composite coating and the following conclusions are drawn;

1. Normal load applied on the substrate material is found to be more influencing followed by sliding speed and sliding distance. Where load contributing 31% on wear rate.
2. The interaction effect of load with is more significant compared to with interaction effect with distance of sliding.
3. The better wear rate is observed at the load, distance, and speed of 18N, 702m, and 321 rpm respectively.

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