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THE INFLUENCE OF NANO PARTICLES ADDITIVE ON TRIBOLOGICAL PROPERTIES OF AA2024-T4 COATED WITH TiN OR SiN THIN FILMS

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ABSTRACT

In the current study, the radio frequency magnetron sputtering technique was used to sputter a thin layer of titanite nitride (TiN) or silicon nitride (SiN) on the surface of AA2024-T4 alloy. To investigate the wear behavior and coefficient of friction between coated aluminum alloy pin and a steel disc (Ck50) contact bodies, different percentages of Copper oxide (CuO) and molybdenum disulfide (MoS_2) Nanoparticles were added to the sunflower and engine (HD 50) oils. The results reveal important enhancement in wear rate and coefficient of friction when Nanoparticles powder was added to the oil in comparison with dry and base oils conditions. The optimum results for wear rate and coefficient of friction were obtained at the 1%wt of both Nanoparticles additive. The results also show a significant enhancement in wear and friction conditions when the surface of the aluminum alloy pin was coated with TiN and SiN in comparison with the uncoated surface.

KEYWORDS

Wear, Nanoparticles additive, coating, magnetron sputtering, hybrid lubricant.

1. INTRODUCTION

When surfaces of bodies rubbing each other, friction generates, and this causes wear so that we need lubricants to reduce the amount of wear. Nowadays, base oils mixed with additives are used as lubricants; these additives play a major role in reducing friction and wear. Additives act as a third body that reduces the contact between the rubbing bodies. Aluminum and its alloys are widely used in industry [1]. They have very attractive properties which include low density, good corrosion resistance, low cost, high strength to weight ratio, high elastic modulus to density ratio [2-6]. These alloys are widely used in many applications such as aircraft applications and automobile industries [7].

Many studies had been conducted on friction, wear, and lubrication. A group researchers found that adding Nano additives like (MWCNTs and ZnO) to engine oil can reduce wear significantly up to 15 times than that of engine oil without additives [8]. A studied the wear behavior of AA 2024 and stainless steel 316L coated by Ni-graphite with 40 % wt. of Al (Ni-Gr/Al), the results indicated that the coating of stainless-steel samples has a low coefficient of friction and high content of graphite and high thickness as compared with the aluminum samples [9]. A studied the influence of MoS_2 as a lubricant additive on the wear and coefficient of friction for EN31 Alloy Steel and AISI 52100 Steel Ball [10]. They observed that as the particle size decrease the coefficient of friction and wear decreased. Some researcher found that Adding up to 1% weight percentage of MoS_2 and CuO Nanopowder additives to castor oil or molding oil lubricants decrease the coefficient of friction and surface roughness significantly [11].

A studied the effect of TiVN, TiNbN and TiNbVN thin films deposited on AA2024; they found that the TiNbVN thin film exhibit good wear resistance, lowest surface roughness, highest film thickness and lowest coefficient of friction when compared with other thin films [12]. A studied the effect of duplex layers (TiN0.3, Al3Ti, and Al18Ti2Mg3) deposited on AA2024 at different temperatures, the results show that the coefficient of friction decreased with increasing the deposition temperature and the wear rate of coated piece improved by 56% in comparison with the uncoated piece [13]. A group researcher observed that reinforcing AA2219 with boron carbide and graphite particles effects the wear results and the hybrid composite show high wear resistance in compared with mono composite material [14].

A studied dry sliding wear of AA7075 reinforced with different percentages of graphite particles and Al2O3, the results show that the wear rate decreased with increasing in Al2O3 while the coefficient of friction is significantly influenced by graphite percentage [15]. In other study, they observed that the hardness and wear of AA6063 reinforced with tungsten carbide increased by 52 % and 50 % respectively in compared with base metal [16]. The aim of the current study is to investigate the effect of adding different weight percentages of MoS_2 and CuO Nanoparticles to sunflower and engine (HD 50) oils on wear rate and friction coefficient of AA2024-T4 alloy pins coated with thin layers of TiN or SiN. A hybrid containing the optimum weight percentage of MoS_2 and CuO Nanoparticles will be added to the sunflower and engine oil. The hybrid will be used to study its effect on wear rate and friction coefficient too.

2. EXPERIMENTAL PROCEDURE

2.1 Samples preparation

[1] AA2024-T4 aluminum alloy was used in this study; its chemical composition is listed in table 1. Deposition of TiN and SiN thin films on AA2024-T4 specimen's surface was done by radio frequency magnetron sputtering at (13.56MHz) radio frequency. Table 2 represents the sputtering conditions of TiN and SiN thin films.

Table 1: Chemical Composition of AA2024-T4

Item %	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Pb	V	Al
Standard	0.5	0.5	4.9	0.6	1.8	0.1	0.05	0.25	0.15	0.05	0.05	94.7
Actual	0.113	0.352	4.6	0.534	1.6	0.0024	0.014	0.049	0.022	0.008	0.01	92.7

Table 2: Sputtering conditions of TiN and SiN thin films

Parameter	TiN and SiN Sputtering condition
Ultimate pressure	1*10-5 Torr
Gas pressure	1*10-3 Torr
Power	300 Watt
Substrate rotational speed	4 cycle/min
Substrate temperature	100°C
Deposition angle	55°
Deposition time	4 hrs
Distance between the target and substrate	10 cm

2.2 Preparation of Nano lubricants

Different weight percentages (0.25, 0.5, 0.75, 1.0, 1.25 and 1.5%) of MoS_2 and CuO Nanoparticles were added to sunflower and organic (HD 50) oils. The original viscosity of the sunflower and organic (HD 50) oils were 60 and 140 pascal*sec at room temperature.

2.3 Friction and wear test

Friction and wear experiments for coated and uncoated AA2024-T4 specimens were conducted by using (MMW-1A) Vertical universal friction testing machine. Preliminary experiments with dry and wet conditions for uncoated samples at different loads (100, 125, 150, 175, 200 and 225N) had been conducted to evaluate the ideal load which gives the minimum wear rate and coefficient of friction. The ideal load was used to carry out the wear and friction experiments for AA2024-T4 specimens with and without TiN and SiN thin films. The other conditions were: sliding speed 1.5176 m/s, testing time 600 sec, different percentages of MoS_2 and CuO Nanoparticles.

3. RESULTS AND DISCUSSION

3.1 Coefficient of friction

Figure 1 shows the variation of coefficient of friction for uncoated AA2024-T4 aluminum alloy with the applied load at dry and wet conditions in the present of sunflower and engine (HD 50) oils. When compared with dry conditions, it can be noted that the sunflower oil gives a significant improvement in coefficient of friction up to 55% at different loads, while the engine (HD 50) oil improvement reaches 57% at the same applied loads. Engine (HD 50) oil has better results than sunflower oil because of its better viscosity in compared with sunflower oil.

Figures 2 and 3 show the influence of adding CuO and MoS_2 as Nanoparticle additives to the sunflower and engine oils on the coefficient of friction for AA2024-T4 specimens uncoated and coated with TiN and SiN respectively. It can be noted that the lowest coefficient of friction had been achieved at (1%wt) for both CuO and MoS_2 Nanoparticles, and Engine oil (HD 50) exhibit better coefficient of friction results when compared with sunflower oil.

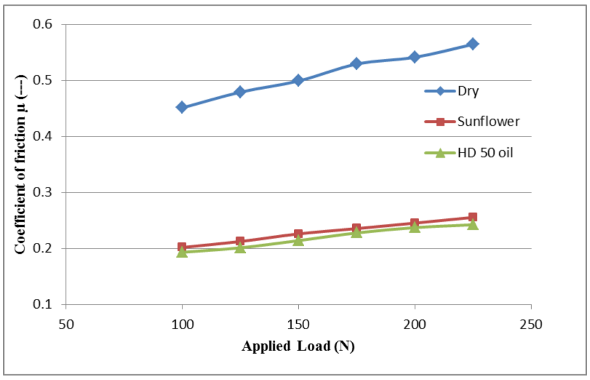
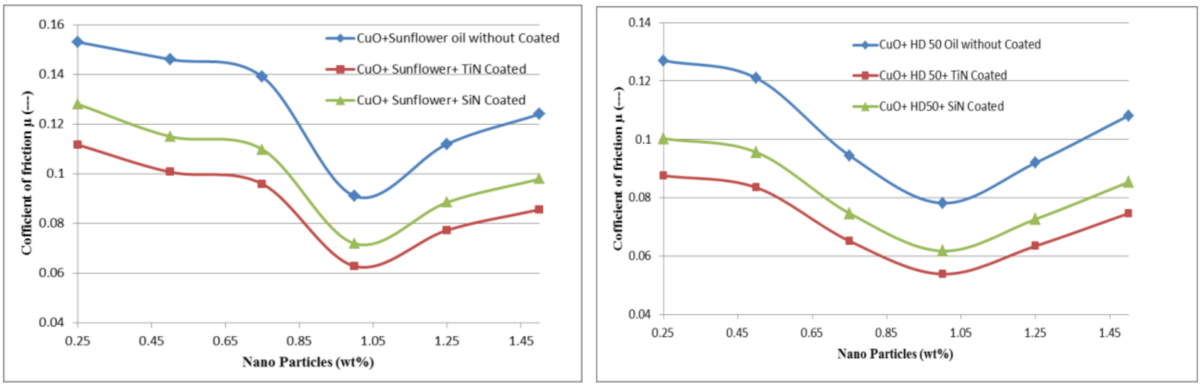


Figure 1: Effect of applied load on the coefficient of friction



(a) Sunflower oil (b) Engine oil (HD 50)

Figure 2: Effect of adding CuO Nanoparticles on the coefficient of friction

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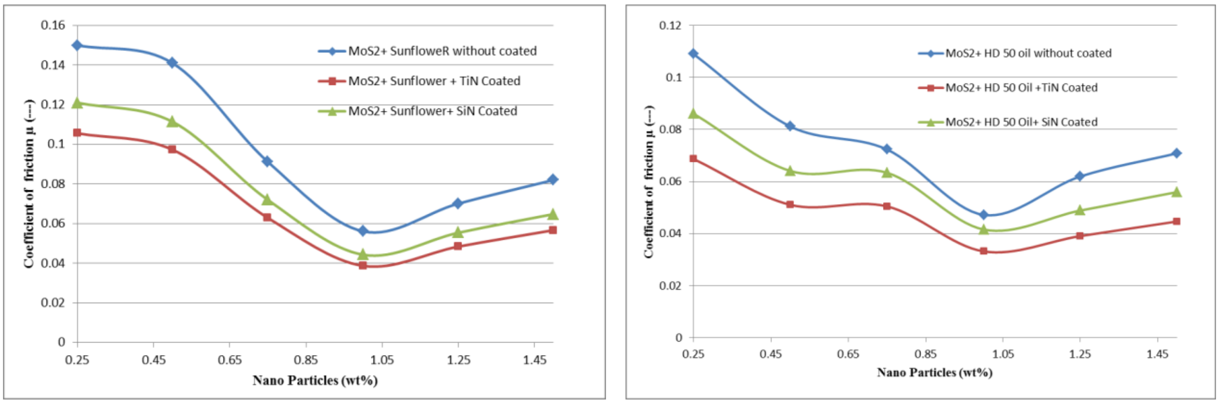

(a) Sunflower oil

(b) Engine oil (HD 50)

Figure 3: Effect of adding MoS2 Nanoparticles on the coefficient of friction

For uncoated AA2024-T4 aluminum alloy, it was found that adding (1%wt) of MoS_2 and CuO Nanoparticles to engine oil improves the coefficient of friction by 76% and 61% respectively when compared with using engine oil without additives. Adding the same weight percentage of MoS_2 and CuO Nanoparticles to sunflower oil improves the coefficient of friction by 72% and 55% respectively when compared with using sunflower without additives. The coefficient of friction results for AA2024-T4 specimens coated with TiN and SiN are better than that of uncoated ones, and specimens coated with TiN shows better results when compared with that coated with SiN. A hybrid of (1%wt) MoS_2 and (1%wt) CuO Nanoparticles was mixed with sunflower and engine oil and the coefficient of friction results are summarized in Figure 4.

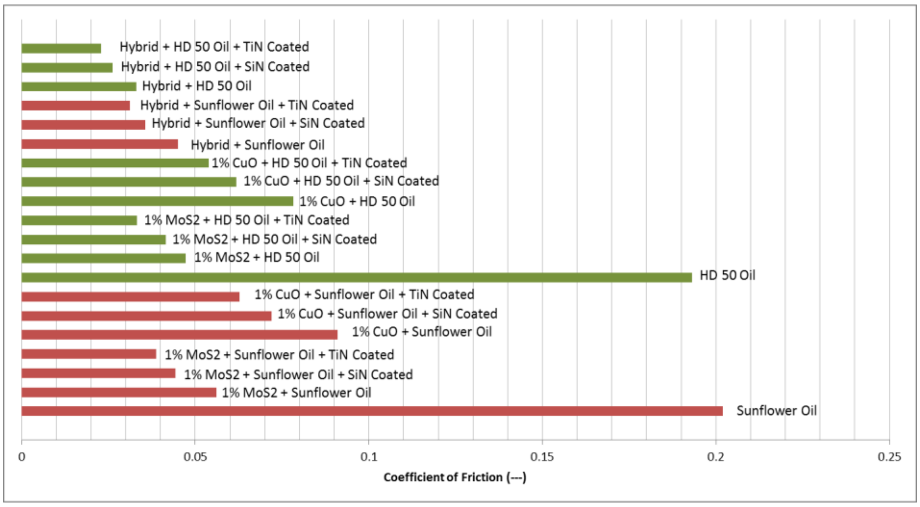

Figure 4: Coefficient of friction results at different conditions.

For uncoated AA2024-T4 aluminum alloy, using hybrid additive of MoS_2 and CuO Nanoparticles to engine oil improves the coefficient of friction by 30% and 57% respectively when compared with that results correspond to the case of adding only (1%wt) MoS_2 or (1%wt) CuO Nanoparticles to engine oil. On the other hand, the improvement in the coefficient of friction was 20%, and 50% for hybrid additive of MoS_2 and CuO Nanoparticles to sunflower oil respectively. Again, better results were obtained for specimens coated with TiN in comparison with that coated with SiN, and the coefficient of friction results for coated AA2024-T4 specimens were better than uncoated ones.

3.2 Wear rat

Using lubricants affects the wear rate of AA2024-T4 aluminum alloy as shown in figure 5. Comparing with dry conditions, an average improvement in wear rate of about 57% and 55% can be achieved when using engine oil (HD 50) and sunflower oil respectively

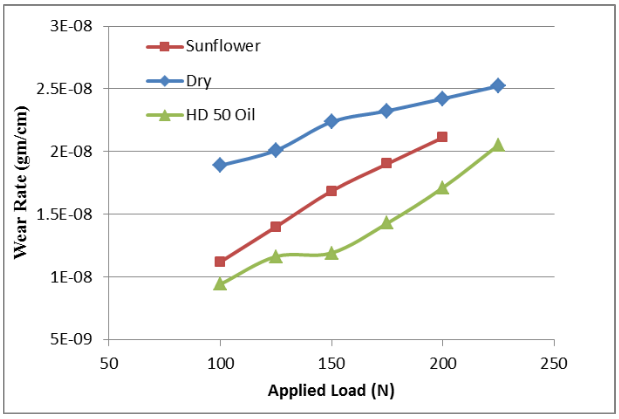

Figure 5: Variation of wear rate with applied load

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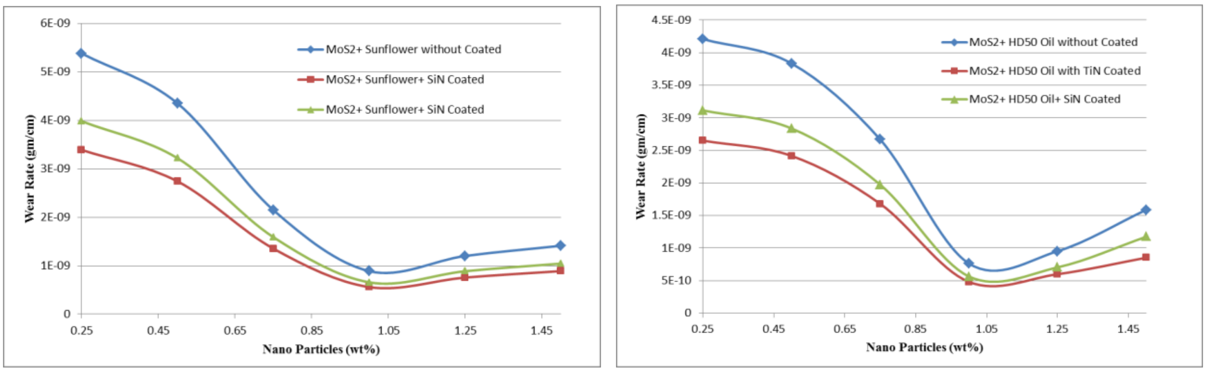
Figures 6 and 7 illustrate the effect of using oils with Nanoparticles on the wear rate for uncoated and coated specimens. The lowest wear rate had been achieved at (1% wt.) of each additive. For uncoated AA2024-T4, when adding MoS_2 and CuO for engine oil (HD 50), the wear rate decreased by 92% and 82% respectively when compared with using engine oil without additives. For the sunflower oil, the reduction in wear rate was 95 % for MoS_2 and 85% for CuO. The improvement at this percentage is due to lubricant film thickness stability and constant heat generation between the contact surfaces.

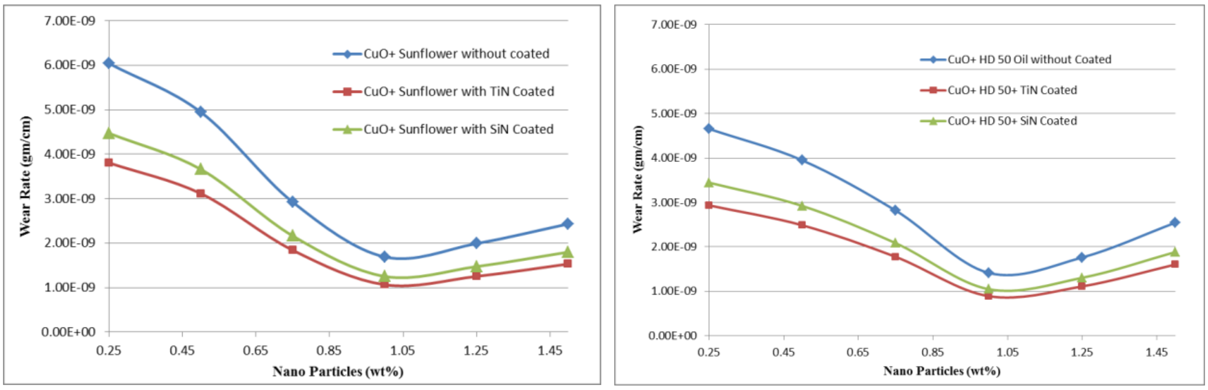
Increasing the Nanoparticle percentage above (1%wt) increases the wear rate, and this can be related to increasing the lubricant film thickness which in turn leads to instability in heat generation and the contact pressure between the surfaces of the pin and disc. When comparing the results, it can be noted that engine oil exhibit a lower wear rate than sunflower oil at the same percentages of Nanoparticles, MoS_2 Nanoparticle have better results than CuO Nanoparticles, the wear rate results for coated specimens are better than uncoated ones, and finally specimens coated with TiN reveal better results than SiN coated specimens.

The Nanoparticles hybrid was used again with the base oils; the improvement in the wear rate results was summarized in Figure 8. It can be noted that the lowest wear rate had been achieved when using a hybrid of (1%wt) MoS_2 and (1%wt) CuO Nanoparticle mixed with engine oil for AA2024-T4 aluminum coated with TiN.



(a) Sunflower oil (b) Engine oil (HD 50)

Figure 6: Effect of adding MoS2 Nanoparticles on the wear rate



(a) Sunflower oil (b) Engine oil (HD 50)

Figure 7: Effect of adding CuO Nanoparticles on the wear rate

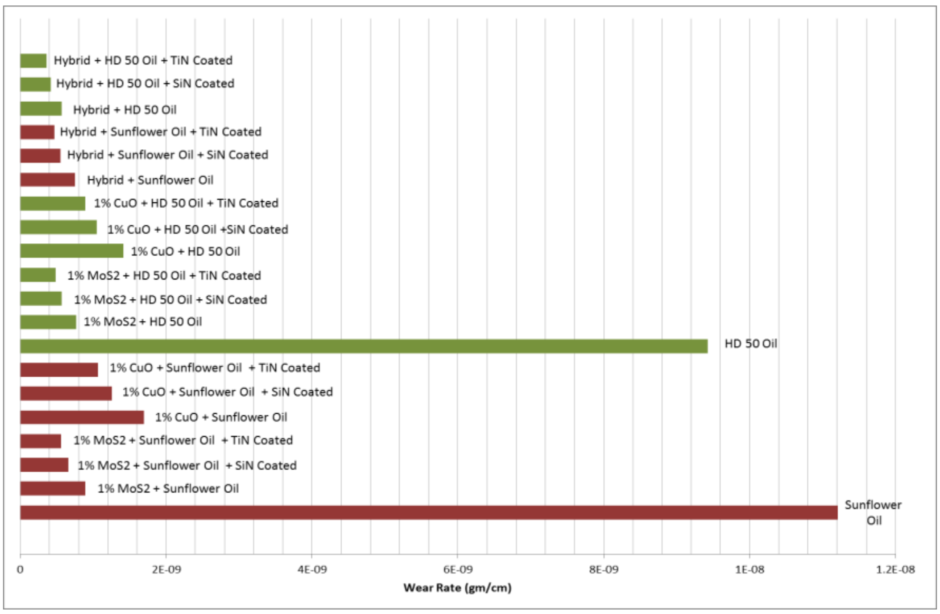


Figure 8: Wear rate results at different conditions.

4. CONCLUSIONS

The main conclusions from this work as follow:

1. The wear rate and coefficient of friction increased with increase in applied load for dry, sunflower oil and HD 50 oil without additives.
2. The addition of Nanoparticles powder to the base oil shows a remarkable improvement in the coefficient of friction and wear rate.
3. Engine (HD 50) oil with different concentrations of Nanoparticles powder reveals better results when compared with the sunflower oil.
4. The MoS_2 Nanoparticles show best tribological results in comparison with the CuO Nanoparticles.
5. Using the TiN and SiN coated layers show a good enhancement in wear rate and coefficient of friction as compared with uncoated layers.
6. Using hybrid Nano lubricant gives a significant improvement in wear rate and coefficient of friction

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