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Araştırma Makalesi / Research Article

Friction Reducing Composite Plating in Rocket Launchers

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Abstract

Composite plating is commonly used for reducing friction and wear. It is a method that can be used in the environments exposed to friction such as rocket launchers. Steel specimens were coated by nickel including MoS2 particles in this study. The effects of MoS2 particle concentration and particle size on the coefficient of friction and the amount of wear were determined by pin on disc tribometer. It is revealed that the particles with small size and high concentration are more effective in decreasing the friction coefficient.

Key Words

"MoS_2, nickel, electroplating, friction, wear"

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1. INTRODUCTION

Friction and wear of surfaces that are in contact with each other especially under high vacuum is an important issue that has to be considered according to Hilton and Fleischauer (1992). Hilton and Fleischauer (1992) claimed that films such as molybdenum disulphide or soft metals like gold, lead, or silver are efficiently used to overcome this problem. Siopis and Cowan (2014) stated that rocket sleds, launchers, and large caliber gun applications are the areas where mechanical wear at high sliding velocities has to be considered The friction at the contact regions between the launch package (slider) and rail/bore (guider) may lead to severe wear of both components that will end up with short life time and decreased performance of these devices according to Siopis and Cowan (2014). Therefore, friction decreasing applications are attracted. For instance, Charles et. al. (1963) put forward that a wheeling system is proposed for the launching of rockets from aircraft especially in the backward direction. Composite deposition including particles with self-lubricating property can be another solution for friction and wear. Electrodeposition is a well-known technique to embed particles into the matrix to improve the frictional properties of the surface. The particles that are commonly used to decrease friction and wear rate are MoS2-W MoS2, W-diamond in the studies of Cardinal et. al. (2009), Huang and Xiong (2008) and Hou et. al. (2014), respectively.

Pin-on-disc tribometer is the most widely used equipment to determine the wear rate and friction coefficient of materials. The tester consists of a stationary pin under an applied load in contact with a rotating disc. Either the pin or the disc can be tested depending on the geometry of the sample that is going to be examined. A load cell attached to the pin-on-disc tester is used to measure the evolution of the friction coefficient with sliding distance (ASTM-G99-95a, 2000)

The aim of this study is to observe the effects of MoS2 particle concentration (three concentrations) and particle size (two different sizes) on friction and wear behavior.

2. EXPERIMENTAL STUDIES

2.1 Electrocodeposition (Composite electroplating)

The constituents of the Watts bath are 300 g/l NiSO4.6H2O (63035981; Umicore, Belgium), 50 g/l NiCl2.6H2O (7791-20-0; Selnic, France), and 40 g/l boric acid (minimum %99.9 H3BO3, Etibank, Turkey) and additives from SurTec 855 which are 4 ml/l carrier, 10 ml/l leveler, 1 ml/l brightener and 1 ml/l wetting agent. Two different sizes 1.440 µm (Merck-product no: 1122570250) and 5.156 µm (Sigma Aldrich-product no: 69860) of MoS2 particles were used to agitate for 5 hours in 50 ml Watts solution to make slurry and then the slurry was added to the desired volume. The substrates were 4x4 cm AISI 304 stainless steels. The previously optimized parameters to produce coatings with low internal stress (thickness: 50 µm, pH: 2, temperature: 50 ºC and current density: 4.8 A/dm2) in the study of Saraloglu Guler et. al.(2013:5496) were used during the experiments. Optical micrograph and X-ray diffraction analysis were completed after the deposition process.

2.2 Tribological Investigation

Nickel coated and composite (nickel + MoS_2) coated AISI 304 stainless steel specimens were tested using a standard pin-on-disc tribometer (CSM Instruments) at ambient conditions. 6 mm diameter 100Cr6 steel pin (ISO 683-17:1999) was rotated within the pin holder. A constant load of 1N was applied during the experiments. The linear sliding speed and the wear track radius were 5 cm/s and 2 mm, respectively. The tests were run for 4000 cycles. The wear volumes of the specimens were calculated by measuring the width of the wear track by optical microscope. The calculations were conducting according to ASTM standard G99 assuming that the pin wear is negligible (ASTM-G99-95a, 2000). The wear rate was calculated by dividing the volume loss by both the total sliding distance and applied load.

$$\text{Disk Volume Loss, mm}^3 = \frac{\pi \times R \times (d^3)}{6 \times r} \tag{1}$$

Where **R:** wear track radius (2mm), **d:** wear track width, **r:** pin end radius (3mm)

3. RESULTS

MoS_2 particles that have the concentration of 30 g/l in the Watts bath and having the size of 1.44 µm were distributed homogeneously in the nickel matrix (Figure 1). The presence of MoS_2 was confirmed by X-ray diffraction analysis of the specimen coated from the electrolyte containing 10 g/l MoS_2 particles with the size of 1.44 µm is given in Figure 2. Quantitative analysis of the coating by Rigaku is also given in Table 1. The specimens were subjected to tribological investigation following the deposition processes to observe the effects of size and concentration of MoS_2 particles. Figure 3 shows the results of pin on disc experiments regarding the change in the COF as a function of number of cycles for three MoS_2 concentrations: 5, 10 and 30 g/l and the average COF values are 0.51, 0.46 and 0.41 respectively. The corresponding wear rates are listed in Table 2.

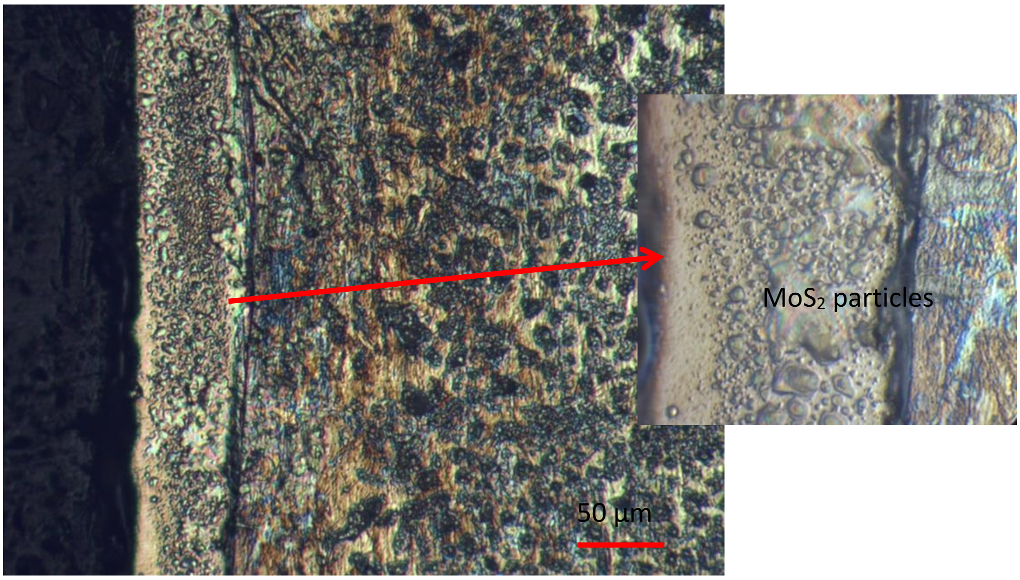

Fig. 1. Optical micrograph of Ni-MoS_2 composite coating on AISI 304 stainless steel substrate from the electrolyte containing 30 g/l MoS_2 with 1.44 µm particle

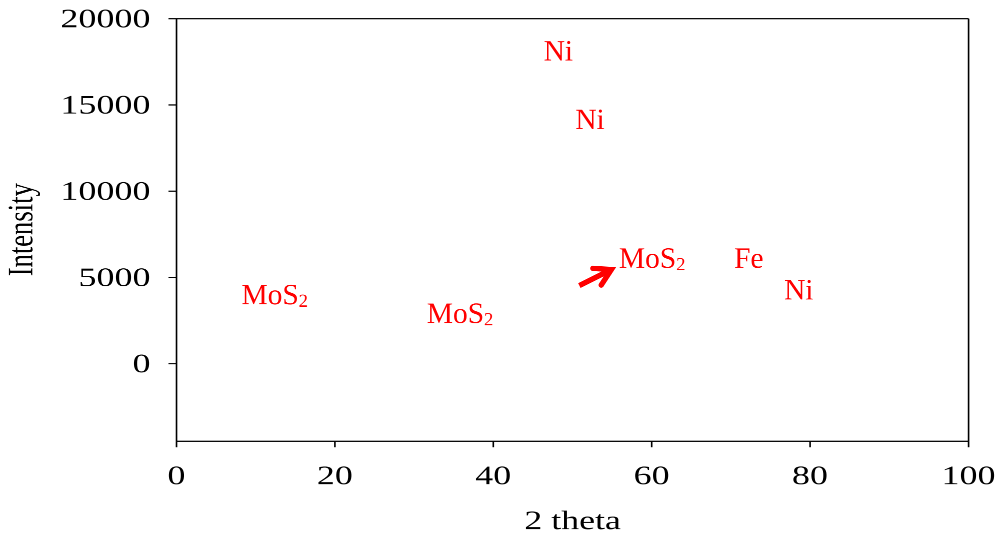

Fig. 2. X-ray diffractogram of Ni-MoS_2 composite coating on AISI 304 stainless steel substrate from the electrolyte containing 10 g/l MoS_2 with 1.44 µm particle

Table 2: Quantitative analysis by Rigaku software of the sample in Figure 2

Element/compound	% percent
Ni	82.5
Fe	11.2
MoS_2	6.3

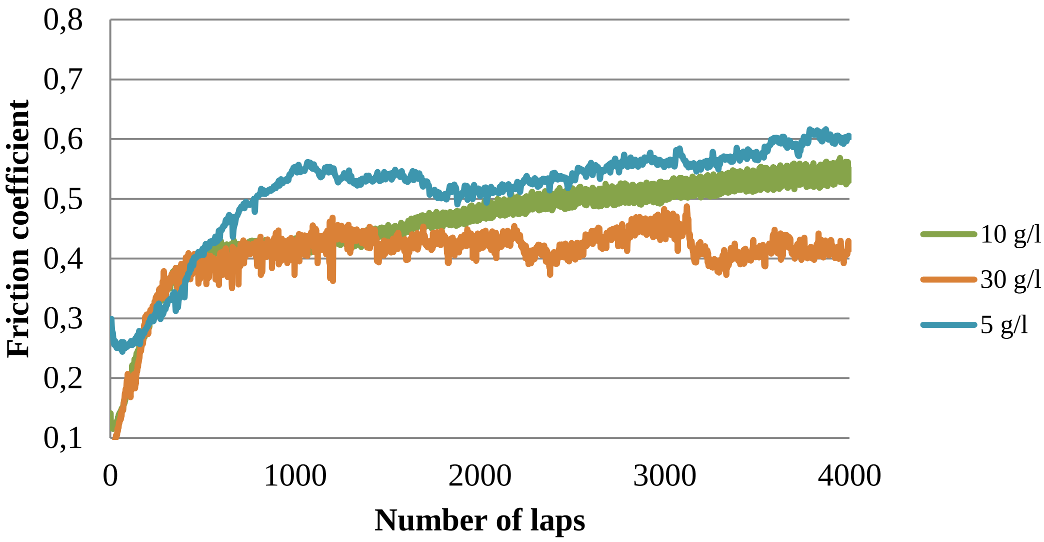

Fig. 3. Change in COF as a function of number of cycles for the Ni-MoS_2 composite coating samples showing the effect of MoS_2 concentration

Table 2. The deposition conditions and the average COF of the Ni-MoS_2 coated AISI 304 stainless steel samples (pH=2, current density=4.8A/dm^2, particle size=1.440 µm, T=50 °C, coating thickness = 50µm)

MoS_2 Concentration (g/l)	COF	Wear Volume (mm^3)	Wear Rate (mm^3/Nmx10E-3)
5	0.51	0.0048	0.094
10	0.46	0.0387	0.759
30	0.41	0.0679	1.329

The COFs of the composite coatings significantly decreased from 1.12 that is the COF value of pure nickel coated specimen to as low as ~0.40. According to the study of Huang and Xiong (2008), the COF of Ni-plated steel specimen was 0.45 and then decreased to 0.2 upon addition of 30 g/l MoS_2 into the Watts bath. The COF values are system dependent so the difference may stem from the change in the test conditions like ceramic pin (Al_2O_3) was used and the sliding velocity was 35.5 cm/s that are both higher than the parameters used in this study of Huang and Xiong (2008). Figure 4 shows the change in COF as a function of number of cycles for the Ni-MoS_2 composite coating samples showing the effect of both MoS_2 size and concentration. Table 3 summarized the conditions for four samples given in Figure 4. The deposition conditions and their wear volumes and rates were listed together with the corresponding COF values in Table 4.

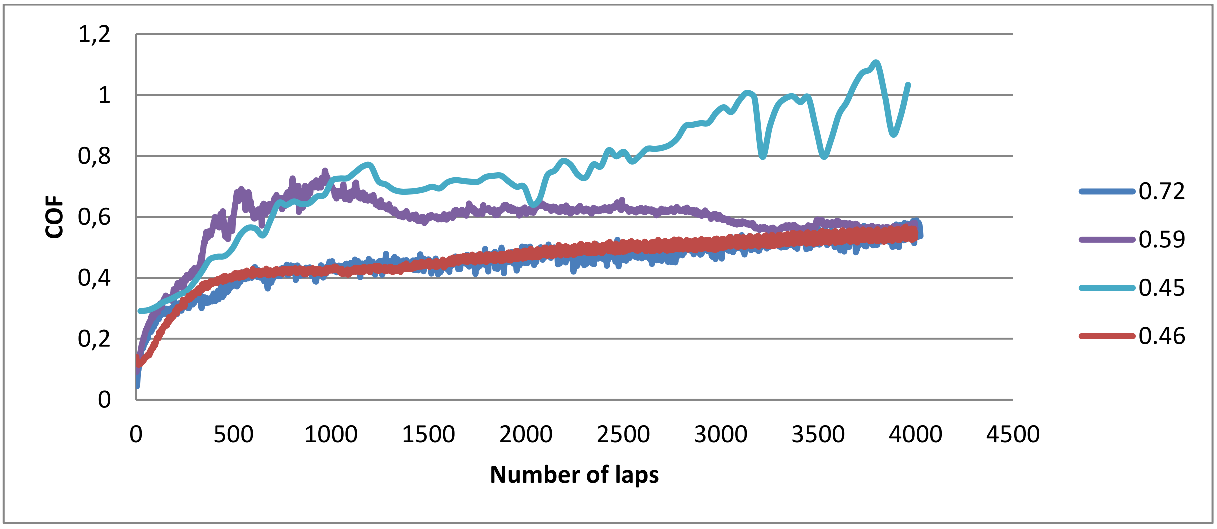

Fig. 4. Variation of the COF of composite coating samples as a function of number of cycles showing the effect of MoS_2 size and concentration given in Table 3.

Table 3. The deposition conditions and the average COF of the Ni-MoS_2 coated AISI 304 stainless steel samples (pH=2, current density=4.8A/dm^2, T=50 °C, coating thickness =50µm)

MoS_2 Concentration (g/l)	**MoS_2 Size (µm)**	**COF**
10	1.440	0.59
30	1.440	0.46
30	5.156	0.45
10	5.156	0.72

After pin on disc tribometer experiments, the specimens with the wear track were subjected to surface profilometer that shows the depth of track. A profilometer for the specimen with an average COF of 0.51 is given in Figure 5.

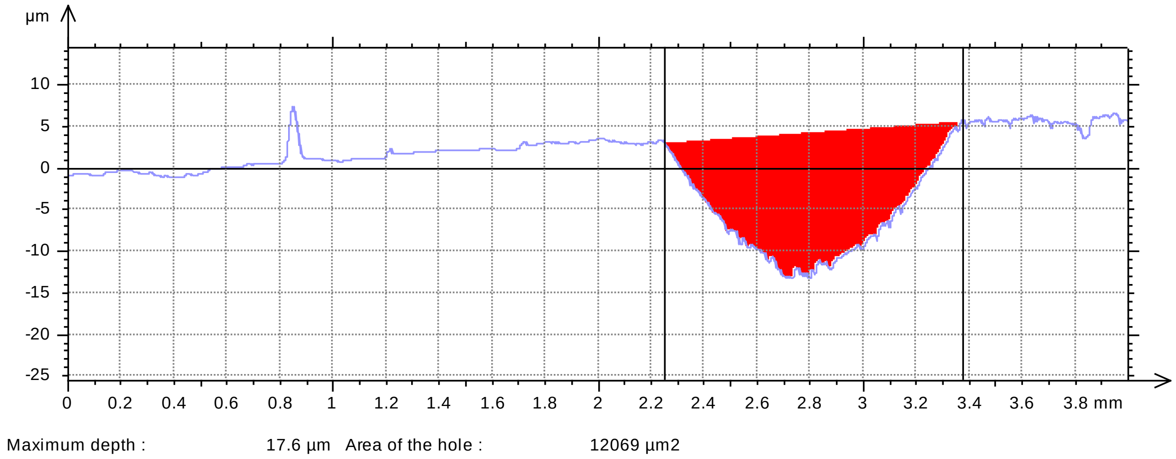

Fig. 5. Surface profilometer for specimen with an average COF value of 0.51.

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