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Influence of WS_2 Nanoparticles Lubricants on Physical Characteristics of Wrought Aluminium Alloys

Riyadh A. Al-Samarai*, Amjed Saleh Mahmood, Omar M. Ahmed
Electromechanical Engineering Department, College of Engineering, Samarra University, Samarra, Salah Ad Din, Iraq

Abstract

The present study considers the influence of WS_2 nanoparticles lubricants on physical characteristics of wrought Aluminium alloys. It is investigated parameters-performance relationship via tribological pin-on-disc tests, the pin is made of Aluminium alloys and the disk is made of AISI.1045, and the humidity was 70%. Oils with WS_2 nanoparticles and without them reveal the loss rate of wear. In this study, the coefficient of friction (CoF) is reduced from 0.27 to 0.22 and the wear rate decreased from 0.128 x 10^{-6} Nm^{-1} to 0.107 x 10^{-6} Nm^{-1} at a load of 20 N. All worn surfaces were typically three types in wear mechanisms such as adhesive, abrasive, and oxidative wear. In addition, the use of nanoparticle enhanced viscosity. This study showed promising results and concluded that the wrought Aluminium alloy to be the superior with WS2 nanoparticles, Furthermore, the wear rate has been reduced by 14% comparison without the use of WS_2.

Keywords: anti-wear, lubricating oil, tribology, WS_2 nanoparticles, wrought aluminium.

تأثير الجسيمات النانوية لثاني كبريتيد التنكستن (WS2) المضافة مع الزيت على الخصائص الفيزياوية لسبائك الألمنيوم المطاوع

رياض عزاوي بدر، امجد صالح محمود، عمر محمد احمد
قسم الهندسة الكهروميكانيكية, جامعة سامراء , كلية الهندسة ,صلاح الدين، العراق

الخلاصة

تتناول الدراسة الحالية تأثير جسيمات ثاني كبريتيد التنكستن النانوية WS_2 المضافة للزيت على الخصائص الفيزياوية لسبائك الألمنيوم المطاوع. تم فحص علاقة المتغيرات والأداء عن طريق اختبارات البليان بواسطة طريقة الدبوس على القرص، الدبوس مصنوع من سبائك الألومنيوم المطاوع والقرص من حديد الصلب نوع AISI.1045 وكانت الرطوبة 70 ٪. الزيوت مع الجسيمات النانوية WS2 وبدونها تكشف عن معدل فقدان البلى. في هذه الدراسة تم تخفيض معامل الاحتكاك (CoF) من 0.27 إلى 0.22 وتراجع معدل البليان عند حمل 20 N من 0.128 x 10−6 Nm−1 الى 0.107 x 10−6 Nm−1 . كانت جميع الأسطح البالية عادة متكونة من ثلاثة أنواع من البليان هي اللاصقة ، الجلخ ، وبليان الاكسدة.. بالإضافة إلى ذلك ، فإن استخدام الجسيمات النانوية عزز لزوجة الزيت. كما أظهرت هذه الدراسة نتائج واعدة وخلصت إلى أن الخصائص الفيزياوية لسبائك الألومنيوم المطاوع هي الأفضل مع استخدام الجسيمات النانوية WS_2. علاوة على ذلك ، كان الانخفاض في عمق البلى 14٪ مع استخدام WS_2

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*Email: riyadh2824@yahoo.com

Introduction

In recent years, it has been proved that the uses of different nanoparticles on reducing wear of high-loading, and improving that lubricants properties could achieve the objective of reducing the wear [1]. However, no comprehensive studies have shown a comparative assessment of nanoparticles. Some studies investigated nanoparticles, and show conflicting results. It has been discovered that MoS2 is mixed with the oil as a materials powder, and improve the properties of contact compared to typical lubricants [2]. Tangential resistance is associated with shears to the weak interaction between layers [3, 4]. The most of particles are effective in increasing resistance of MMC containing to 15% of the silicon particles, continuously or intermittently, and is connected by friction and cohesion, and consequently, the wear for each metal depends on a high load, and is not associated with corrosion resistance in less severe conditions of friction [5]. Depreciation depends on the load that points to the law of Archard. In addition, increasing the applied load increases temperature [6]. This means that the mechanism for rapid deterioration, at increasing sliding rate / speed / distance; loss of accumulated depreciation increase. To reduce stress, Chang et al., [7] have searched the properties of TiO2 on piston surfaces. They concluded that the lubricant with TiO2 can protect the surface. They reached the fact that there the ratio of Cu. NPs to SPs is 7.5:92.5 with the mixture of oil could improve the oil containing SPs. Gu et al. [8] has searched the application of CeO2 and CaCO3 nanoparticles and the tribological reactions of calcium, cerium, an oxide film. The use of nanoparticles such as WS2, CeO2, CaCO3, and MoS2 could reduce of the contact of surface and reduce the wear by the film. Thus, the nanoparticles, which are added to the lubricant, can protect the surface. The present study considers the influence of WS_2 nanoparticles lubricants on tribological characteristics of wrought aluminum alloys.

Materials and Methods

Chemical analysis was conducted for the wrought aluminum alloy. The chemical analysis is illustrated in Table-1. The wear was analyzed using X-ray, scanning Electron microscopy SEM and atomic force microscopy AFM. Vickers hardness was (ASTM E-384 Std), (Load: 80gF, 12 sec). Roughness average Ra = 0.25 ± 0.05, taking into consideration WS_2 nanoparticles μm. Vickers hardness Hv = 95.25 ± 6 kg/mm^2, on disc of steel AISI 1045 (Ra = 0.2 ± 0.05 μm, Hv= 312 ± 20 kg/mm^2. Pin-on- dick wear tester was at temperature 25 ^{0}C, 70% humidity, a fixed sliding speed 1.32 m/s, and load at 10, 20, 30 N respectively. The samples were polished to a 0.25 μm and cleaned by acetone. Experiments were repeated at every boot to determine which transition could effect. The diameter of the specimen was,10 mm, and it was cleaned for 3 min in acetone. After that, the test used commercial oil. The data of Lubricant are given in Table-2, in addition to a ratio of 0.05 g/l WS_2 nanometric tungsten disulphide nanoparticles (WS_2). The tests were run for 60 min to create a total distance of 75 m. SEM is used to study the microstructures of the samples as shown in Figure-(1a) which is illustrated the microstructures without adding the WS_2 and Figure-(1b) which is illustrated them with WS_2. All samples are tested under contact load =10, 20 and 30N, sliding speed = 200 as illustrated in Table- 3.

Wear rate *(WR)* was calculated by using:

$$WR=\Delta W/S.D \tag{1}$$

Wherein ΔW is the the mass loss and *S.D* is the sliding distance.

The coefficient of friction *(μ)* of composite was calculated from:

$$\mu = Ff / Fn \tag{2}$$

Wherein *Ff* is the force and *Fn* is the applied load.

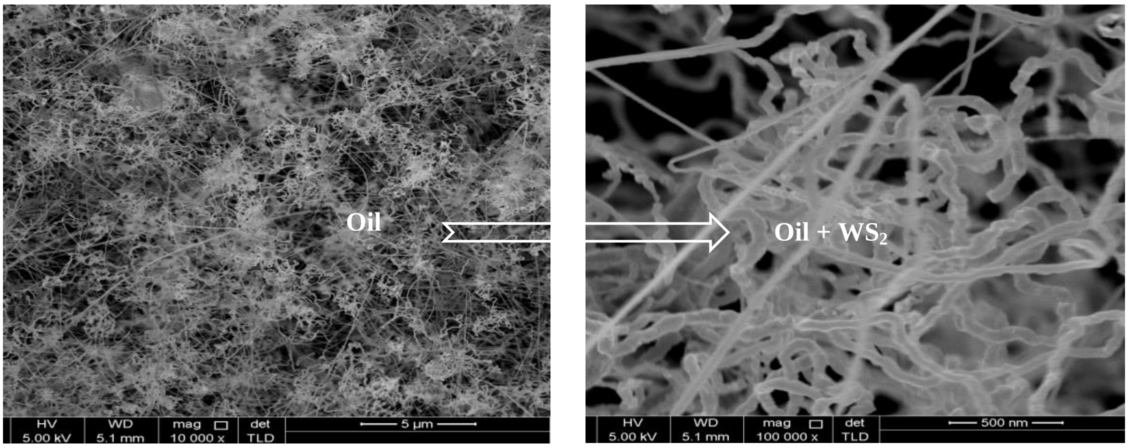


Figure 1-SEM of (a) Oil and (b) Oil with WS2.

Table 1-Compositions of alloy (wt %)

IADS	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Ni	Al
A 3003	<0.05	0.38	0.02	1.08	<0.02	0.02	<0.02	<0.01	<0.02	Balance

Table 2-Lubricant data

Lubricant type	Viscosity(mm^2/s) index, ASTM, D 2270	Additives	Density (g/ml)	Flash point, °C, ASTM D 92
Mobil 1	168	None	0.95	210

Table 3-Results for friction coefficient and the wear rate under contact load =10, 20 and 30N, sliding speed = 200 at Lubricant sliding.

Load (N)	M	S.D (m)	$\times10^3$ Oil	Oil +WS2	Oil	W.R $\times10^{-6}$(N/m) Oil +WS2	Oil	Oil +WS2
	0.2870	4.7520	0.1122	0.0942	0.1473	0.1457	0.1815	0.1383
10	0.2600	9.5000	0.0837	0.0732	0.1158	0.1062	0.1579	0.1473
	0.2200	14.2560	0.0802	0.0661	0.1052	0.0992	0.1573	0.1332
20	0.2700	19.0000	0.0679	0.0626	0.1000	0.0957	0.1468	0.1315
	0.2600	23.7520	0.0647	0.0605	0.0986	0.0956	0.1447	0.1263
30	0.2500	28.5000	0.0561	0.0691	0.0987	0.0942	0.1398	0.1228

Results and discussion

Friction and Wear Results

Figure-2 shows that the CoF with WS_2 is lower than the CoF without WS_2 nanoparticles, and both are inversely proportional with the load. It is known that WS_2 nanoparticles reduce temperature and friction, leading to decrease wear. Furthermore, micro hardness can estimate the change in viscosity of the contact surfaces. The ability of the lubricant to promote the strength and the wear was better with the addition of WS_2 nanoparticles. It promotes the film at low temperatures which reduces the friction. Contact surfaces in the rough were found equal to Ra =35 µm. The wear rate was high when Ra gets a high value. The most dominant parameter was Ra. A change on the surface was after a few of sliding, WS_2 can be accessed in the contact surface, thereby improving the friction behaviour [9, 10]. The depth of wear differs from one alloy to another, as one would expect from wear theory. The cause of several resistances of wear at the start is a layer between the corroded surface of disc and pin and this is a continuation of the process and hardness [11]. All wear parameters at medium level leads to an overall loss of weight [12].

Figure-3 shows that the wear is reduced by using WS2 at different loads. However, without WS2, the wear increases as load increases. There was adhesive at all loads; the wear was inversely proportional to the sliding distance which leads to a reduction of wear rate. This was in direct contrast to the effect of load in both alloys.

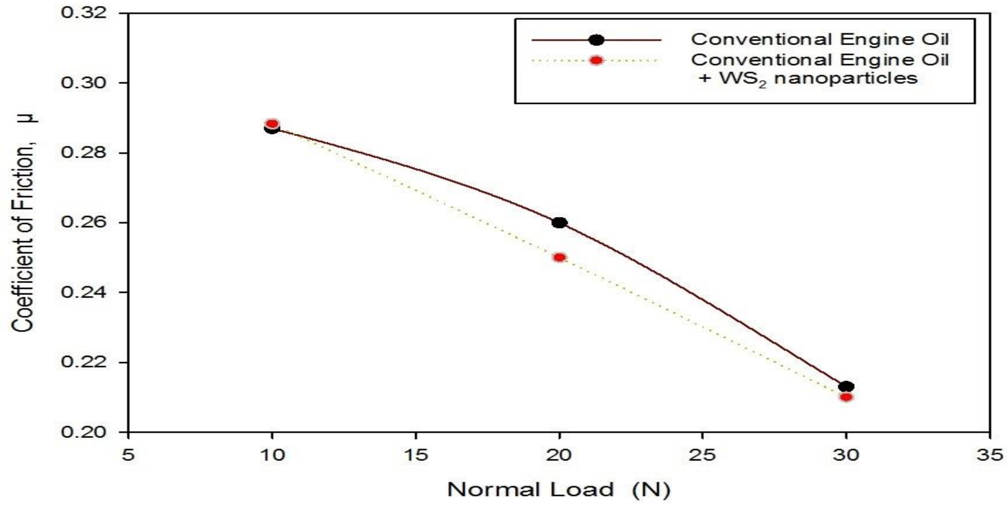


Figure 2-CoF versus normal loads.

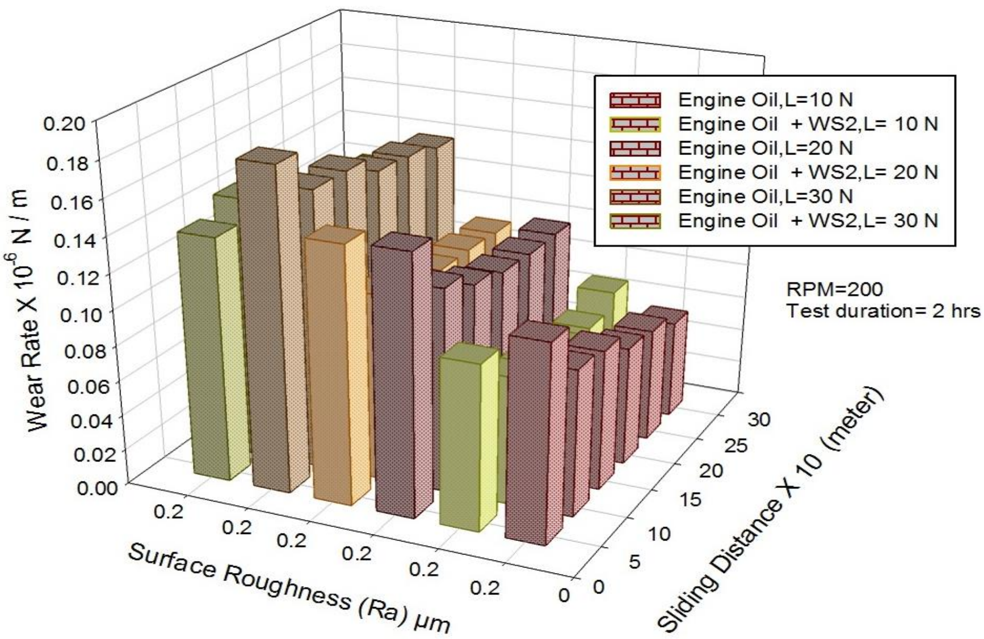


Figure 3-Wear rate versus sliding distance for different loads.

Surface Analysis of Worn Surfaces

Figure-4 shows that the profiles of curve reflect of WS2 adopted the track after 30 min and load 30 N at 200 rpm. The wear in the alloy with the use of WS_2 is better. However, the use of WS_2 reduced the wear rate, it could be associated with an increase in viscosity. The alloy which shows deeper traces of wear is revealed to more material which is lost from the pin, and it is due to deep fluctuations [12-15]. The changes in surface topography and roughness of pin are tested; ORL formation was observed in Figure-5. However, further changes have been observed on the pin check. Thus, the surface profile curves were used for analysis.

Figure-6 shows small debris and the matrix consists of fractured particles, microgrooves parallel sliding, and the mixture is confirmed by EDS. The oxidized particles, in wear mixed with steel material counter tribo-layer, are formed under the microscope [15-18]. In general, based on the erosion of the surface, EDS indicates the oxygen in the worn surfaces, which suggested the contained aluminium oxide particles. The WS2 leads to increment in the formation and a decrease in abrasion and stripes [19]. The relative motion between forced surfaces raised the temperature and that leads the oils to use the WS_2 nanoparticles that dictated by adhesion and deformation, i.e., the force is necessary to the adhesion that made the surface worn surfaces which is similar to the cold welding [20-24].

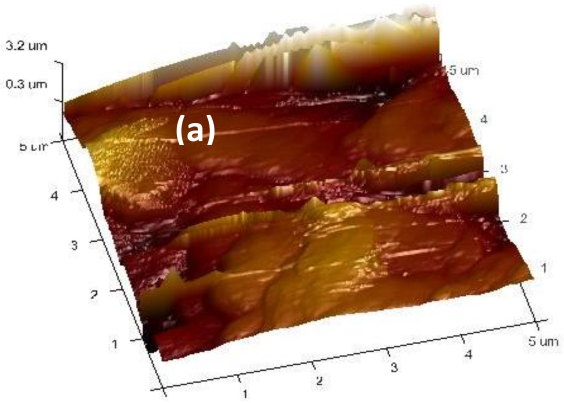
Figure-7 shows the wear rate from 25 to 50 meters with the deepening of wear rate. The worn were found to be similar, and a micrograph for the alloy was tested for 1 hr corresponding to a distance. The wear which increased again to an almost with a constant level, the slightly wear is obtained with the alloy compared with the use of WS_2 [25-27]. The wear is reduced compared to the absence of WS_2 where it is associated with improvement of viscosity [28]. In addition, the adding of WS_2 would reduce direct shear with the mixed irregularities of lubrication regime.

Finally, Figure-8 shows the SEM corresponding AFM of the surface under a load of 10 N with WS_2 and without it. The wear rate was proportional to the load. Most alloys operated in a steady state after about 2 m with some exceptions. The wear was different from one stage to another. However, each of alloys shows wider and deeper traces of wear, which revealed that more material losses are from pin; this is due to deep fluctuations in the curve and strong adhesion at contact regions [29]. The depth of wear differs from alloys to another. However, several resistances at a layer between the corroded surfaces of disc and pin, and that continuation of the process that leads to hardness [30,31]. In general, the initial period of the corresponding sliding was below the strength probably had some effects in reducing (CoF) at an increasing distance [32]. To sum up, researchers stated that the rheological properties of nanoparticle lubricants and tribological performance are used to reduce friction and wear. In addition, oils without nanoparticles reveal the level of friction losses and that the nanoparticles dispersed lubricating oil can reduce wear and improve mechanism. Nanoparticles used such as CaCO3, WS2 and MoS2, and promotion of the contact surface as a combined reduction of wear on the film surface. Thus, the lubricant that is added to the nanoparticles may protect the surface. In comparison with other studies, this study showed promising results and concluded that the wrought Aluminium alloy to be the superior with WS2 nanoparticles, Furthermore, the wear rate has been reduced of 14% comparison without the use of WS2.

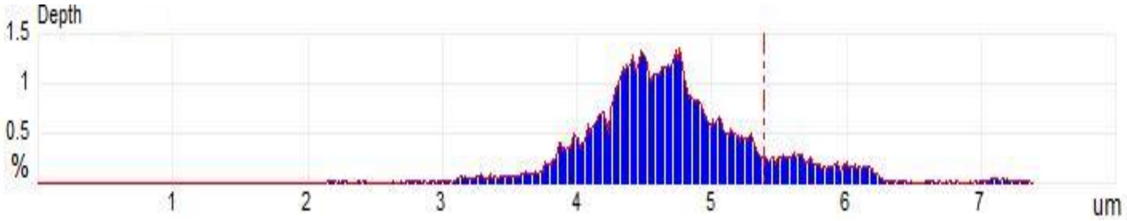
Conclusion

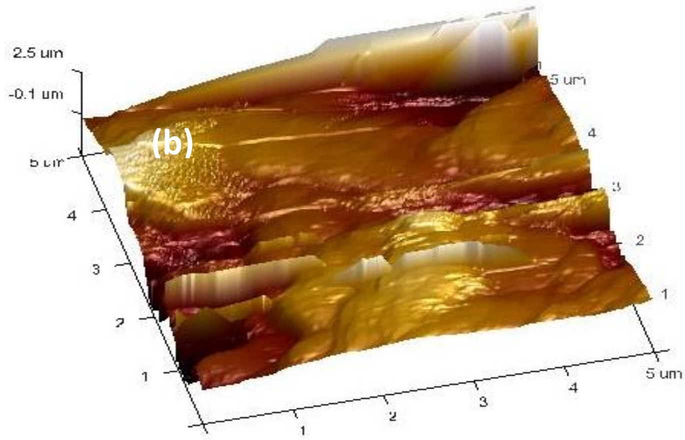
The following conclusions can be drawn from the work reported in this study:

1. The friction and wear resistance were improved with the use of WS_2 due to the strength of nano-features which promotes the film at low temperatures to reduce the (CoF). The coefficient of friction has been reduced from 0.27 to 0.22, and the wear rate decreased from 0.128 x 10^{-6} Nm^{-1} to 0.107 x 10^{-6} Nm^{-1} at a load of 20 N.
2. The maximum reduction of wear rate was 14% with the use of WS_2 in comparison without it.
3. The use of the WS_2 nanoparticles could improve the viscosity of the oil.
4. All worn surfaces were typically three types in wear mechanisms such as adhesive, abrasive, and oxidative wear.
5. The use of WS_2 nanoparticles with oil could lead to promising results.

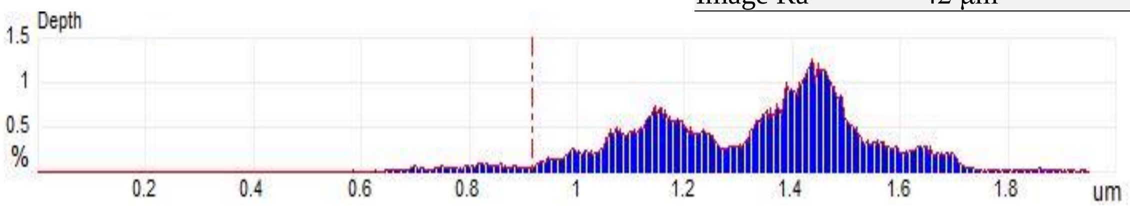


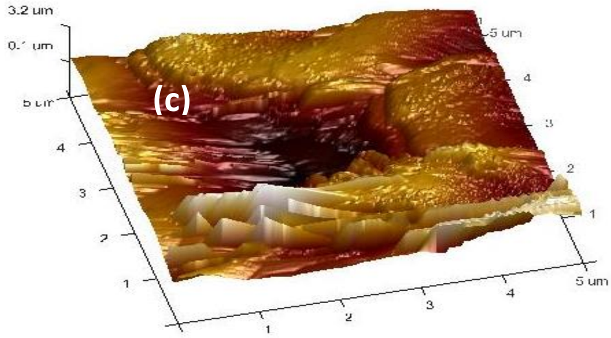
Roughness results	
Image Raw Mean	73 μm
Image Mean	0.0014 μm
Image Z Range	104 μm
Image Surface Area	23.4 μm
Image Projected Surface	25.0 μm
Image Surface Area	33.6 %
Image Rq	67 μm
Image Ra	35 μm





Roughness results	
Image Raw Mean	97 µm
Image Mean	0.00145 µm
Image Z Range	104 µm
Image Surface Area	23.4 µm
Image Projected Surface	25.0 µm
Image Surface Area	33.6 %
Image Rq	77 µm
Image Ra	42 µm





Roughness results	
Image Raw Mean	93 µm
Image Mean	0.0145 µm
Image Z Range	104 µm
Image Surface Area	33.4 µm
Image Projected Surface	25.0 µm
Image Surface Area	33.6 %
Image Rq	85 µm
Image Ra	47 µm

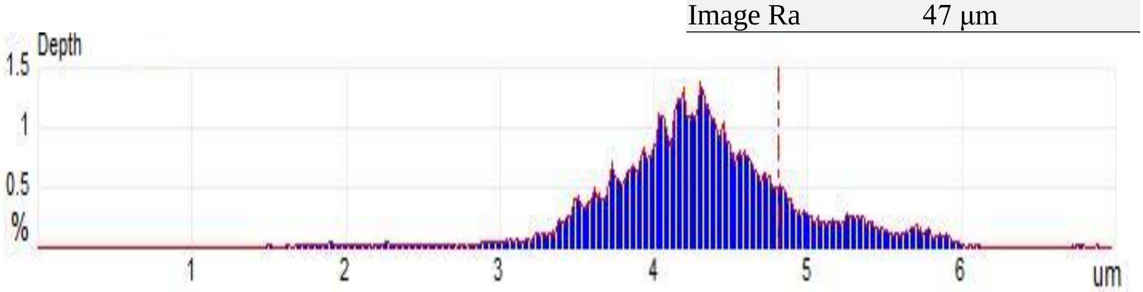


Figure 4-3D Optical surface after 30 min, (10, 20 and 30) N loads, 200 rpm. (a) Oil only and (b) oil with WS_2.

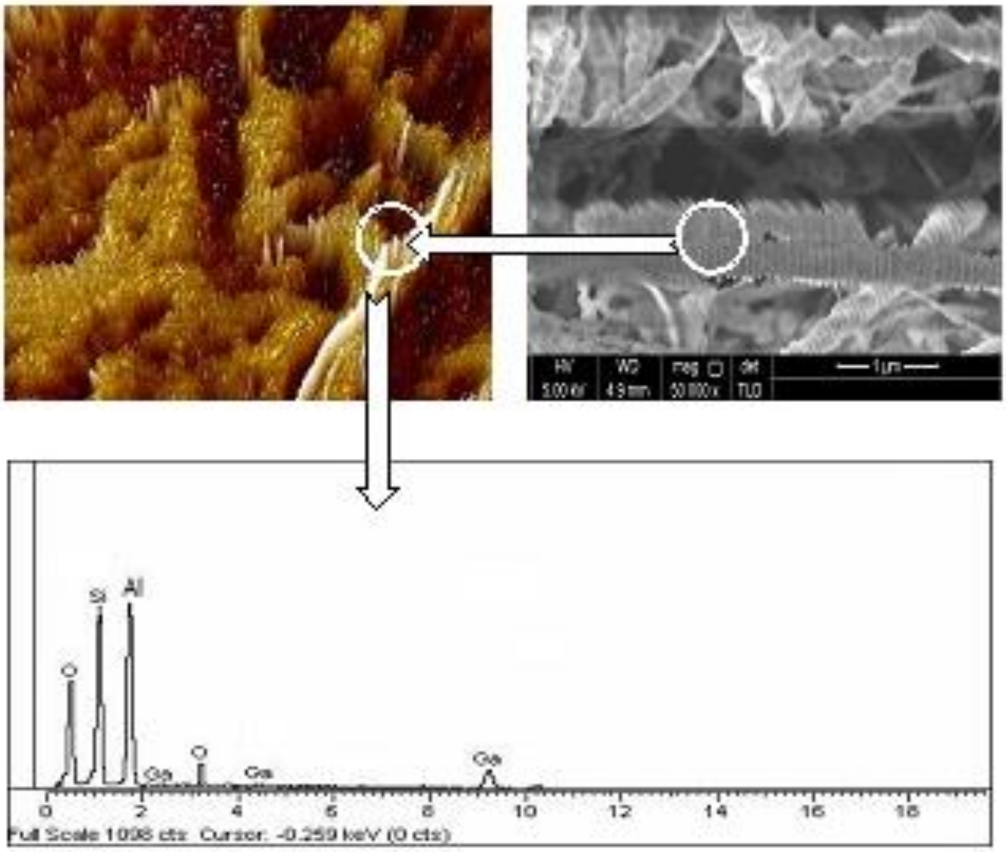


Figure 5-SEM- EDS & AFM of ORL formation observed at 30 N.

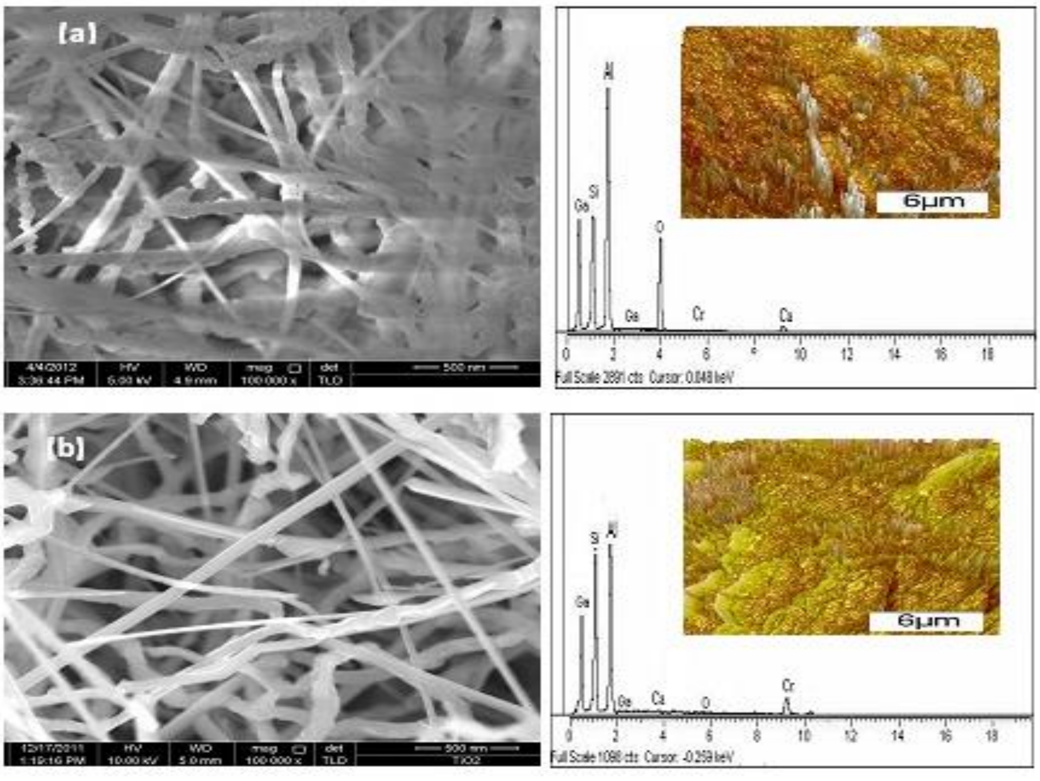


Figure 6-SEM and corresponding EDS for wear rate of (a) Lubricated with oil and (b) oil + WS_2.

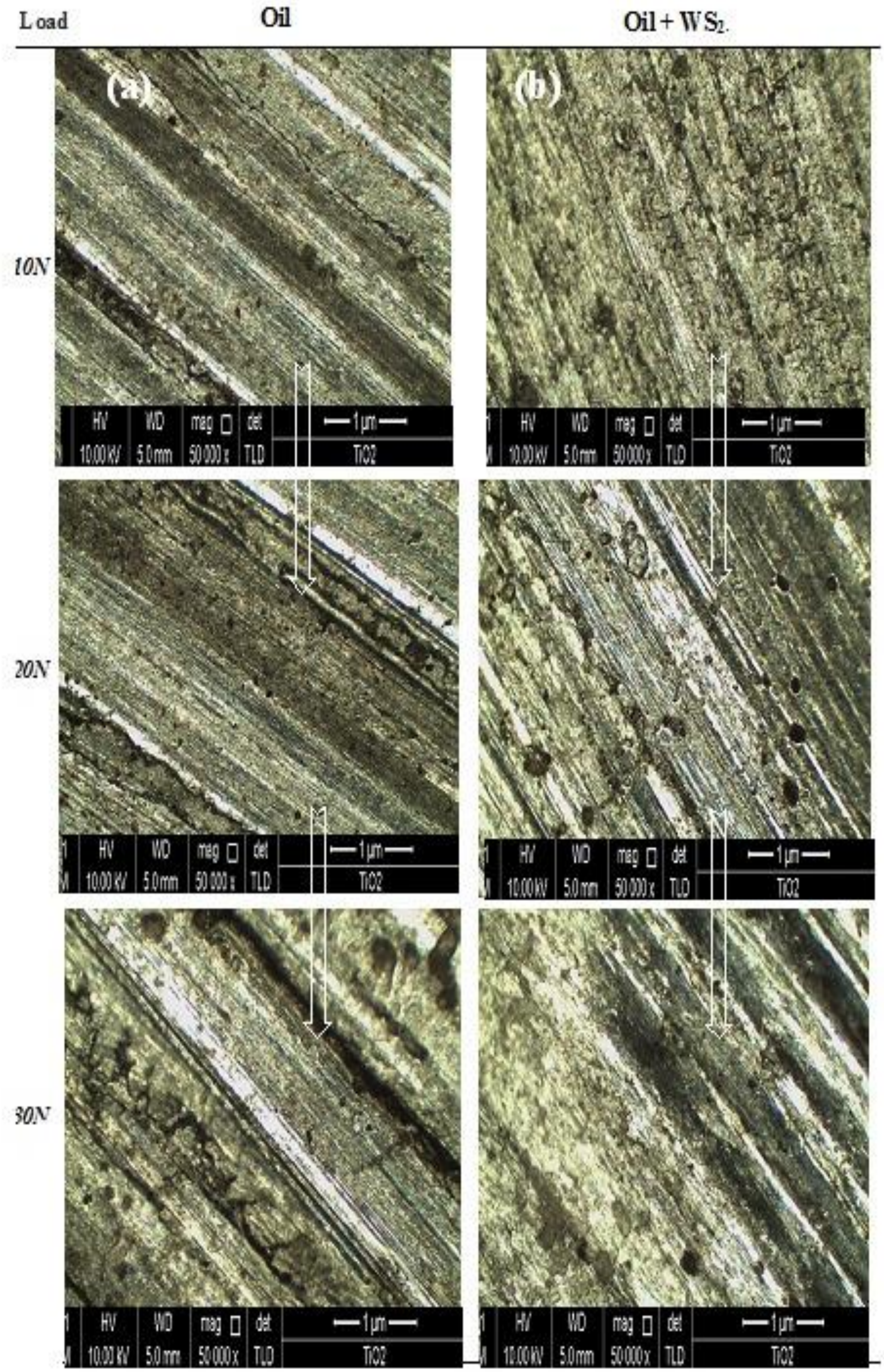


Figure 7-SEM of wear at loads (10, 20, 30) N for (a) Oil only and (b) oil with WS

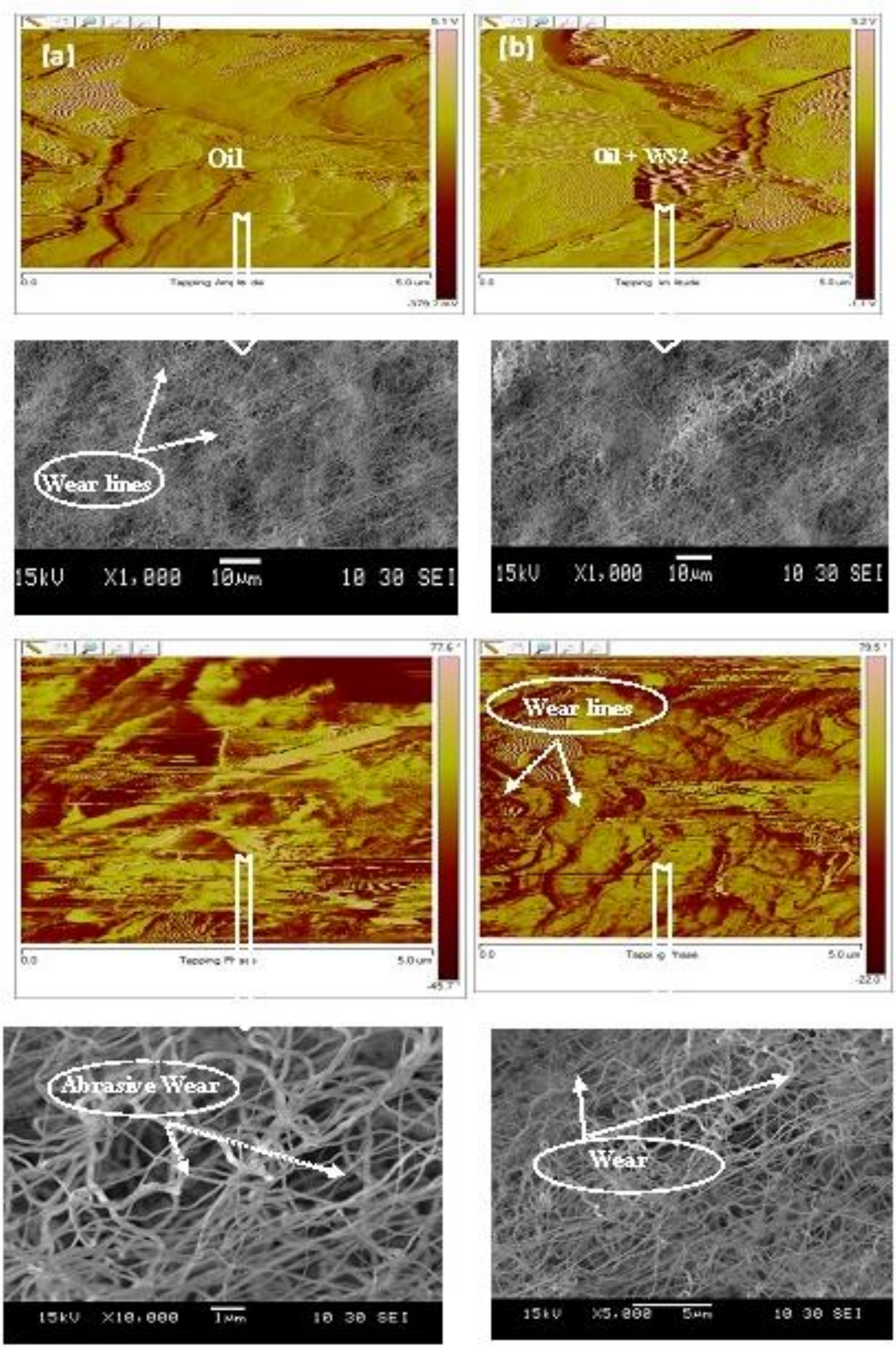


Figure 8 -SEM corresponding AFM of surface under load (10) N for (a) oil only and(b) oil with WS2.

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