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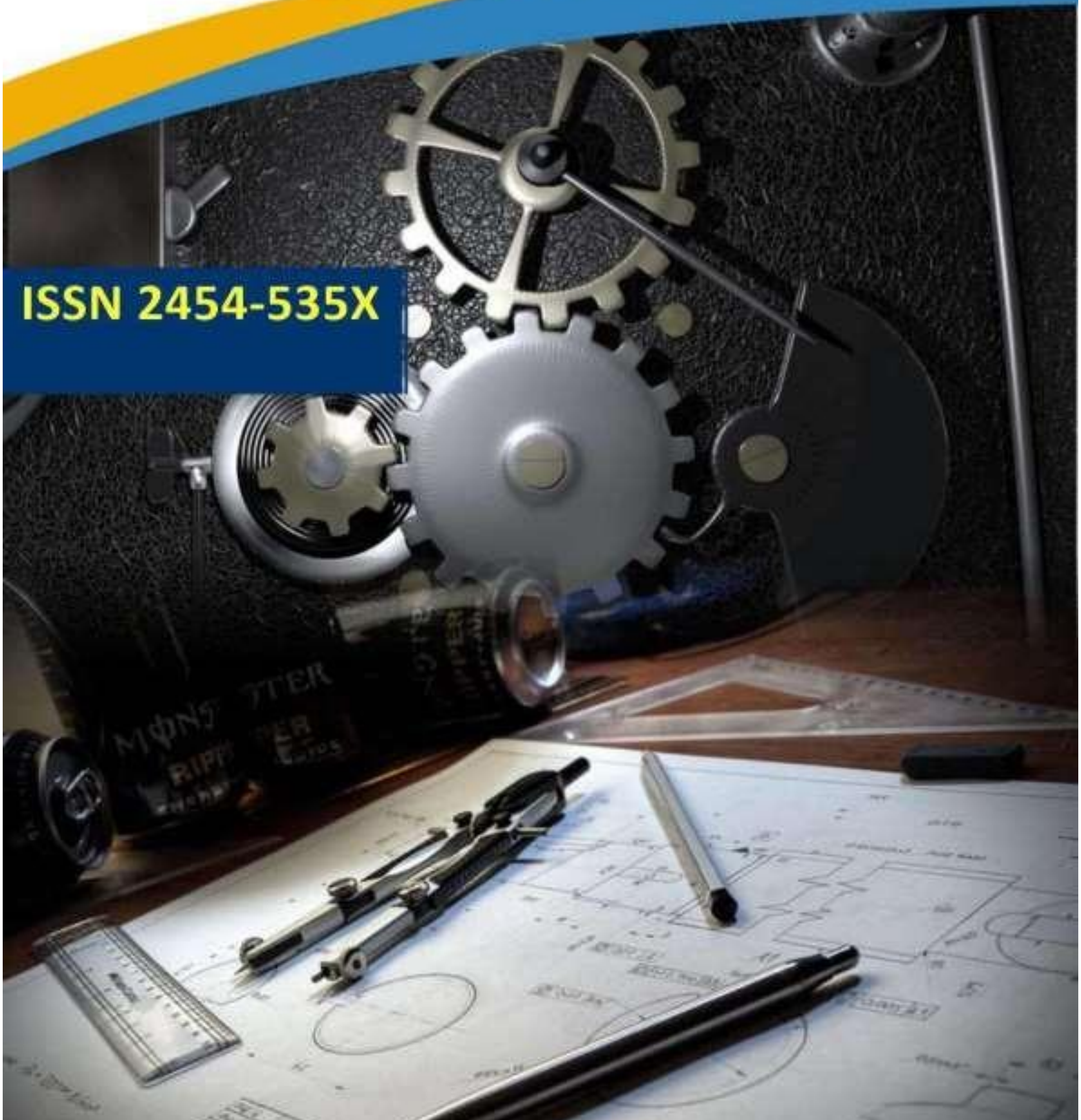

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The Effect of MgO & TiO_2 on Wear Behavior of Composite Material

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ABSTRACT: Due to their exceptional hardness and capacity to withstand wear, aluminum metal matrix nanocomposites have garnered significant interest for use in aerospace, automotive, and marine applications. This work used powder metallurgy to create a metal matrix nanocomposite made of titanium dioxide (TiO2) and magnesium oxide (MgO) nanofillers of ceramics with an aluminum (Al) matrix. Brinell hardness, optical microscopy, X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), and interfacial region were used to assess the importance of controlling the nanofiller surface for improving mechanical properties as well as the role of surface modifications and microstructure properties. It was found that the hardness and wear resistance of the nanocomposite are improved by the interface interaction between the nanofillers and the aluminum matrix. The wear test was performed by varying the applied stresses as

KEYWORDS: nanocomposites; aluminum matrix; powder metallurgy; SEM, XRD; hardness; wear.

INTRODUCTION

These days, composite materials are necessary due to technological advancements. Monolithic materials with no reinforcement materials added to enhance their qualities yielded less usable specifications [1, 2]. Magnesium, titanium, and aluminum are significant metal matrix materials. However, ZrO2, TiC, SiC, B4C, and Al2O3 are frequently used as fibers or particles in reinforcing ceramics [3]. Due to its many applications and studies, aluminum matrix composites are valued for their excellent thermal conductivity, low density, and high resistivity [4]. There is a growing need for innovative materials with superior mechanical and thermal qualities for a wide range of applications in order to enhance aerospace technology. The electronics and computer sectors are also included in these applications [5]. Because of its safety, aluminum is a material that is experiencing a rebirth. Samples preparation

The Al-TiO_2 and Al-MgO nanocomposites were synthesized using powder metallurgy route. Aluminum powder with particle size (50µm) , while the nano sized TiO_2 and MgO are 30 and 40 nm respectively. The powders were weighed accuracy, and then added the reinforcement ceramic materials (TiO_2 or MgO) with 3, 6, 9 and 12 wt. %. The powders were mixed carefully with methanol as a binder by planetary ball mill mixer for 1 hour.

After mixing operation, the mixture will compact. Pressure was enforced to achieve by using unaxial pressure manual hydraulic press at (200) Mpa to achieve green compacts of 10 mm in diameter 14 mm in height. Finally, the green compacts were sintered in muffle electrical furnace at 650 C° for 30 min [16]. Table. 1 shows the physical and mechanical properties of the powders used in this work.

Table 1. Shows the physical and mechanical properties of the powders used in this work.

Powder	Particle size	Density g/cm3	Melting temperature C°	Young modulus Gpa	Manufactured company
Al	50 µm	2.7	660	69	ACM material

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TiO2	30 nm	423	1843	230	Sky spring nanomaterial ,Inc.
MgO	40 nm	3.58	2852	270	Nanjing Nano technology

The phases analysis (XRD and FESEM)

The phases analysis of nanocomposites (Al-TiO_2), (Al-MgO) were carried out by X-ray diffraction (XRD) SHIMADZU 6000, PW-1800 diffractometer with Cu=1.54060 A r, 40Kv, 30 mA.

While the phases of the synthesized nanocomposites were analyzed by scanning electron microscope FESEM TE SCAN (RAZI FOUNDATION) HV: 15kv.

Hardness test

The hardness test was done by using Brinell hardness apparatus for the polished specimens of nanocomposite (Al-TiO_2 and Al-MgO). Hardness test was carried out for at least four different positions in the surface of each specimen and then calculated the average as shown in Table.2.

Table 2. Brinell hardness values of the specimens before and after sintering.

Material	Sample	Before sintering	After sintering
TiO2	3% TiO2	154	157
	6% TiO2	157	158
	9% TiO2	157	1 60
	12% TiO2	159	162
MgO	3% MgO	152	153
	6% MgO	1 53	155
	9% MgO	155	157
	12% MgO	160	164

Wear test

Wear test was carried out using pin-on-disc technique (supplied by Ducom) according to ASTM –G99 for sintered specimens as 10 mm diameter and 14 mm height. The rotating disc made of hardened tool steel 60 HRC with rotating speed 500 rpm and track radius 6 cm. Initially the specimens weighed using electronic weighing balance (Mettler AE-60 type) with an accuracy of 0.0001 gm. The experiments were done by changing the loads as 2,4,6,8 and 10 N at constant time 6 min and sliding time as 3, 6, 9,12 and 15 min at constant load 6 N , wear rate of the sintered specimens was calculated by the following formula [15].

Wear rate $=\Delta WW/S_D$ (g/cm) ……. (1)

$\Delta WW = WW_1 - WW_2$

Where:

WW 1: weight of the specimen before the test

WW 2: weight of the specimen after the test

While the sliding distance is calculated as

$S_D = 2\pi.r.n.t$.. (2)

Where:

r : radius of the center rotating

n : number of rotating disc (500 rpm)

t : sliding time (min)

RESULTS AND DISCUSSION

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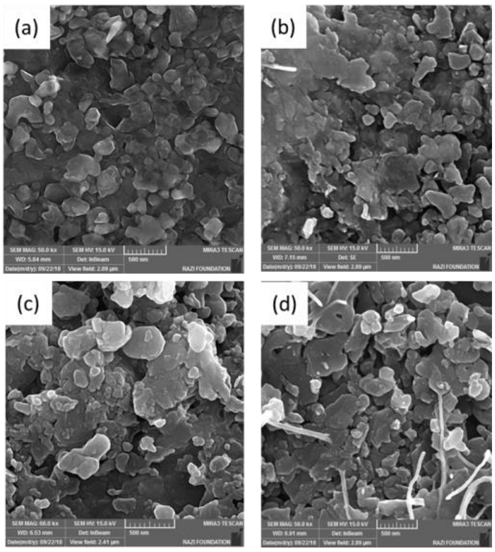
Microstructure analysis

Fig 1. And Fig 2. shows the field emission scanning electron microscope (FESEM) images for the nanocomposites (Al-MgO and Al-TiO_2) synthesized by powder metallurgy route. Mixing conditions as the time and speed extremely affected on the distribution of nano TiO_2 and nano MgO in Al matrix. Each of TiO_2 nanoparticles and MgO nanoparticles were homogeneously distributed in Al matrix and filling the voids of Al matrix. Increasing the concentration of each TiO2 nanoparticles and MgO nanoparticles causes more



filling the voids between the particles of Al matrix with little amount of porosity. This is attributed to the arrangement of powder particles as a result of the compacting pressure. The compacting pressure causes a localized plastic deformation at the contact points between particles. Furthermore, the increasing in weight percentage of TiO_2 or MgO nanoparticles causes shrinkages of pores. This is agreed with Amin et al [16]. After sintering process, the increasing of the concentration of TiO_2 or MgO leads to a good diffusion of nanoparticles in matrix and decrease the porosity. This is return to forming the necking between particles, and then these necks will coalesced together and in turn decreasing the porosity and improving the mechanical properties with high

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stability of the phases of the resultant nanocomposites [17].

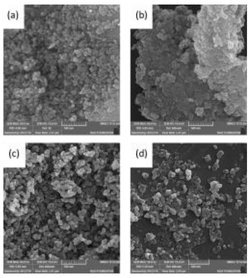

Figure 1. Secondary electron FESEM images of surface of (a)3%wt MgO , (b)6%wt MgO, (c)9%wt MgO, (d)12%wt MgO, of nanocomposite.

Figure 2. Secondary electron FESEM images of surface of (a)3%wt TiO_2 , (b)6%wt TiO_2, (c)9%wt TiO_2, (d)12%wt TiO_2, of nanocomposite

X- Ray Diffraction (XRD) analysis

The phases identified by XRD analysis were similar for all nanocomposites. Although the intensities of the peaks were different, only magnesium oxide (MgO) and aluminium (Al) phases were detected for (Al/MgO) nanocomposite. While for (Al/TiO_2) nanocomposites, only titanium oxide (TiO_2) and aluminium (Al) phases were detected. Fig-3 shows the XRD pattern of a nanocomposites (Al/MgO) and (Al/TiO_2) respectively.

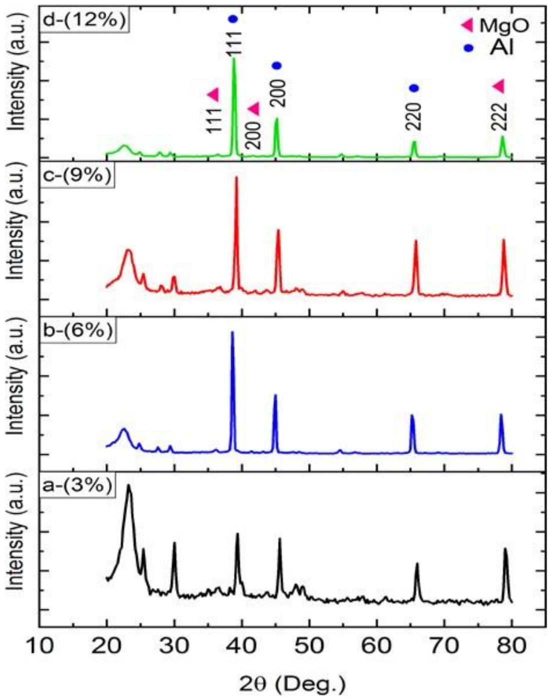

Figure 3(a). XRD diffraction pattern of Al matrix doped MgO (0.03-0.12)%wt

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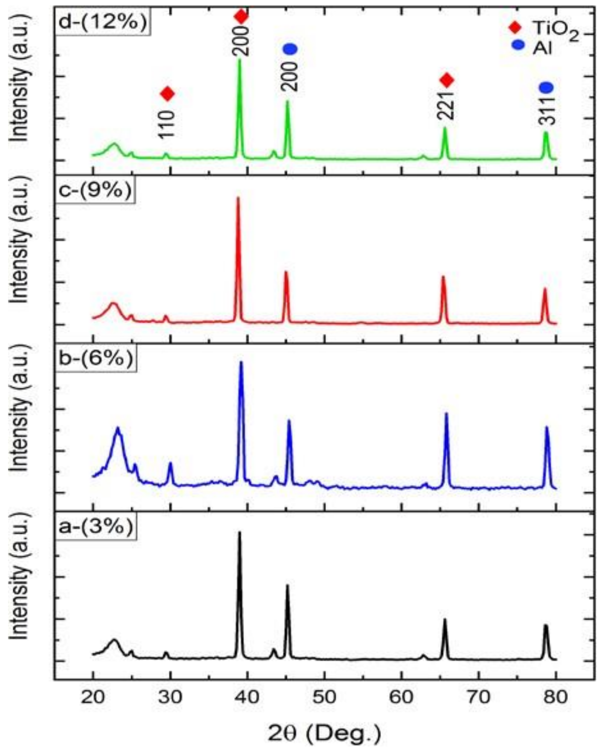
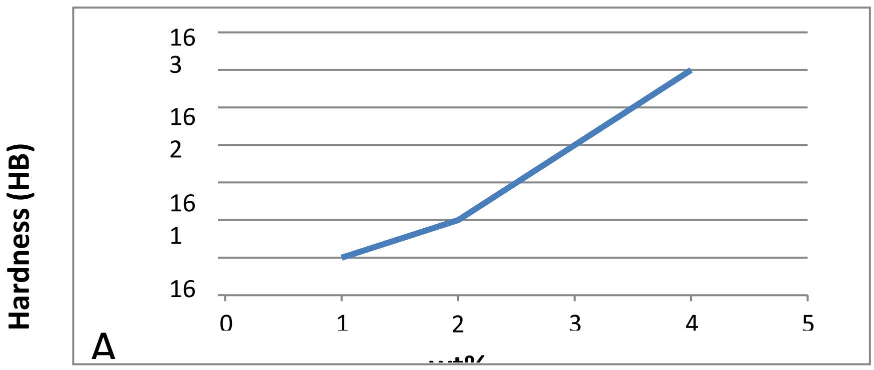


Figure 3(b). XRD diffraction pattern of Al matrix doped TiO_2 (0.03-0.12)%wt

Hardness properties

The Hardness test was conducted using Brinell hardness test on (Al/MgO) and (AL/TiO_2) nanocomposites. The test results show that hardness of each the nanocomposites increases with increasing MgO nanoparticles and TiO2 nanoparticles content. The hardness of (Al/MgO) nanocomposite higher than for (Al/TiO_2) as shown in Fig-4(A,B). This is due to the hardness of MgO more than the hardness of nano TiO_2 and fill the pores between aluminum particles, as well as MgO nanoparticles are responsible of work hardening. Also another physical parameters affecting on the hardness values such as binding energy and wettability between MgO nanoparticles and aluminum particles more than TiO_2 nanoparticles.



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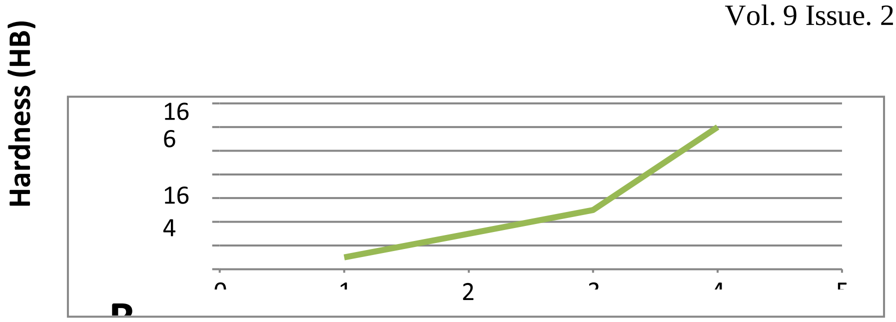

Figure 4. A show the effect of TiO2 on the hardness properties

B show the effect of MgO on the hardness properties

Sintering process leads to grain growth due to the sintering temperature extensively effect on hardness. This increasing the amount of MgO particles in Al matrix powder which prevent the grain growth and then improve sinter ability more than TiO_2 particles, therefore the hardness will be improved. Nano MgO particles obstacle the plastic deformation which in turn increase the hardness more than nano TiO_2 particles.[19]

Wear test results

Changing the load at constant time

In this investigation, aluminum powder as a matrix was gradually reinforced with a little amount of TiO_2 nanoparticles and MgO nanoparticles to enhance the wear resistance of produced nanocomposites. Fig 5 illustrate the wear rate versus applied load about 5, 10, 15 and 20 N for all the weight percentages of nano TiO_2 and nano MgO. Wear rate increases with the increasing of applied loads for all the specimens, it is noted clearly that wear rate slightly decreases with increasing the amount of nano MgO more than increasing the amount of nano TiO_2. Nonlinear curves will increase with increasing the applied loads which in turn rising the temperature between the pin (Al/MgO or Al/TiO_2) and rotating disc as a result of friction between them Also increasing the weight concentrations of nano MgO increases the hardness more than nano TiO_2 and then decreasing wear rate. Increasing the applied loads constitute wear debris as a result of cracking and forming cavities at the surface. Increasing the loads will break the oxide films and ploughing them to form the wear debris, however causes delamination and abrasive wear. Increasing the applied load will increase the shear stress at the interfaces between the pin and rotating disc. Wear rate for Al/MgO slightly lower than for TiO_2. The increasing in appliedload lead to transfer wear mechanism from mild wear to severe wear and make more damage in the worn sufaces [7]

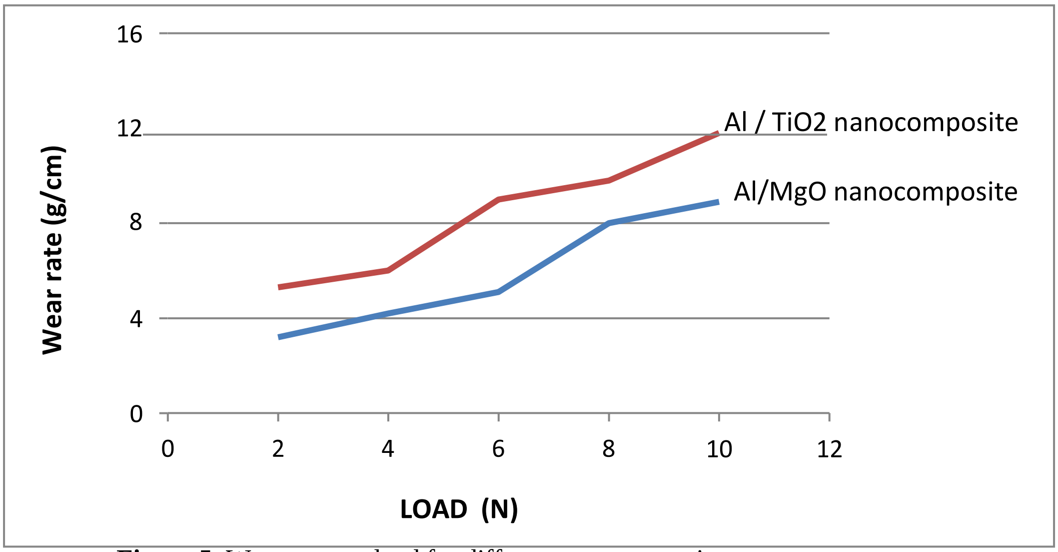

Figure 5. Wear rate vs. load for different nanocomposites at constant content.

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(12 wt%) of MgO and TiO2 for constant time (6 min)

Change the time at constant load

Demonstrated wear rate verses the sliding time. It has been shown that increasing in sliding time will increase wear rate. The effect of increasing in the sliding time on wear rate for all the specimens of this work is the same for that increasing in the los as discussed previously as shown in Fig 6.

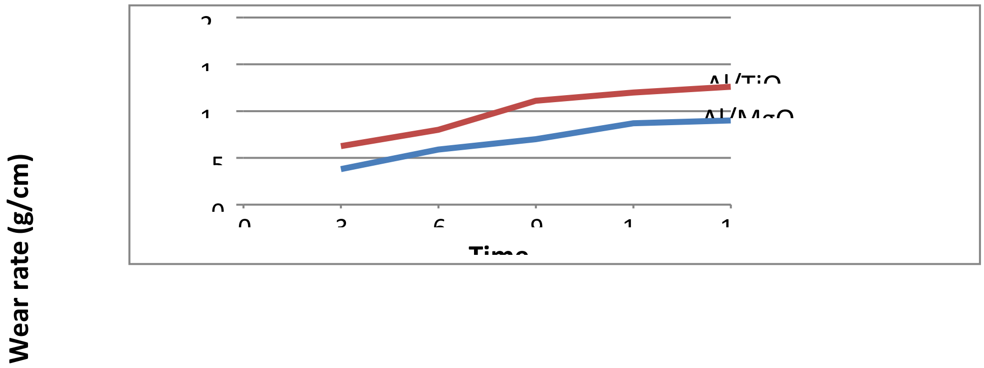

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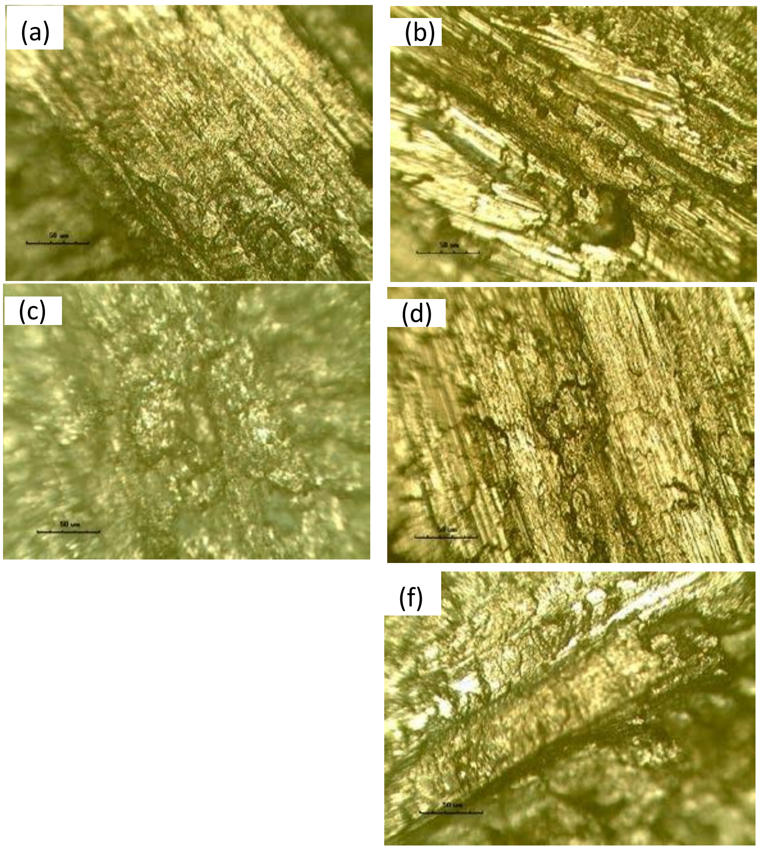
Figure 6. wear rate vs. time for different nanocomposite at constant content (12 wt%) of MgO and TiO2 for constant load (10N)

Surface topography

Figure 7 shows the surface topography of all specimens were examined by optical microscopy (OM). Increasing the percentages of nano TiO_2 and nano MgO into aluminum matrix leads to improve wear resistance (decreasing wear rate) for many reasons mentioned previously. The variation in wear resistance is considered asa result in changing the applied loads and time, which rises the heat temperature of friction between the rubbingsurfaces (the pin of nanocomposite and the rotating disc) and forming oxidation layer, which fragment and making grooves at the worn surfaces. These grooves are finer for the Nano-composite material with high percentages of nano Mg0 (12 wt.%) for wear test either changing the load or time which increases the hardness and wear resistance. The grooves refer to microcutting and micro-ploughing as result of the sliding between the pin and rotating disc. While at low percentages of the additive reinforcement nano TiO_2 or nano MgO the wide longitudinal grooves and partial irregular pits along the sliding direction are seen on the worn surfaces , therefore the size of fragment is larger than for high load and long time. Figure 7 depicts surface topography of the chosen specimen tested by wear technique this is in line with [18].



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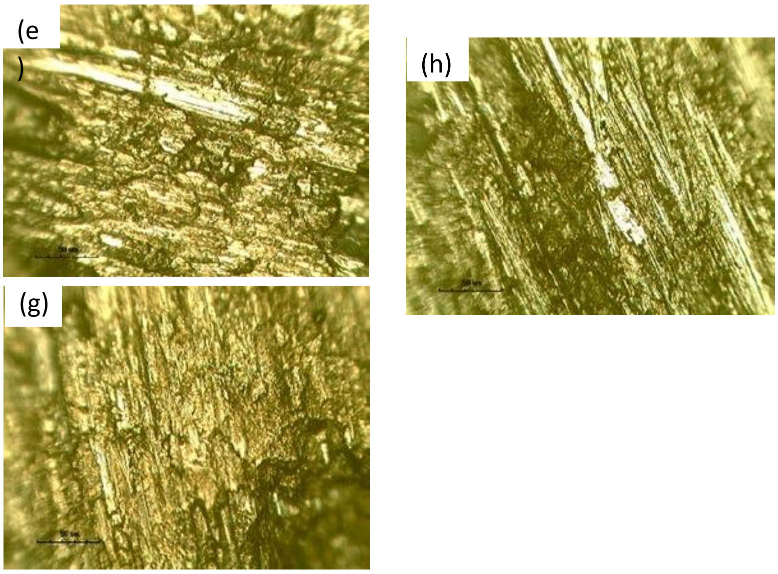

Figure 7. Show optical microscopy for the surface of nanocomposites a-3wt% Al-MgO, b-6wt% Al-MgO, c-9wt% Al-MgO, d-12wt% Al-MgO, e-3wt% Al-TiO_2, f-6wt% Al-TiO_2, g-12wt% Al-TiO_2, h-12wt% Al-TiO_2

CONCLUSIONS

1. SEM micrographs show that MgO and TiO_2 nanoparticles were homogenously distributed in aluminum matrix.
2. XRD analysis depicts the presence of Al, MgO, TiO_2 phases
3. The hardness of specimens with increasing MgO amount more than for TiO_2 to a value of 164 BHN
4. It is noted that increasing wear rate with increase of applied load for all specimens and noted decreasing the wear rate for Al/nano MgO than for Al/nano TiO_2.

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