



Improve Wear Resistance on Al 332 Alloy Matrix- Micro -Nano Al_2O_3 Particles Reinforced Composite

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Abstact

The wear behavior of alumina particulate reinforced A332 aluminium alloy composites produced by a stir casting process technique were investigated. A pin-on-disc type apparatus was employed for determining the sliding wear rate in composite samples at different grain size (1 μm , 12 μm , 50 nm) and different weight percentage (0.05-0.1-0.5-1) wt% of alumina respectively. Mechanical properties characterization which strongly depends on microstructure properties of reinforcement revealed that the presence of (nano , micro) alumina particulates lead to simultaneous increase in hardness, ultimate tensile stress (UTS), wear resistances. The results revealed that UTS, Hardness, Wear resistances increases with the increase in the percentage of reinforcement of Al_2O_3 when compared to the base alloy A332. The wear rates of the composites were considerably less than that of the aluminum alloy at all applied loads with increasing percentage of reinforcement when compared to the base alloy A332.

Keywords: Aluminium matrix composites, wear resistance, Micro -Nano Al_2O_3 particles.

1. Introduction

Interest in developing metal matrix composites for use in high performance applications has increased significantly [1]. Among these composites, aluminium alloy matrix composites attract much attention due to their lightness, high thermal conductivity, moderate casting temperature, etc.[2,3]. Various hard ceramic particle materials such as SiC, Al_2O_3 , MgO and B_4C are used extensively to reinforce aluminium matrices. The superior properties of these materials such as high refractive index, high hardness, high compressive strength, wear resistance, etc. makes them suitable for use as reinforcement in matrices of composites [4,5]

Normally, micro-ceramic particles are used to improve the hardness and ultimate strength of the metal. However, the ductility of the ALMCs deteriorates with high ceramic particle concentration [6]. It is of interest to use nano-sized ceramic particles to strengthen the metal matrix, while maintaining good ductility, high temperature creep resistance and better fatigue [7,8]. A variety of methods for producing nano-ALMCs have recently become available including mechanical alloying [9] ball milling [10], nano-sintering [11], etc. Compared with other methods, melt processing which involves the stirring of ceramic particles into melts, has some important advantages such as better matrix-particle bonding, easier control of matrix structure, simplicity, low

cost of processing and nearer net shape. Wear is a common occurrence on most plant and machinery and is often a slow and progressive process, which may be accepted, as normal. However, if the rate of wear on particular machine component is high, so that it requires frequent repair and replacement, then it may constitute a wear problem. Therefore, deciding whether a wear problem exists and requires attention calls for a degree of judgment of the circumstance. Several researchers have worked on sliding wear mechanism of ALMCs reinforced with ceramic particulates like SiCp, Al_2O_3 and garnet particles etc, and have observed improvement in wear resistance [12,13]. A dry sliding wear test under the load 5-30 N, was conducted on aluminum composite. Composites were prepared using stir casting method and reinforced with Al_2O_3 particles by [14]. They concluded that wear rate of composite and unreinforced alloy decreased with increasing load. Wear rate decreased with increase in volume fraction and particle size 125 μm . The wear surface appearance showed plastic deformation at matrix alloy when the composites wear was caused by abrasions. The present study was conducted to evaluate the effect of the nano micro alumina particles on wear behaviour of A332 alloy and develop a fundamental understanding of the wear mechanisms and wear induced micro structural changes of alumina particle reinforced A332 alloy composite during dry sliding at different load and sliding distances.

2. Experimental Procedure

2.1. Preparation of the Composites

A332 aluminium alloy and particulate alumina powder with size of (12 μm , 1 μm , 50 nm) respectively, were used as the matrix and reinforcement phases the chemical composition for alloy fabricated chemical composition of the A332 alloy fabricated is listed in Table. 1. Composite specimens were manufactured by stir casting methods using mechanical mixing of the molten alloy. Micro and nano-particles were heated at 1000 °C for 20 min and injected into the melt by using a stainless steel injection tube and inert argon gas in a graphite crucible inserted in a resistance heating furnace. The wet fraction of alumina powder injected into the composites were chosen (0.05-0.1-0.5-1) wt% micro-alumina and (0.05-0.1-0.5-1) wt% respectively nano -alumina. The stirring was continued for 15 min to produce homogenous mixture. . The speed of impeller was 400 rpm .Stirring process was started 10 min before addition of reinforcement particles in the melt and continued 15 min after that. Then, the stirrer was turned off and finally composite slurry was poured in a preheated cylindrical steel mould .The pouring temperature for the processes was 700 °C. The Design of experimental rig is shown in Fig. 1.

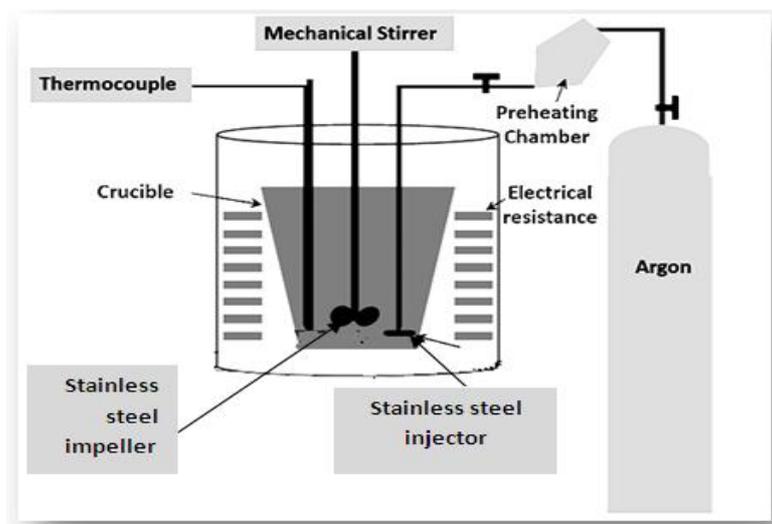


Fig. 1. Design of experimental rig.

Table1,
Chemical composition (wt %) of the A332.

alloys	Si%	Cu%	Fe%	Mg%	Zn%	Mn%	Cr%	Ni%	Pb%	Ti%	Al%
Nominal Chemical composition	8.5-10.5	2-4	1.2	0.5-1.5	1	0.5	0.03	0.025	0.02	0.03	Bal
A332	9.62	3.2	1.1	1.2	1	0.1	0.022	0.016	0,012	0.036	Bal

2.2. Measurements and Testing

The density of the samples was measured by the Archimedes's method, while the theoretical densities calculated by taking the densities of A332 aluminium alloy and Al_2O_3 particles were equal to 2.7 and 3.9 g/cm³, respectively. The porosity percentage in the materials was calculated according to the difference between the theoretical and measured density. To investigate the mechanical properties of the composites The Brinell hardness values of the samples were measured on the polished samples using a ball with 5 mm diameter at a load of 250Kgf. The tensile tests were carried out using Instron testing machine according to ASTM.B 557, respectively. The cross head speed was set at 3 mm/min on the round specimens. Each test was repeated two times to obtain a precise average value for each property.

A pin-on-disc test apparatus was used to investigate the dry sliding wear characteristics of Al- MMC as per ASTM G99-95 standards. The wear specimens (2×1) cm were machined, cylindrical in shape shown in Fig.2. The initial weight of the specimen was measured in a single pan electronic weighing machine with a least count of 0.0001 g. During the test the pin was pressed against the counterpart rotating against EN-32 steel disc by applying the load [5, 10, 15, 20, 25 and 30 N]. A strain-gauged friction-detecting arm holds and loads the pin specimen vertically into a rotating hardened steel disc. After running through a time [5, 10, 15, 20, 25 and 30 min] period, the specimen were removed, cleaned with acetone, dried and weighed to determine the weight loss due to wear. The difference in the weight measured before and after the test gives the wear of the specimen. The wear rates were determined using the volumetric loss method. A schematic diagram for the pin-on-desk wear testing machine is shown in Fig. 3.



Fig. 2. Wear sample.

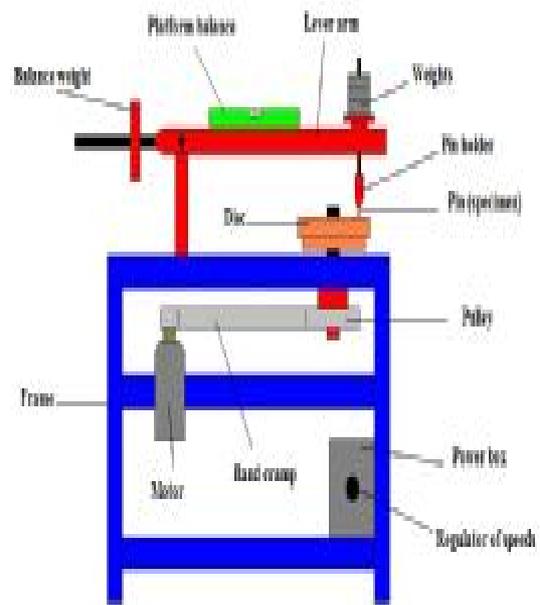


Fig. 3. Schematic diagram of pin-on-disc wear testing machine.

Wear rates were calculated by the weight loss measurement. The formulae used to convert the weight loss to wear rate [16]:

$$W_r = \Delta W / S \quad \dots(1)$$

Where,

W_r : wear rate in (g/cm).

ΔW : weight difference of the sample before and after each test in (gm) ($\Delta W = W_1 - W_2$).

Volumetric wear rate can be calculated as [16]:

$$W_v = W_r / \rho_m \quad \dots(2)$$

Where,

W_v : volumetric wear rate (cm^3/cm).

ρ_m : density of pin (g/cm^3).

Pin-on-disc apparatus has a regulator of speed used to control or change the disc rotational speed, and a tachometer device to evaluate this speed practically. Six rotational speeds were used, [50,100,150,200, 250 and 300 r.p.m], that means six linear velocities of [0.392, 0.785, 1.178, 1.570, 1.963 and 2.355 m/sec] were calculated respectively using the formula:

$$V = 2\pi \times r \times n \quad \dots(3)$$

Where:

V: linear sliding speed (m/min).

r: distance from the center of sample to the center of disc (0.075 m).

n: disc rotational speed in r.p.m.

Total sliding distance was calculated as follows [16]

$$S = V \times t \times 100 \quad \dots(4)$$

Where:

S: total sliding distance (cm).

t: sliding time of running in minute .

V: linear sliding speed (m/min).

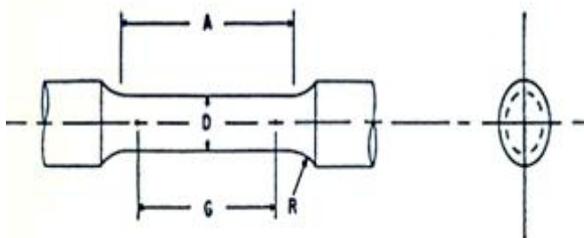


Fig . 4. Tensile test sample.

3. Results and Discussion

3.1. Tensile Strength

The strength has prime importance in engineering design such as yield strength, ultimate tensile strength and modulus of elasticity. The most of these properties are determined by using ASTM standardized testing method. Table. 2 shows mechanical properties of alloy 332 produced by casting. Tensile strength

and elongation are recorded. After preparation A332 we compare it with nominal mechanical properties standard from [17]. Figures 5, 6, 7, and 8 respectively display the tensile curves, yield strength and ultimate tensile strength of the Composites, respectively. It could be noted that the flow curves do not show any sharp yield point irrespective of the material, and the strength values increase with the addition of nano and micro Al_2O_3 particles. It is believed that the great enhancement in tensile stress observed in these composites is due to good distribution of the nano- Al_2O_3 particles and low degree of porosity, which leads to effective transfer of applied tensile load to the uniformly distributed strong Al_2O_3 particulates. The grain reinforcement and strong multidirectional thermal stress at the Al/ Al_2O_3 interface are also important factors which play a significant role in the high strength of the composites. Al_2O_3 particles have grain-refined strengthening effect, which is improved with increasing weight percentage since they act as the heterogeneous nucleation catalyst for aluminium [9–15]. From the above the additive 50 nanometer best composite in tensile strength is A332+1wt% Al_2O_3

3.2. Density and Hardness

The density of A332 and their composite were computed by mass- volume relation and plotted against wt % of alumina. As shown in Fig. 9. the variation in density decreases with an increase in weight percentage of alumina in the composite. Also, according to the measured and theoretical densities of composite samples, it is revealed that the amount of porosity in the composite samples increases with increasing weight percentage of Al_2O_3 particles and decreasing the size of particles.

Fig.10 shows the results of micro hardness tests conducted on A332 alloy Composite containing different weight percentage of Al_2O_3 particles.. A significant increase in hardness of the alloy matrix can be seen with addition of Al_2O_3 particles. Higher value of hardness is clear indication of the fact that the presences of particulates in the matrix have improved the overall hardness of the composites. This is true due to the fact that aluminium is a soft material and the reinforced particle especially ceramics material being hard, contributes positively to the hardness of the composites. The presence of stiffer and harder Al_2O_3 reinforcement leads to the increase in constraint to plastic deformation of the matrix

during the hardness test. Thus increase of hardness of composites could be attributed to the relatively high hardness of Al_2O_3 itself. As shown in Fig. 10. The best composite in hardness is A332+1wt% Al_2O_3 (50nano alumina). The percentage value of increasing hardness is 50% between 0.05 wt% to 1wt% (nano alumina), 37% between 0.05wt% to 1wt% (1 micron) and 25% between 0.05 wt % to 1 wt % (12 micron) as the same result with Davious found hardness of the composites is increased with increase wt% of reinforcement [18].

3.3. Effect of Time, Load and Sliding Speed on Wear Characteristics

As shown in Figs. 11, 12, 13 the variation of wear rate (volumetric loss/min) with varying time, load and sliding speed for A332 aluminum alloy. The wear increases when the time is increasing but after 15 min the increasing of wear slowly so we choose time 15 min when load and sliding speed are constant. The wear increase when increasing load but after 15 N the increasing of wear slowly so we choose load 15 N when time and sliding speed are constant. The wear increase when increasing sliding speed but after 150 r.p.m the increasing of wear slowly so we choose speed 150 r.p.m when time and load are constant.

3.4. Effect of Reinforcement and Particle Size on Wear Rate

Dry sliding wear behavior of matrix alloy reinforced (0.05-0.1-0.5-1) wt% at different alumina particle size (50 nm, 1 μ m, 12 μ m) respectively as shown in Fig. 14 reasonable increase in wear resistance. It is observed that addition of different (0.05-0.1-0.5-1) wt% nano-

micro alumina particle size shows lesser wear rate than the base alloy. And shown the highest wear rate is distinct for matrix alloy and linearly the wear rate decreased by increasing the percentage of reinforcements. The maximum wear resistance of the composites is considerably improved due to the addition of 1 % nano alumina particle.

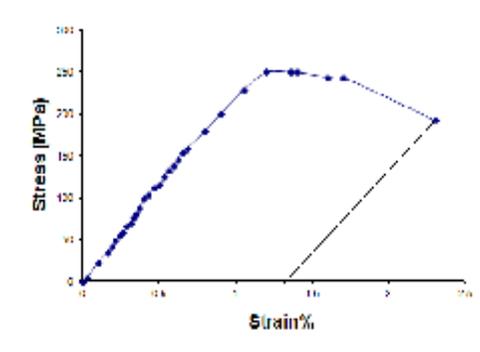


Fig. 5. Stress-strain diagram of A332 fabricated.

4. Conclusion

1. It was revealed that the hardness of composite samples increased with increasing the weight percentage of Al_2O_3 particles.
2. Strength of prepared composites both tensile and yield was higher in case of composites, while ductility of composites was less when compared to as cast 332 Al. Further, with increasing wt% of Al_2O_3 , the tensile strength shows an increasing trend.
3. The maximum wear resistance at 1% nano alumina.

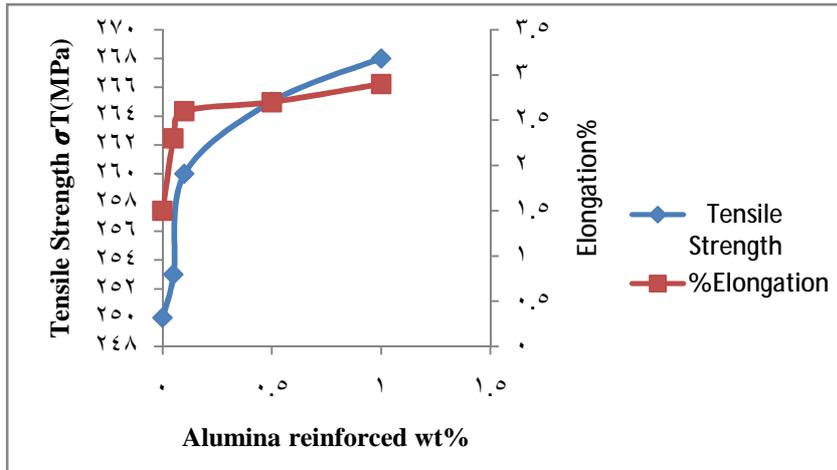


Fig . 6. Tensile strength and elongation for12 micron.

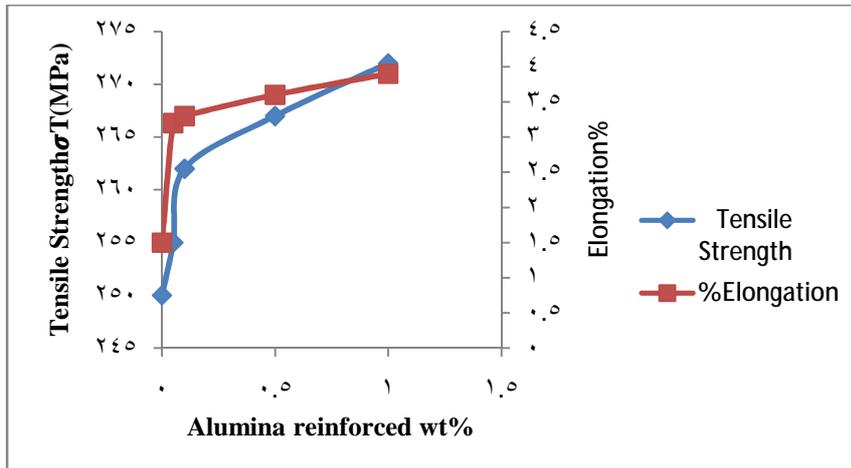


Fig . 7. Tensile strength and elongation for1 μm grain size.

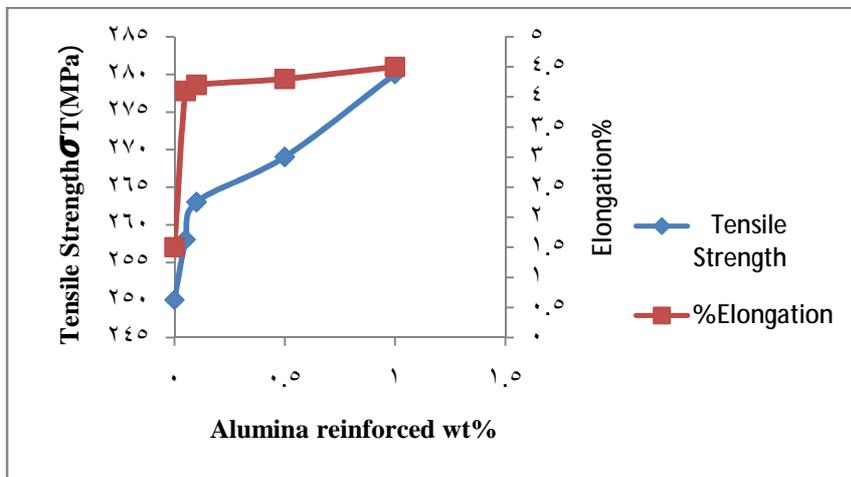


Fig. 8. Tensile strength and elongation for nano composite.

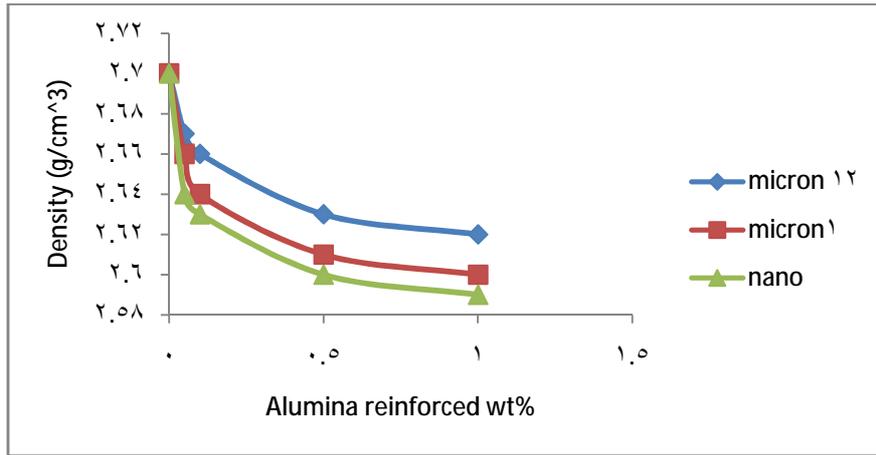


Fig . 9 . Density for composite.

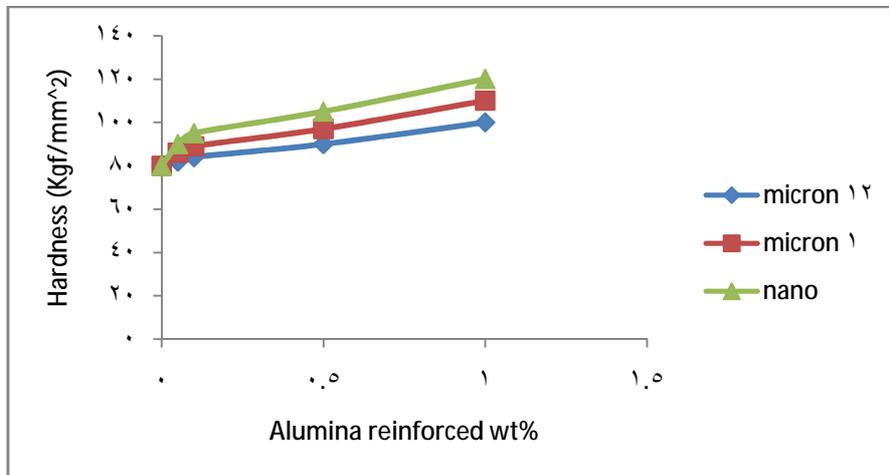


Fig . 10 . Hardness for composite.

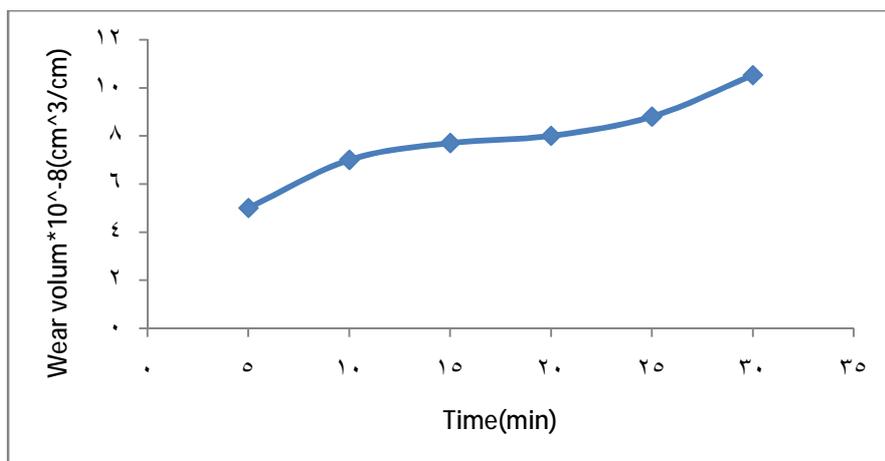


Fig. 11. Effect of time on wear rate A332.

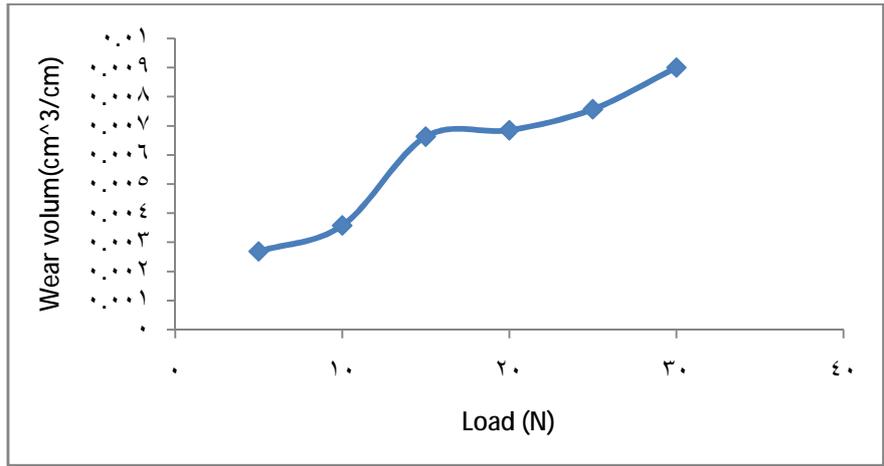


Fig. 12. Effect of load on wear rate A332.

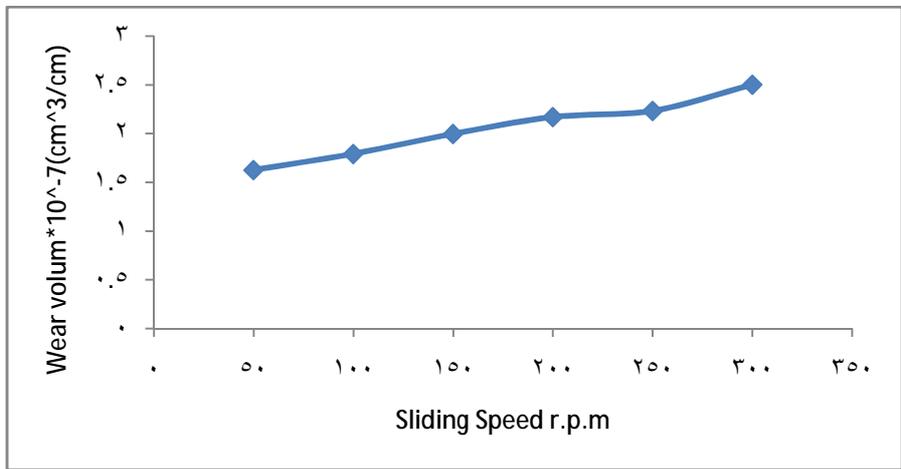


Fig. 13. Effect of sliding speed on wear rate A332.

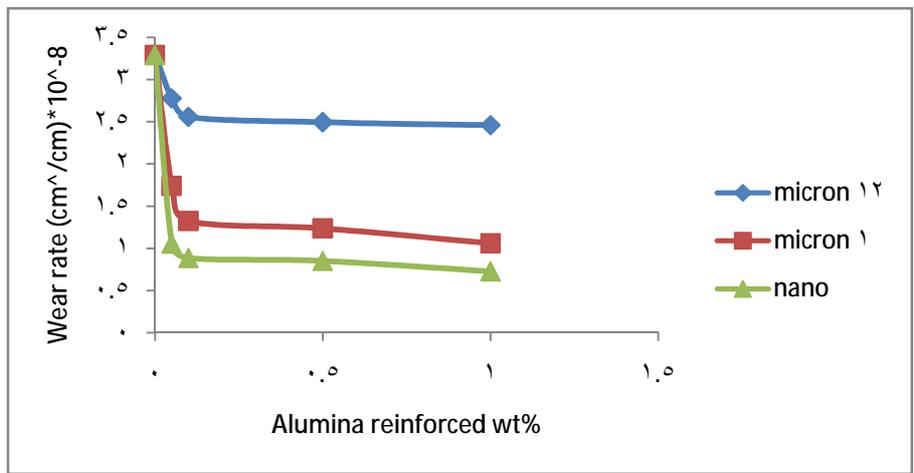


Fig. 14. wear rate for composite.

Table 2,
Properties of standard and fabricated A332 [17].

Property	Tensile strength(Mpa)	Yield strength(Mpa)	Elongation %
Material	σT	$\sigma Y (0.2\%)$	
Nominal A 332	248	193	1
Fabricated A332	250	195	1.5

5. Refrences

- [1] Hatch G.E., Aluminum, in: Properties and Physical Metallurgy, ASM International, Metals Park, OH, 1984:pp 30-35.
- [2] Hull D., An Introduction to Composite Material, second ed., McGraw-Hill, New York, 1981:pp 196-252.
- [3] Smith W.F., Principles of Materials and Engineering, McGraw-Hill, New York, 1996.
- [4] Hassan S.B., Aponbiede O. and Aigbodion V.S., Effect of particle size, forging and ageing on the mechanical fatigue characteristics of Al₂O₃/SiCp metal matrix composites, J. Alloys Compd., 2008;466: pp268-272.
- [5] Zhang S., Zhao Y., Chen G. and Cheng X., (Al₂O₃ + Al₃Zr)/A356 nanocomposites fabricated by magnetochemistry in situreaction, J. Alloys Compd., 2009; 475:pp261-267.
- [6] Sahin Y., Kok M. and Celik H., Toolwear and surface roughness of Al₂O₃ particle-reinforced aluminium alloycomposites, J. Mater. Process. Technol.,2002; 128: 280-291.
- [7] Chou S., Huang J., Lii D. and Lu H.,The mechanical properties of Al₂O₃/aluminum alloy A356 composite manufactured by squeeze casting, J.Alloys Compd., 2006; 419: 98-102.
- [8] Shorowordi K.M., Laoui T., HaseebA.S.M.A., Celis J.P. and Froyen L.,Microstructure and interface characteristics of B₄C, SiC and Al₂O₃reinforced Al matrix composites: acomparative study, J. Mater. Process.Technol., 2003; 142:pp 738-743.
- [9] K. Akio, O. Atsushi, K. Toshiro and T. Hiroyuki. J. Jpn. Inst. Light Met. 49 (1999), pp. 149–154.
- [10] K.M. Mussert, W.P. Vellinga, A. Bakker and S. Van Der Zwaag. J. Mater. Sci. 37(2002), pp.
- [11] D.M. Lee, B.K. Suh, B.G. Kim, J.S. Lee and C.H. Lee, Mater. Sci. Technol. 13 (1997), p. 590.
- [12] V. Laurent, P. Jarry, G. Regazzoni and D. Apelian, J. Mater. Sci. 27 (1992), p. 447
- [13] R.A. Saravanan and M.K. Surappa, Mater. Sci. Eng. A276 (2000), p. 108.
- [14] Huseyin Sevik, S.Can Kurnaz, "Properties of α Alumina Particulate Reinforced Aluminum Alloy Produced by Pressure Die Casting" Materials and Design 27(2006) pp, 676-683.
- [15] KoK M " Abrasive Wear of Al₂O₃ Particles Reinforced 2024 Aluminum Alloy Composite Fabricated by Veretex Method" Composite part A37,(2006),pp457-464.
- [16] A.Kr ishnan, S. M. Achary, "Wear Behavior Investigations of Journal Bearing Materials", 10thNational Conference on Technological Trends, (NCTT09), 2009, pp 20-25.
- [17] G. F. Vander Voort, " Metallography and Microstructures", ASM Handbook Committee ,Volum9 , 2004.
- [18] Davis, L. W., Bradstreet, S. W. A Study of Wear Behaviour of Matrix Metal Composites Wear 113 1970:pp. 234 – 239.

تحسين مقاومة البليان لسبيكة الالمنيوم A332 المقواة بدقائق سيراميكية ونانوية من الالومينا

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الخلاصة

ان سلوك البليان لسبيكة المنيوم A332 مدعمة بدقائق سيراميكية من الالومينا وباحجام مختلفة (12 مايكرون، 1 مايكرون، 0.5 نانومتر) و بنسب وزنية مختلفة (0.5، 1، 5، 10) % وباستخدام تقنية السباكة احتسبت وباستعمال جهاز فحص العينات. ان خصائص المواصفات الميكانيكية تعتمد على توزيع الدقائق النانوية والمايكروية، فهذا التوزيع ادى الى تحسن الصلادة وواجهاد الشد الاعلى ومقاومة البليان حيث ان مقاومة البليان تزداد بزيادة نسبة الالومينا. ان معدل البليان للمتر اكبات يعتبر اقل من سبائك الالمنيوم تحت تأثير نفس الحمل مع زيادة نسبة الالومينا مقارنة بالسبيكة الاصلية.