The Effect of Ceramic Particale Oxides addition on Wear Resistance of Composite Material for Aluminum Base Alloy

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ABSTRACT

To The aim of this research is to study the effect of 5 wt % Al_2O_3 addition Al- base alloy on sliding wear resistance under dry sliding conditions using pin- on- disc machine . Wear test was conducted after squeeze casting under different pressure (30 , 60 , 90) Mpa.

The results show that wear rate for Al- base alloy composites increases with increasing applied load but decreases with increasing sliding speed conditions . The composites which casting at 90 Mpa pressure represents lower wear rate than those which cast at 30, 60 Mpa pressure and the base alloy . The results also observed that the coefficient of friction increasing with increasing sliding time but reaches to the steady state after 200 sec. The microhardness and ultimate tensile strength increases with increasing squeeze casting pressure.

Keywords: Aluminum alloy, Al_2O_3, Particulate composites, mechanical properties, Squeeze casting.

تأثير اضافة دقائق أوكسيدية سيراميكية على مقاومة البلى لمادة متراكبة ذات أساس من سبيكةألالمنيوم

الخلاصة

يهدف هذا البحث الى دراسة تأثير أضافة دقائق أوكسيد ألالمنيوم بنسبة مئوية وزنية 5 % لسبيكة ذات اساس المنيوم على مقاومة البلى الانزلاقي تحت ظروف الانـزلاق الجـاف باستخدام جهاز ذو ترتيبة المسمار على القرص . لقد تم اجراء اختبار البلى بعد اجراء السباكة بالعصر تحت ضغوط عصر مختلفة Mpa (30 ، 60 . 90) .

تبين من النتائج ان معدل البلى للسبيكة الاساس والمادة المتراكبة يزداد مع ازدياد الحمـل المسلط لكنه يقل مع ازدياد سرعة الانزلاق . كما تبين ان المادة المتراكبة الناتجة بعد اجـراء سباكة العصر تحت ضغط 90 Mpa اظهرت معدل بليان منخفض مقارنـة مـع المـادة المتراكبة المسبوكة تحت ضغط Mpa (60 و30) والسبيكة الاساس . كما اظهرت النتـائج ان معامل الاحتكاك يزداد مع ازدياد زمن الانزلاق ثم يصل الى حالة الاستقرار بعد مـرور 200 ثانية من الاختبار . أما بالنسبة لقيم الصلادة الدقيقة ومقاومة الشد القصوى فانها تزداد مع ازدياد ضغط السباكة بالعصر.

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INTRODUCTION

Three decades at intensive research have provided wealth of new scientific knowledge on the intrinsic and extrinsic effects of ceramic reinforcement to metals and their alloys [1,2,3]. The successes of these various researches have stimulated application of metal matrix composite in the design of many engineering and non engineering component [1,3].

Aluminum matrix composite have shown high mechanical properties such as high strength , high stiffness wear resistance and good elevated temperature properties when compared with aluminum matrix composite in the following electronic heat sinks , automotive drive shaft , ground vehicles brake rotors , jet fighters , air craft firms , electronic instrument racks , crank shafts , gear parts , brake drum cylinder block and suspension arms [4,5]. New researches on metal matrix composite have focus on particle reinforcement due to low cost of the ceramic reinforcement and less complex fabrication technique [1,6]. Stirring casting route has been used successfully to synthesis metal matrix composite.

However, initial investigation employing a squeeze casting process (the application of external pressure on the molten metal) for Aluminum based MMC have also demonstrated many the stir cast production technique, such as (a) better compatibility between the metal matrix and the reinforcement particles, (b) a more improved structure of the matrix alloy (c) better mechanical properties and (d) pressure activation of the reinforcement – metal interface [6]. Apart from the use of particles aluminum matrix composites PAMC in space application, PAMC have been successfully used as components in automotive aerospace, opted – mechanical assemblies and thermal management. PAMC are used as fan exit guide vane (FEGV) in the gas turbine engine, as ventral fins and fuel access cover doors in gas milititary aircraft [7]. Also PAMC are used as rotating blade sleeves in helicopters flight [1,2]. Fing et.al [8] , studied the fabrication and characteristic of Al- based hybrid composite reinforced with tungsten oxide particle and aluminum borate whisker , fabricated by squeeze casting , and showed that the ultimate tensile strength and the yield strength of the hybrid composites are higher than those of the matrix while the elongation is lower than that of matrix .

Jinfeng Leng [9] , found by the addition of graphite with different volume fraction and particle sizes , SiC/ Gr/Al composites were fabricated by squeeze casting . These composites are macroscopically dense and homogeneous, with no distinct presence of Al_4C_3 in the composites and showed that with increasing volume fraction and particle size of graphite , the tensile strength decrease from 420 to 235 Mpa and the elastic modulus decrease from 166 to 116 Gpa .

MATERIALS SELECTION AND EXPERIMENTAL PROCEDURES

The Al –3.5% Cu – 1.28 Mg alloy / Al_2O_3 composites used for this research were synthesized by the squeeze cast method.

The chemical composition of the alloy used in the present investigation is given in table (1).

Table (1).Chemical composition of Al-Cu-Mg alloys in weight %

Element	Wt %
Cu	3.5
Mg	1.28
Mn	0.75
Si	0.12
Fe	0.15
Cr	0.023
Ti	0.08
Zn	0.11
Al	balance

The alloy was melted in electrical melting furnace the maximum temperature of the furnace 1200 C^o. This furnace was also used to heat the squeeze die before pressing, also the reinforcement particles was heating before adding into the melt. The Al_2O_3 of average particle size (+53- 75) µm was used to having 5 wt% of second phase particle , the composite was synthesized by vortex method . During melting 1 wt% Mg was added to improve the wet ability of the matrix and improving the interfacial bonding between the particles and matrix.

When the amount of reinforcement was 5wt% the particles were wrapped in a very thin foils and heated to 400 C^o for 1 hrs in heating furnace then adding the heated Al_2O_3 particles with the Al foil to the molten Al-Cu-Mg alloy for 15 minutes using an electrical stirrer at speed (600 rpm) After then the molten composite is put again in the melting furnace for increasing the temperature to 700 C^o , then stirring the molten composite again for 10 min and then pouring it into the squeeze die cavity which preheated at 300 C^o for 30 min and placed on the hydraulic press table as shown in fig .(1) ,. The application of the squeeze pressure for 30 sec at a delay time of 5 sec and allowing for solidification , the casting pressures are (30, 60 , 90) Mpa , after solidification removing the solidified composite casting from the die of 30mm diameter and 170mm height as shown in fig. (2). In order to examine the microstructure of the base alloy and the squeeze casting composites, the specimens were cut from the center of the samples , wet ground and then polished. Grinding was conducted with silicon carbide papers 1000 grit using grinding machine (Struers DAP-5, Denmark). The specimens were then polished on polishing cloth using 5 µm and 0.3 µm alumina suspension consequentially. These samples were then washed in water and alcohol, and then dried in hot air. The worn surface was examined by an optical microscope with digital camera. The micro hardness of the base alloy and composites was measured by using Vickers hardness apparatus, and calculated by the following:

$$Hv = 1.8544 \; [F/ d^2] \quad \ldots (1)$$

Where:-

F : The applied load 500 gm.

d : The diameter of the rhombus indentation in(mm) .

The tensile strength measurement by using the Instron machine type 1195, the specimen dimensions with standard (ASTM, E8). The dry sliding wear tests were conducted on Al_2O_3 particles reinforced Al-Cu –Mg matrix composite specimens on the pin – on-disc machine which belongs to tribology laboratory , and metallurgy , university of technology as shown in fig. (3). The wear specimens were cylindrical with a diameter of 10 mm and a length of 20mm. The wear test carried by using pin –on- disc method, the following procedure was conducted as follows:-

1- Carbon steel disc was mounted in its position with hardness 60 HRC.
2- The pin was weighted accurately before test and then mounted on the specimen holder.
3- The lever arm was balanced by adjusting the weights in the rear position, and kept at a horizontal position so that the specimen was close to the disc but no force acted on it.
4- The pin was loaded normally by adding (5, 10, 15, 20) N load.
5- At the instance of running system, the stop watch was started for the purpose of measuring the testing time. Each test took 20 min, and the weight loss from the specimen was recorded, for the purpose of calculating the wear rate.

For measuring the coefficient of friction the strain meter was set to zero reading before each test and every 30 sec of the whole
Period of 20 min, the strain meter reading was recorded and the average value was then calculated . The friction force between the pin and disk surface was measured using two strain gauges cemented on the vertical face of the lever arm , in order to measure the elastic bending strain resulting from tangential force at the sliding interface . Fig(4) shows the calibration curve of the system to estimate the value of tangential force using the microstrain reading .The coefficient of friction can be calculated as follows:-

$$\mu = F/N \qquad \text{....... (2)}$$

Where:-
F: Friction force (N)
N: Normal applied force (N)

The wear rate was calculated from weight loss measurement, by using sensitive balance with an accuracy of ± 0.0001 gm (Mettler type AE 200, Swaziland) and the wear rate can be calculated as follows :

$$\text{Wear rate (Wr)} = W_1 - W_2 / S \qquad \text{... .. (3)}$$

Where:-
W_1: Specimen weight before wear test (gm).
W_2: Specimen weight after the wear test. (gm)
S : Sliding distance (cm)

$$S = V \times t \qquad \text{---- (4)}$$

Where:-

T: Running time (20) min at each test.
V: Linear sliding speed (m/sec).

The disc rotational speed was 520 rpm with a linear sliding speed (V) of (2.7, 3.08, 4.7) m/sec. Loading was carried out normally by putting suitable weight on the specimen holder weighting (5, 10, 15, 20) N. The coefficient of friction also measured for the base alloy and the composite specimens under different load (5,10,15,20) N at constant sliding speed (3.08 m/sec)

RESULTS AND DISCUSSION

The results obtained from the experimental work are discussed here, Fig. (5) , shows the relationship between the squeeze pressure and the wear rate under different applied load (5,10, 15,20) N and at constant sliding speed (3.08 m/sec) it is clear from this figure that the wear rate increases generally with increasing the applied load , but it is also represents that the reinforced composite pin which is casting at squeeze pressure 90 Mpa shows lower wear rate when compared with other pins which casting at 60 Mpa , 30 Mpa and the base alloy , because at these values of loading the particles acted as a load bearing element between the contact surfaces and this particles have higher hardness than the base alloy it also act as protrusion over the matrix and protect the composite surface from sever wear [10]. Fig. (6). show the relationship between the squeeze pressure and different sliding speed (2.7,3.08,4.7) m/sec under constant load (10 N) it is clear that the wear rate decreases with increasing the sliding speed but the composite pin reinforced by Al_2O_3 which casting at pressure 90 Mpa has lower wear rate when compared with the base alloy and other composites which casting at 60 and 30 Mpa . This is because of the increased flash temperature produced at contact interface, with increasing sliding speed , this flash temperature may reach the melting point at surface asperities[11,12] . The flow of heat through the specimen metal at higher sliding speed is lower than that at lower sliding speed. At low sliding speed there is enough time for metal contact for cold welding, because of the atomic diffusion between contact surfaces. Also plastic deformation of these asperities is higher than that at high sliding speed , this cause a strong contact between surfaces and finally the wear will increase [13,14] . Fig. (7)and (8), represents the surface topography of different worn surfaces under different load (10, 20)N and at constant sliding speed 3.08 m/sec, the plowing markings can be seen in these figures as a result of plastic deformation and verifies the above findings.

The fig. (9,10) represents the relationship between the coefficient of friction and the sliding time under high and low applied load and constant sliding speed (3.08 m/ sec) . The coefficient of friction increases and reaches to a steady state at 200 sec, this is because the number of asperities contact and will lead to increasing in the actual contact area between the specimen surface and disc then it increases the force required to shear contact tips of asperities and an increasing in the coefficient of friction [15,16]. The squeeze pressures effects also on the mechanical properties as shown in fig.(11,12) , its clear that the micro hardness and the ultimate tensile strength increases with increasing squeeze pressures .

CONCLUSIONS

1- Wear rate decreases with increasing squeeze pressure.

2- Composites when squeeze cast at 90 Mpa shows higher wear resistance than the base alloy and the composites when squeeze cast at 60 and 30 Mpa.

3- The coefficient of friction increases with increasing sliding time and it will reaches to steady state after 200 sec, under high and low load with constant sliding speed .

4- The micro hardness and ultimate tensile strength increases with increasing squeeze pressures.

REFERENCES

[1] Kaczmar J. W, Naplocha .K , " Wear behavior of composite materials based on 2024 Al- alloy reinforced with alumina fibers", J.of. achievements in mat.& manuf. Eng.,Vol.43, Issue 1, 2010.

[2] Dobrzanski L.A, Kremzer . M , "Structure & properties of ceramic performs based on Al_2O_3 particles "., Jo.of. achievements in mat.& manuf. Eng.,Vol,35, 2009.

[3] Das, S., " Development of aluminum alloy composite and opportunities ", Trans Indian Inst. Met. Vol. 57, 2004.

[4] Hu . H, "Squeeze casting of magnesium alloys and their composites" , J, mater, Sci, 3Vol, 33, 1998.

[5 Lioyd .D.J , " Particle reinforced aluminum and magnesium matrix composites" , Int. Mater. Rev, 39, 1999.

[6] Jayalakshmi , S, Kailas, S, " Properties of squeeze cast Mg -10Al-Mn alloy and its alumina short fiber composites"., Vol , 38, 2003.

[7] Ray,. S, "Synthesis of cast metal matrix particulate composites". , Jo., of., mat. Sci.,Vol 28., 1993.

[8] Feng . Y.C, Geng . P.Q. , Zheng Z.Z , and Wang G.S., " Fabrication and characteristic of Al- based hybrid composite reinforced with tungsten oxide particle and aluminum borate whisker by squeeze casting " , Jo. of Mat. & Design , Vol.29, No , 2008.

[9] Jinfeng Leng , Gaohui Wu, Qingbo zhou, and Zuoyong .D ., " Mechanical properties of SiC / Gr/Al fabricated by squeeze casting technology" ., Jo. of Scripta Materialia , Vol. 59, No. 2 , 2008.

[10] Kok., M., " Production and mechanical properties of Al_2O_3 partical reinforced ,2024 aluminum alloy composites" ., Jo. of., mat. Processing tech., Vol- 161., 2005.

[11] Sulttan J.n., and Hannoush . G.M ., Jo. of . Eng. Tech ., Vol .13., No.2., 1994.

[12] Archard H.J,F., The temperature of rubbing surface .,Wear .. Vol.2.,No.6., pp.438.,1959.

[13] Perrin . C , W. Rainforth, The effect of alumina fiber reinforcement on wear of an Al-Cu alloy , wear, Vol.181-183, 1995.

[14] Yue- Ying, Li., Yong-bing ., Liu., " Friction and wear behavior of Al_2O_3 – SiO_2 particle reinforced Al- matrix composites"., Jo., of ., Mater., Sci., Tech., Vol.11., No., 2., 2003.

[15]Mihaly., " Friction and wear of aluminum matrix composites " National tribology conference , 2003.

[16]Veeresh G,B., Kumar C.S.P., Rao.N.S., "Mechanical and tribological behaviour of particulate reinforced Aluminum metal matrix composites"., Jo.of." Minerals and materials characterization and Eng". ., Vol.10. ,No. 1., PP.87.,2011.

Figure (1) the hydraulic press used for squeeze casting .

Figure (2) the punch and die used in squeeze casting

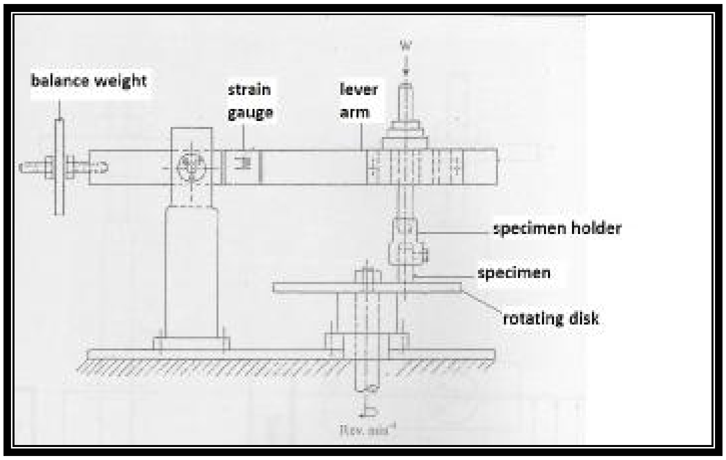


Figure (3) Wear test apparatus

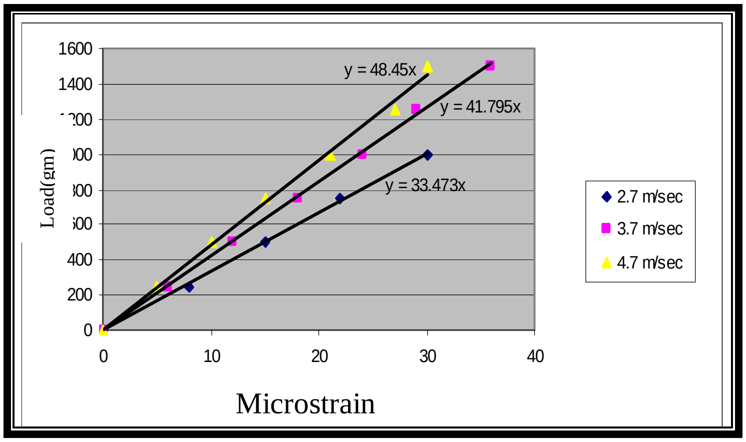


Figure (4) Calibration curves

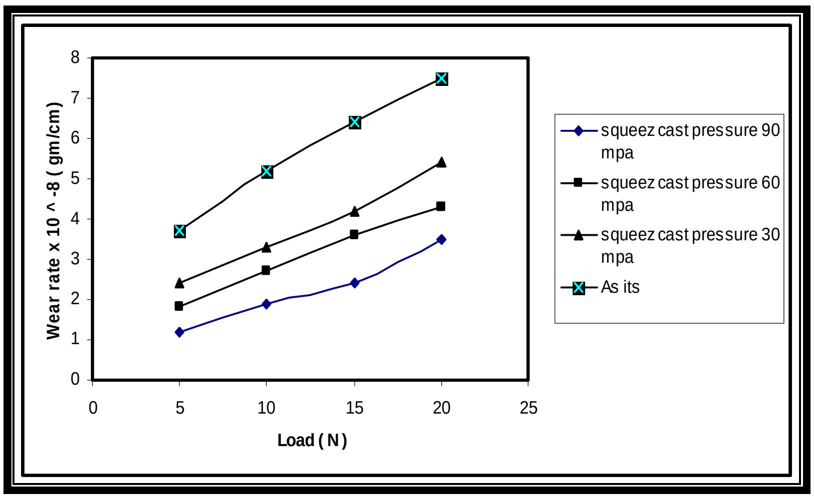


Figure (5) Effect of squeeze cast pressure on wear rate , under different load for the Al- alloy and composites, constant sliding speed (3.08) m/sec.

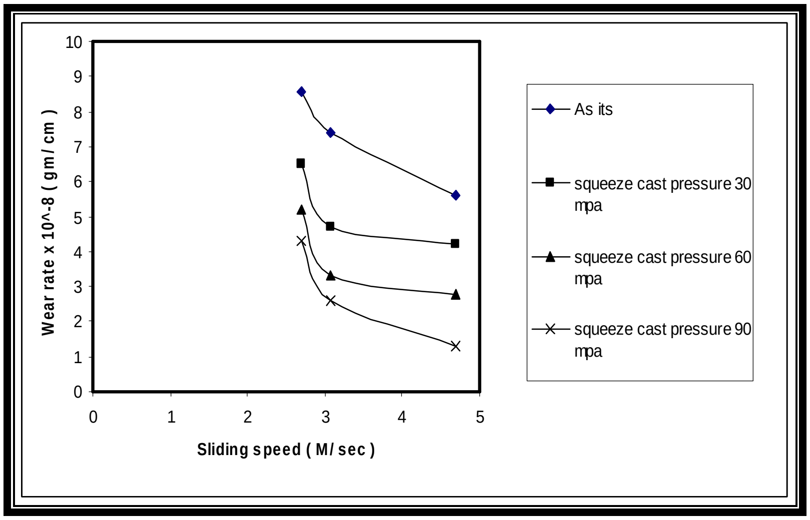
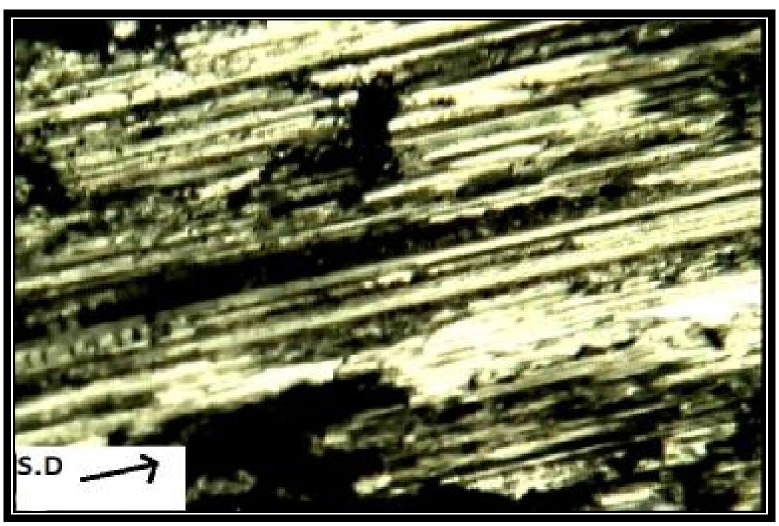


Figure (6) Effect of squeeze pressure on wear rate under Different sliding speed for the base Al- alloy and composite, constant load 10 N .



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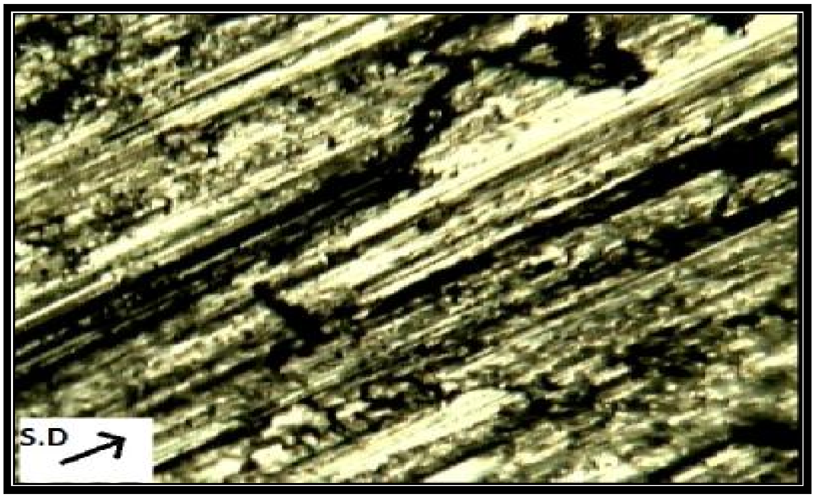

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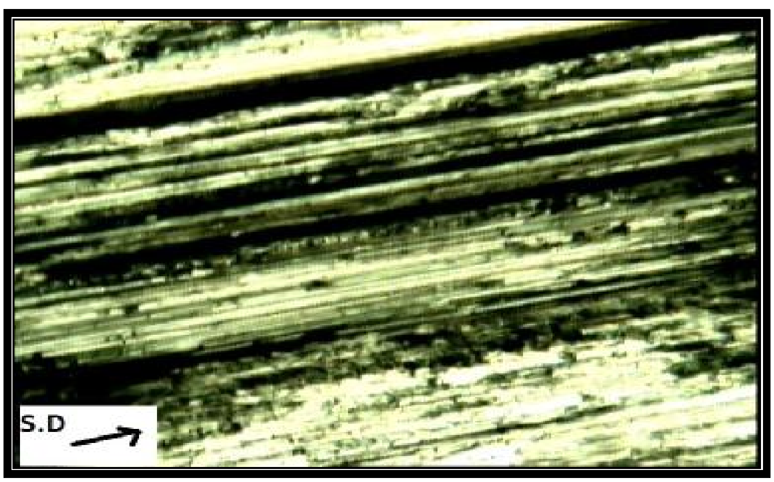

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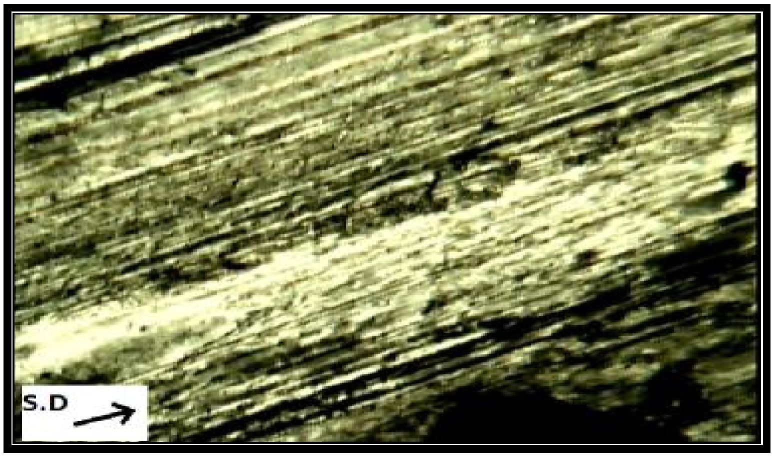
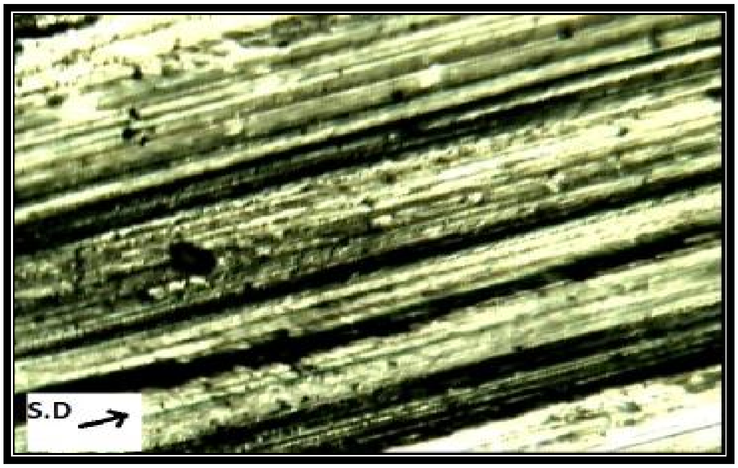


- d -

Figure (7) Optical micrograph of wortn surface at sliding speed 3.08 m/ sec, load 10N. X125.

a- Al – 3.5% Cu alloy as cast .
b- Composite / squeeze cast pressure 30 mpa.
c- Composite / squeeze cast pressure 60 mpa.
d- Composite / squeeze cast pressure 90 mpa.



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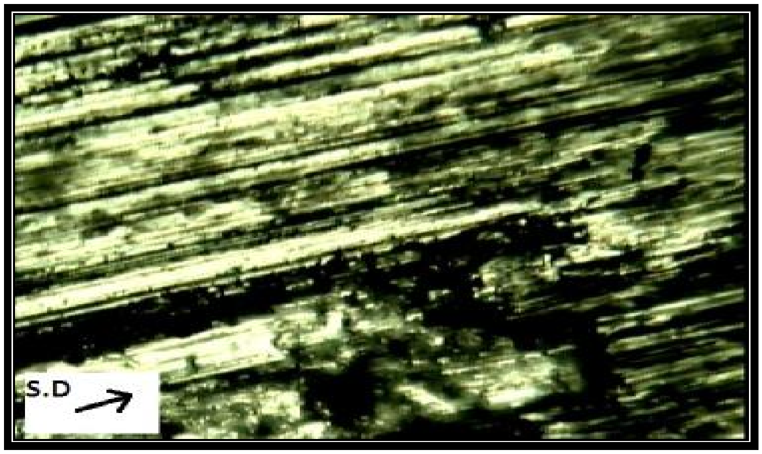

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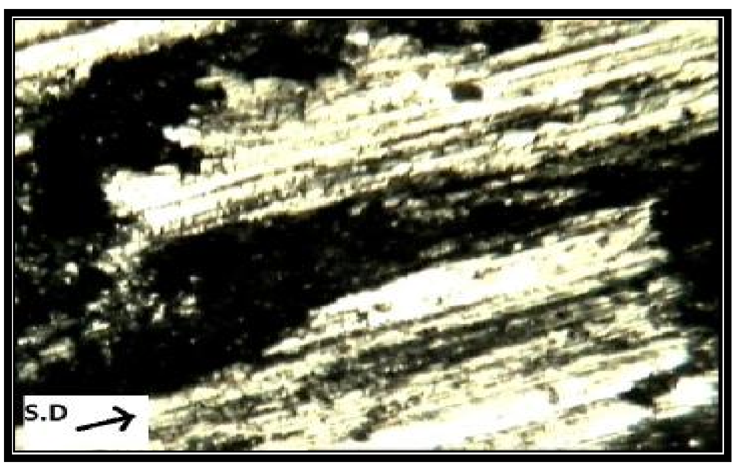

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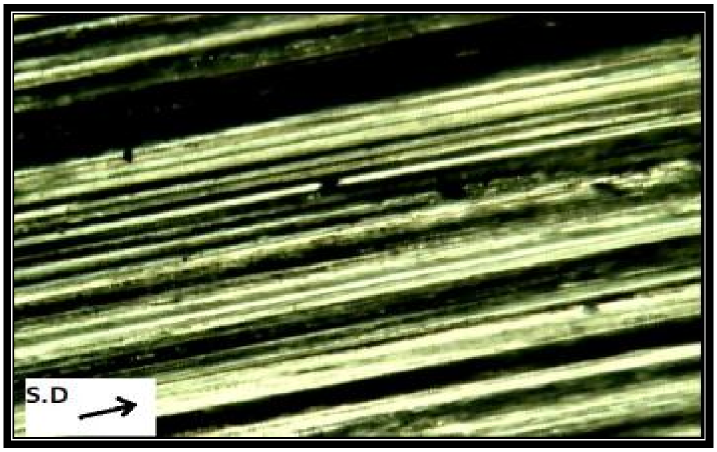

- d -

Figure (8) Optical micrograph of worn surface at sliding speed 3.08 m/sec , Load 20 N . X 125.

a- Al- 3.5 wt %. Cu as cast .
b- Composite / squeeze cast pressure 30 mpa .
c- Composite / squeeze cast pressure 60 mpa .
d- Composite / squeeze cast pressure 90 mpa .

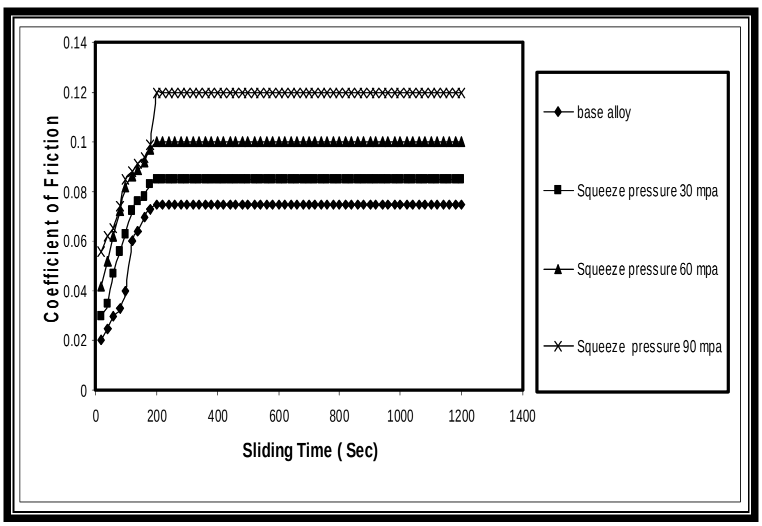

Figure (9) Coefficient of friction the base alloy and composites which casts under different squeeze pressure in function of sliding time. Load 10 N,sliding speed 4.7 m/sec

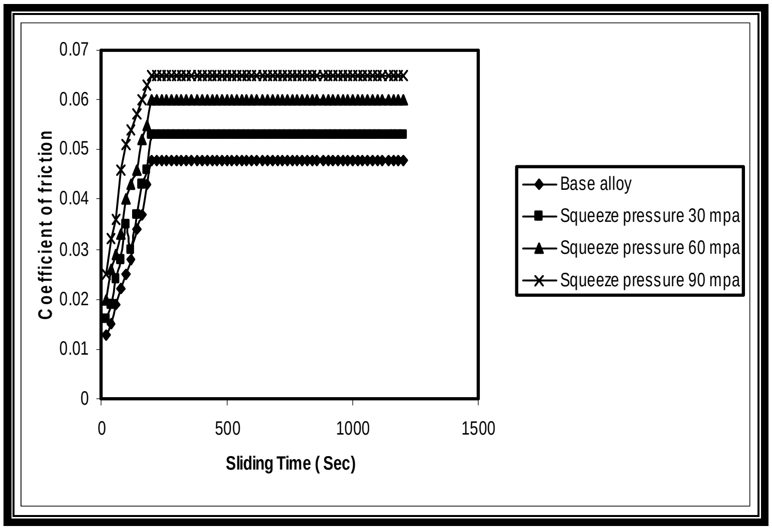

Figure (10) Coefficient of friction for the base alloy and composites which casts under different squeeze pressure in function of sliding time. Load 10 N, sliding speed 2.7 m/sec.

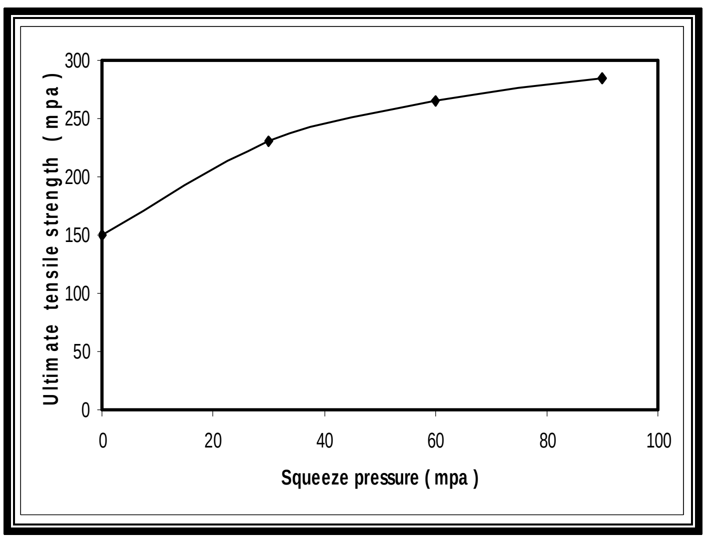

Figure (11). Effect of squeeze pressure on ultimate tensile strength

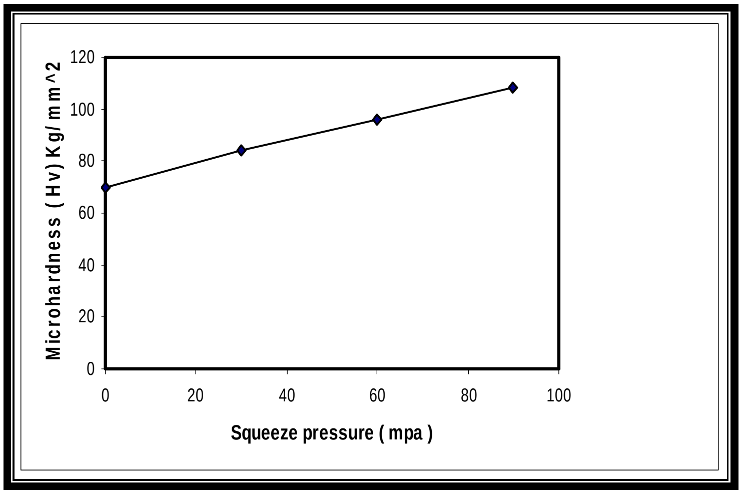

Figure (12) Effect of squeeze pressure on microhardness