Effect of Ageing Time on Adhesive Wear of AL Alloy AA6061-T6

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Abstract

In this study the effect of artificial aging time on adhesive wear of AA(6061-T6) aluminum alloy was investigated for the specimens groups (A , B , C and D)which manufactured in the dimensions of (20*10)mm according to ASTM, heat treatment was implemented to specimens groups(B , C and D) which include solution zing at temperature of 500^0 C for (1 hour) then quenching in water and artificial aging for (1,3,5 ,hr.) at 180^0C The resulting phases after each heat treatment was tested by x –ray diffraction and microstructure was also examined to understand the nature of structure then hardness test was implemented

Adhesive wear test have been conducted on aluminum alloy AA 6061 T6 at variable (time ,loads, and sliding speed) using pin on disc method. The results showed that increasing of aging time increases hardness then decreasing wear rate.
Keyword: Artificial ageing, adhesive wear, aluminum alloy 6061 – T6

الخلاصة

يهدف البحث الى دراسة تاثير زمن التعتيق الصناعي على مقاومة البلى الالتصاقي لسبيكة المنيومAA 6061- T6 حيث تم تصنيع عينات اسطوانية الشكل بالابعاد mm (20*10) وفق المواصفة القياسية ASTM ثم تم تصنيفها الى مجاميع (A,B ,C ,D) بعدها اجريت معاملة حرارية على هذه المجاميع حيث تضمنت تسخين المعدن الى درجة حرارة 500 درجة مئوية لمدة ساعة ثم التبريد السريع بالماء بعدها اجريت عملية تعتيق صناعي بتسخينها الى 180درجة مئوية لفترات (1,3,5) ساعة على التوالي ثم تم تصوير البنية المجهرية لمعرفة التركيب المجهري لكافة العينات وكذلك اجري اختبار حيود الاشعة السينية لمعرفة الاطوار المترسبة بعد المعاملات الحرارية, اجري اختبار الصلادة بطريقة Vickers لبيان تاثير المعاملات على الصلادة وكذلك اجري اختبار البلى الالتصاقي عند زمن وحمل وسرعة متغيين با ستخدام طريقة pin on disc لمعرفة تاثير المعاملات الحرارية على مقاومة البلى الالتصاقي ومن النتائج التي تم الحصول عليها وجد ان الصلادة ومقاومة البلى الالتصاقي تزداد بزيادة زمن التعتيق

Introduction

The AA 6xxx-group contains magnesium and silicon as major addition elements. These multiphase alloys belong to the group of commercial aluminum alloys, in which relative volume, chemical composition and morphology of structural constituents exert significant influence on their useful properties [1].

The aluminum alloys of 6xxx group have been studied extensively because of their technological importance and exceptional increase in strength obtained by precipitation hardening. The 6xxx aluminum alloys are mostly used as extruded products, as well as for construction and automotive application. The precipitation of metastable precursors of the equilibrium Mg_2Si partical for 6061 has occurs in one or more sequences which are quite complex. Their extradubility depends to a large extent on chemical composition, casting condition and heat treatment parameters (eg. homogenization treatment) which determine the microstructure that means the properties of various aluminum alloys can be altered by specific designated heat treatment. The heat treatment process can be classified into two processes; including solution heat treatment and artificial aging. Solution treatment consists of heating the alloy to a temperature between 260^0C and 530^0C and water quench to room temperature and artificial ageing "age hardening" or just "hardening" is carried out at temperatures up to approximately 200^0C (for 6000 alloys generally between 160 ^{0}C and 200^0C) [2] [3]. **G. Mrówka-Nowotnik** [1] studied the effect of the precipitation hardening on the microstructure and mechanical properties of 6061, 6063 and 6082 aluminum alloys, The results show that the microstructure and mechanical properties changes during artificial aging due to the precipitation strengthening process. Some aluminum alloys can be solution treated to increase their strength and hardness which effect on wear resistance that classified to many types such as, adhesive wear which occurs when two surfaces are moving relatively one over the other, and this relative movement is in one direction or a successive movement under the effect of the load so that the pressure on the adjacent projections is big enough to make plastic deformation and adhesion. This adhesion will be at a high grade of efficiency and capability in relative to the clean surfaces, and the area will be increased during movement [4] at the end there will be some relative wear in the superficial tissues in the weak points of the noticeable places. Many studies investigated the adhesive wear **Khairia Salman Hassan** [5] studied the wear rate for different materials (Steel, Aluminum and brass) under the effect of sliding speed, time and different loads, where the apparatus pin on disc has been used to study the specification of the adhesion wear the results will show that the rate of adhesion wear will be direct proportional with (time, sliding speed and load) , and the low carbon steel has less wear rate than the other materials. **C. L. Xu** [6] study, Al–Si alloys with Si contents of 23, 26, 28 and 31 wt.%, respectively on abrasive wear ,they found that The silicon content in the range of 23–31 wt.% has significant effect on the wear rates of the same processed Al–Si alloys (modification and heat treatment). Under the same load, the wear rates of the same processed Al–Si alloys decrease with the increasing silicon content

In this study the effect of ageing time on adhesive wear resistance were investigated for Aluminum alloy AA 6061T6 to determine the least wear rate

Experimental work

The experimental procedure was as follows

1- Metal Selection

Aluminum alloy AA 6061 T6 was selected Its chemical analysis is indicated in **Table (1)** which was conducted by ARL Spectrometer in the specialized institution of engineering industries of Industry ministry.

Table (1) Chemical Analysis of the used metal AA 6061- T6

Elements w%	Si	Fe	Cu	Mn	Mg	Cr	Zn	Al
Nominal value	0.4-0.8	Max 0.7	0.15-0.4	Max 0.15	0.8-1.2	0.04-0.35	Max 0.25	Rem.
Actual value	0.6	0.4	0.3	0.12	1.0	0.2	0.18	Rem.

2- Preparation of Specimens

Cylindrical specimens for the adhesion wear tests were fabricated with dimensions (10x20mm) according to ASTM specifications for the metal used.

3- Categorization of Specimens

After completing the specimen, they were categorized to groups as shown in **Table (2).**

Table (2) Categorization of test specimens

Specimen sample	Condition of specimen
A	As received
B	Solution heat treatment at 500 ^{0}C and artificial aging for 1hr at 180^{0}C
C	Solution heat treatment at 500^{0}C and -artificial aging for 3hr at 180^{0}C.
D	Solution heat treatment at 500^{0}C and artificial aging for 5hr at 180^{0}C

4- Heat Treatment

Solution heat treatment at 500^0C and water quenched was applied on all specimens groups in **Table (2)** except (A) and artificial aging was applied on them in the same table by preheating the Specimens to 180^0C for (1,3,5) hr respectively and cooling in the air.

5-Microstructure

For microstructure test the specimens were prepared as shown below:-

1- The specimens are treated with emery papers grad (220, 320, 500, 800, 1000, 1200).

2-Polishing by gloss cloth with auxiliary glossing of Al_2O_3.

3- Etching for the structure by use consisting of 95 ml distill water, 2.5 ml HNO3, 1.5 ml HCl and 1 ml HF then washed after that with distill water

4- Photographing the microstructure by programmed microscope type advanced polarizing Dark – Field metallurgical microscope MTJ Corporation, the photographs of the microstructure of specimen's shows in **Fig (1)**.

6- X-Ray Diffraction

X-ray diffraction for specimens group (A ,B, C & D) results are shown in **Table (3)** and phase analysis graph are shown in **Fig.(2)**

Table (3) Results of X – ray diffraction

Specimen symbol	Phase
A	Al
B	MgSi
C	Mg_2Si + MgSi
D	Mg_7Si_5+ Mg_2Si+ MgSi

7-Hardness test

Hardness test was implemented on all specimens in **table (2)** by using Vickers hardness method**.**
The result are shown in **table (4)** by using the below equation

$$Hv = 1.854 * \frac{p}{d^2}$$

Were (p) is the applied load in kg
(d^2) Indicator diameter (Square Millimeters).

Table (4) hardness results for all specimens in table2

Specimen symbol	Hardness (Hv) Kg/mm^2
A	87
B	102
C	107
D	110

8- Adhesive wear test

Adhesive wear test was implemented for all specimens in **Table 2** by using pin on disc method as shown in **Fig.(3)** including, fixing the specimen by the bearer in vertical position on steel disc having hardness of 54 HRC and rotated at940 r.p.m ,then Specify the variables which we want to know its effect on the wear rate like(time, load, sliding speed) .each parameter include a series of variables when the stage finished we fixed one parameter and change others ,we weigh the specimen before and after test.

The wear rate is calculated from the following equation

$Wr=\Delta W/2\pi rnt$

Where

Wr is wear rate in gm/cm

$2\pi r$ is the sliding distance (cm)

t is the time n is number of revolution

$\Delta w= w_1-w_2$ and n=940 (r.p.m)

The test results are shown in **Fig (4),(5),(6)**

Results and Discussion

The optical micrograph of base alloy of Al 6061T6 ((Al- Mg- Si) is indicated in **Figure. (1)**.The microstructure consists of α-Al grains and fine particles of phase Mg_2Si distributed uniformly in the matrix alloy of (Al –Mg-Si) and that is appears in **Fig.(2)**which represent the phases analysis of the alloy before and after heat treatment we see that when increasing ageing time many phases precipitate resulting an increasing in hardness which its results shown in **Tab.(3). Fig (4,5&6).**shows the relationship between wear rate and its parameters (Time, Load, sliding speed) wear rate increased when time, load, sliding speed increased and this was clear in all specimens group A, B,C and D in all figs .and wear rate decrease at the same parameters after heat treatment because heat treatment allowed for phases to precipitate and aging time have the main effect for this precipitate , Since wear resistance depend on hardness then when hardness as shown in **Tab.(4)** increase after heat treatment the wear resistance will increased. **Fig.(4)** which represent the relationship between time and wear rate show that specimen (A) gives the high wear rate while specimen (D) gives the lowest for the reason mentioned before. **Fig.(5)** shows the effect of second parameter (load) and wear rate it caused an increasing in the plastic deformation in surface tips peaks between two sliding surfaces, the adhesive process of the two tips surfaces depends on applied load, if the load is low the contact appears in upper bit and this was very thin during sliding process that causes a thin layer from oxide works as a protective surface film which limits the touching between the two sliding surfaces and prevent the direct metallic connection between the surfaces tips thus the required force to cut the occurred connection between the two surfaces tips less than the force between the metal atoms itself and that will cause a decrease in wear rate [7][8]. On the other hand an increasing in applied load will break the oxide film because of its brittleness for its shoots out the friction sliding surfaces for both the discs and specimen during the sliding process which causes a strong metal contact between them make the required force to shear its contact tips more than the force between the metal atoms itself. Also because of the effect of heat treatment contributed to increase hardness this is obvious in specimen (A) to (D) respectively. The third parameter (sliding speed) observed in **Fig. (6)** shows the same result in **Fig. (4 & 5)** for the same reasons which discussed before. These results for all parameters are in agreement with researchers in [6]

Conclusions

1-Heat treatment improve wear resistance and artificial ageing time increased the elements precipitation which effected on hardness that gives the wear resistance improvement

2- All the three parameters (time, load, sliding speed) gives the increasing in wear resistance as increasing its values .

3-Artificial ageing time at 5 hours gives the best value of wear resistance at all parameters

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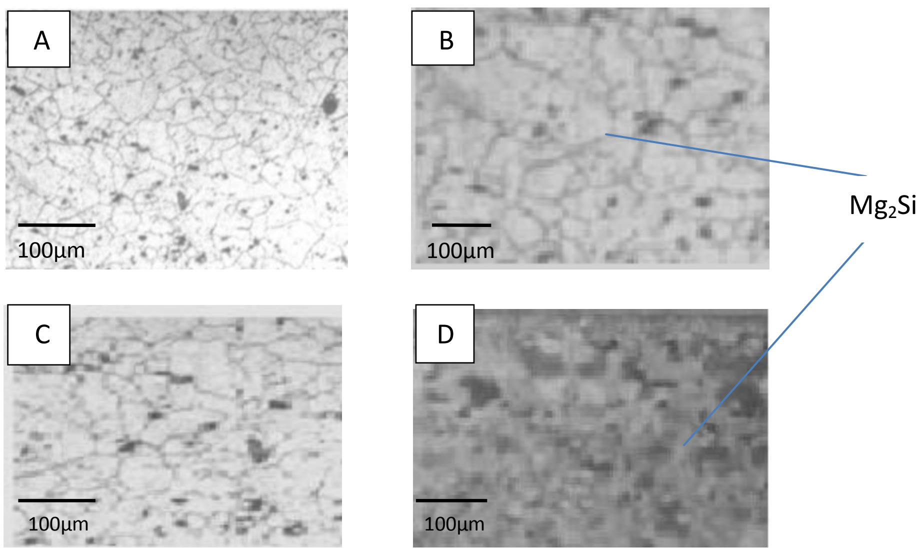
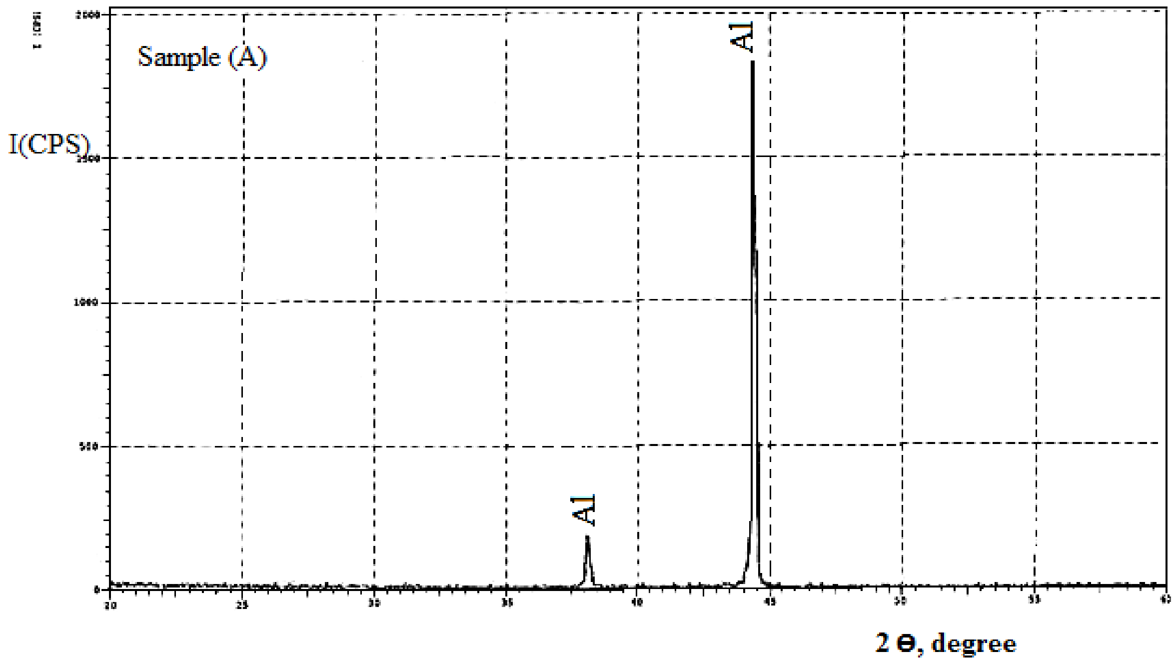
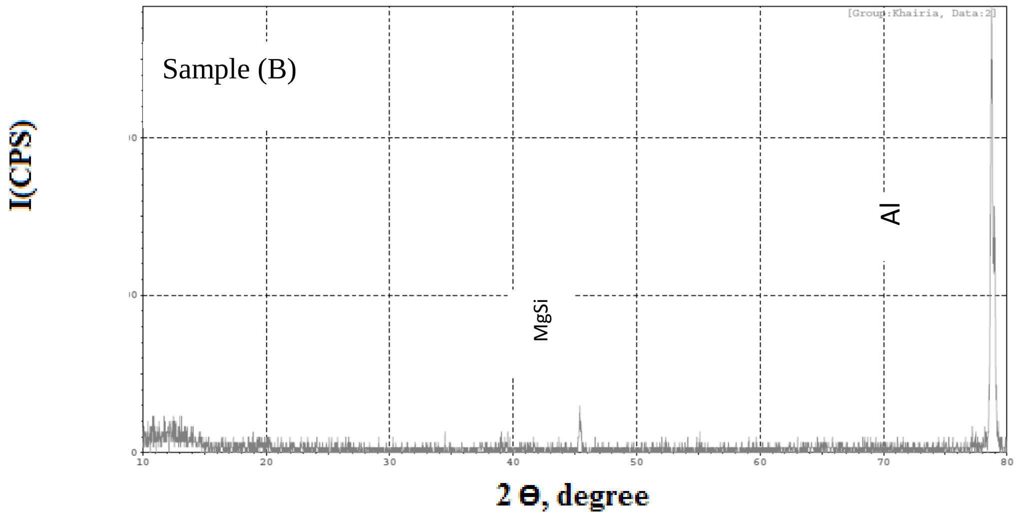
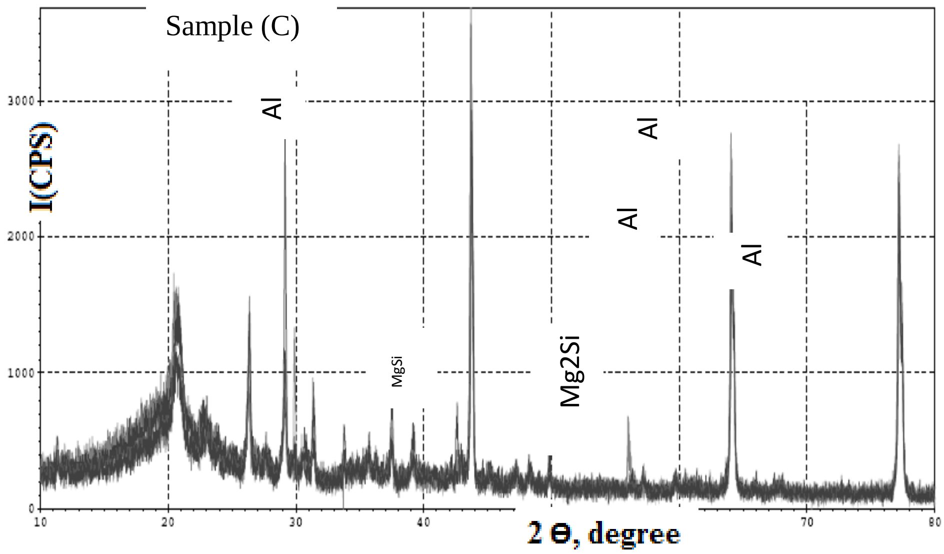


Fig. (1) Microstructure of specimens


Sample (A)
I(CPS)
Al
Al
2 ϴ, degree


Sample (B)
I(CPS)
MgSi
Al
2 ϴ, degree


Sample (C)
I(CPS)
Al
MgSi
Mg2Si
Al
Al
Al
2 ϴ, degree

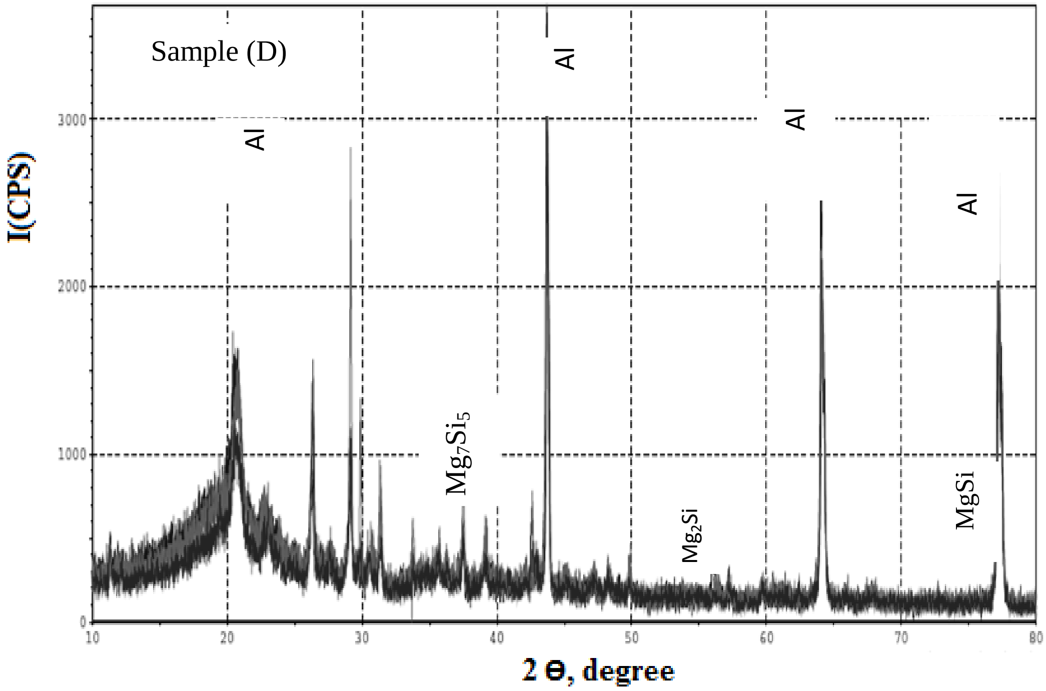
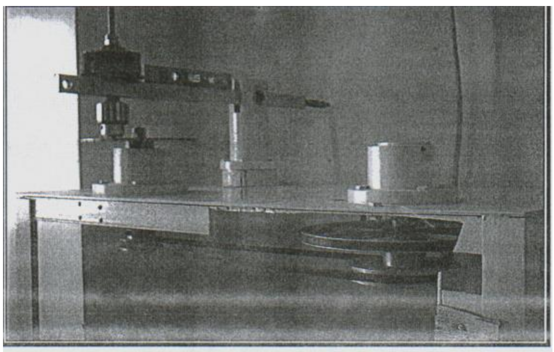


Fig.(2) Phase Analysis Graph



Fig(3) Apparatuses of adhesive wear

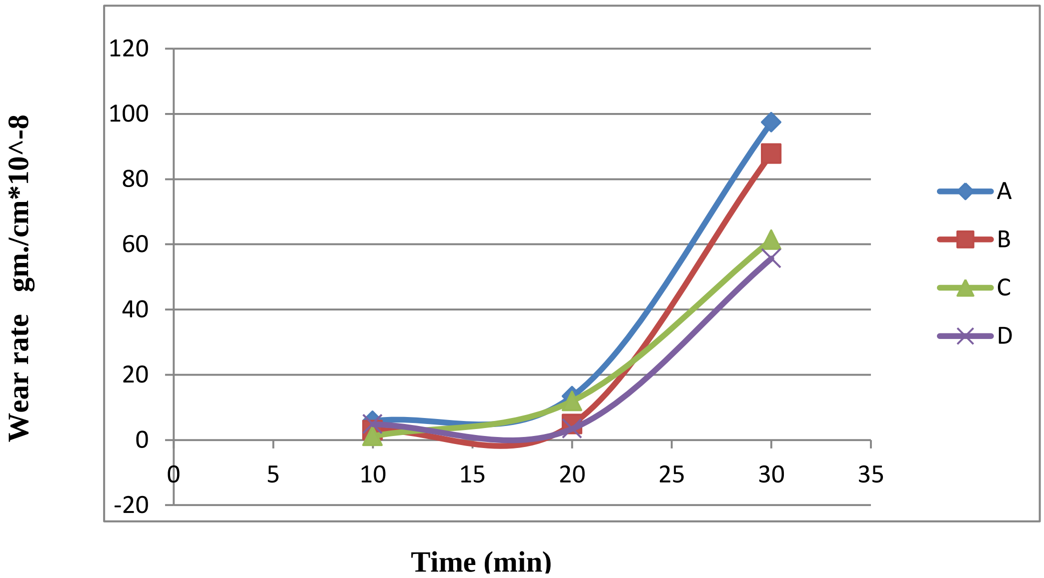


Fig.(4) the effect of time on wear rate at load 1.5 kg and sliding speed 7 m/sec

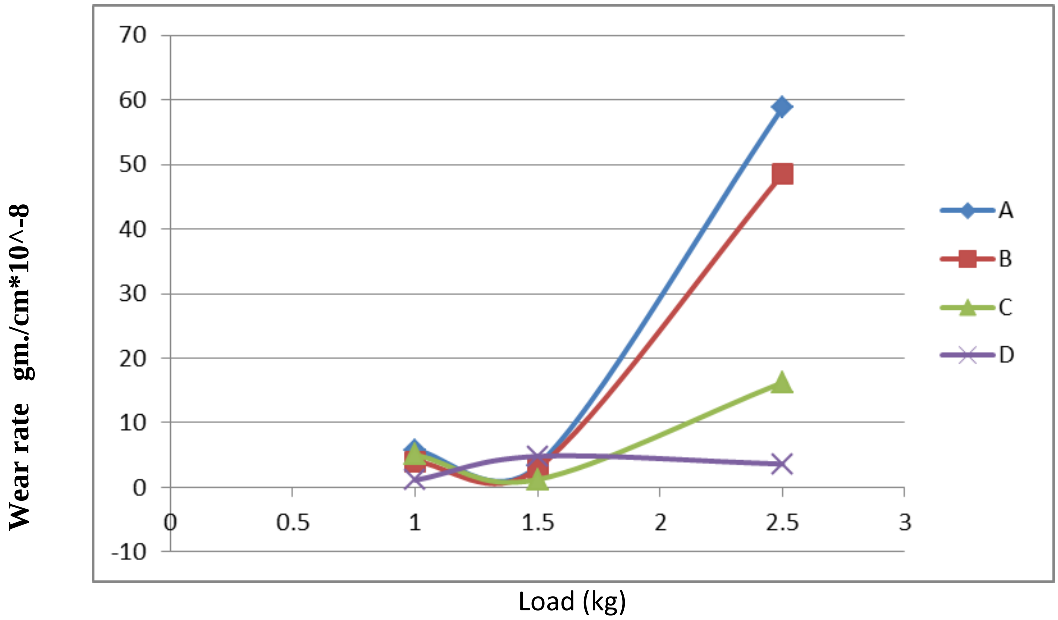


Fig.(5) the effect of load on wear rate at time 10 min and sliding speed 7m/sec

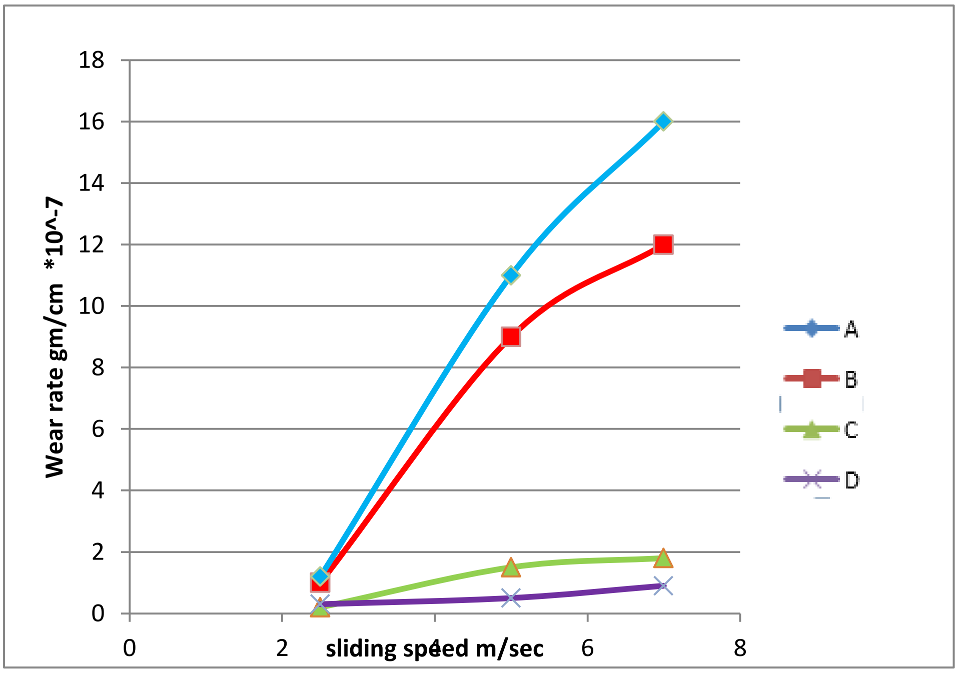


Fig.(6) the effect of sliding speed on wear rate at time 10 min and load 1.5 kg