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Mechanical Properties of The Modified Al-12%Si Alloy Reinforced by Ceramic Particles

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Abstract

The aluminum alloys are important in many industrial applications because of their light weight and good mechanical properties. For this reason many researches had been done to enhance their properties. In this work a modifier was applied to Al-12%Si alloys by adding different percentage of Antimony powder (0.1, 0.2, 0.3, 0.4 and 0.5 Wt %). The mechanical properties of the modified alloys were considered. The optimum properties were found by adding 0.3% Antimony powder. This alloy was used as the matrix for the production of composite material (aluminum matrix reinforced by ceramic particles (Y_2O_3) with different weight percent (3,6,9 and 12%Wt)) using vortex technique. The casting parameters were 3 minute as a mixing time and 300 r.p.m as a mixing speed. The microstructure, hardness and wear test were applied on the modified alloy and composite materials. The effect of the addition of Antimony and reinforcement particles on the microstructure, hardness and wear rate of the composite material were considered. The results show that the addition of Antimony leads to the microstructure refinement and change the silicon shape in the alloy from the flake – like or lamellar – like to fibrous – like In addition to the increasing the hardness when Sb is up to 0.3%, after that the hardness will decrease, as well as the addition of ceramic particles increase the hardness and decrease the wear rate.

Keywords: Al–Si / Y_2O_3, Composites, modifier, wear rate, Hardness

الخواص الميكانيكية لسبيكة المنيوم-12%سليكون المحورة المقواة بدقائق سيراميكية

الخلاصة

ان سبائك الالمنيوم مهمة في تطبيقات هندسية عديدة بسبب خفة الوزن مع الخواص الميكانيكية الجيدة. لذا توجه بحوث عديدة لتحسين خواص هذه السبائك. في هذه الدراسة تم اجراء عملية التحوير على سبيكة Al-12%Si باضافة نسب وزنية مختلفة من مسحوق الانتيمون (0.1و0.2و0.3و0.4و0.5 %). تم دراسة الخواص الميكانيكية للسبائك المحورة و تحديد الاضافة الامثل التي تعطي اعلى الخواص و التي كانت 0.3% انتيمون. استخدمت السبيكة فيما بعد كارضية لمادة مركبة ذات اساس من الالمنيوم و مقواة بدقائق سيراميكية (Y_2O_3) و باضافة نسب وزنية مختلفة (2و4و6و8 %) و باستخدام تقنية الدوامة. متغيرات السباكة التي نفذت هي 3 دقيقة كزمن خلط و 300 دورة/دقيقة لسرعة الخلط. اجري الفحص المجهري و اختبار الصلادة للسبائك المحورة و المادة المركبة. تم دراسة تاثير اضافة المحور و الدقائق المقوية على التركيب المجهري و الصلادة و معدل البلى للمادة المركبة. النتائج اوضحت ان اضافة الانتيمون تؤدي الى تنعيم البنية المجهرية و تغير شكل السليكون للسبيكة الاساس من القشري الى

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الليفي, بالاضافة الى زيادة الصلادة و لحد 0.3% انتيمون تبدا بعدها بالنقصان. كذلك فان اضافة الدقائق السيراميكية عمل على زيادة الصلادة و التقليل من معدل البلى.

1. Introduction

The need for lightweight, high performance, structural materials made Al-Si alloys attractive Candidate for Aerospace, Automotive and Consumer related industries, provided the necessary impetus for the development and emergence of Al-Si alloys Metal Matrix Composites [1, 2]. A further increase in mechanical properties of Al-Si alloys can be achieved by means of a modification treatment with Antimony, sodium and strontium. When the modifying elements are added, the eutectic silicon phase becomes a very fine and fibrous silicon network resulting in an additional improvement to the alloy mechanical properties [3,4]. In composites, the controlled distribution of one or more reinforcement materials in continuous second metal matrix phase is possible. Large majority of these composite materials are metallic materials reinforced with high strength, high modulus and brittle ceramic phases which can be either continuous in the form of fiber, discontinuous in the form of whisker, platelets or particulate reinforcements embedded in a ductile metallic matrix. The reinforcement metal matrix offers potential for improvement in efficiency, mechanical performance and reliability over the new generation alloys [5,6,7]. Aluminum metal matrix composites (MMCs) are attractive materials in the mechanical, automotive and aerospace industry, mainly for their light weight, thermal conductivity, energy efficiency, wear-resistant properties. The latter, makes the collection of data on the friction and wear behavior of these materials very important [6]. The principal tribological parameters that control the friction and wear performance of reinforced aluminum composites can be classified into two categories: one is mechanical and physical factors, and the other is the material factor. Based on detailed tribological analysis by varying mechanical and physical factors like sliding velocity, normal load etc. It was also observed that higher amount of reinforcements increased the transition load for severe wear. With regard to the

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material factors (volume fraction, type and size of reinforcement), the volume fraction of reinforcement (Vf) has the strongest influence on the wear resistance, and this has been well studied by many researchers. However, the variations of the wear rates of MMCs as functions of Vf are influenced by the shape and size of the reinforcement particles [7,8,9].The properties of metal matrix – composite material for modified Al – 12% Si alloy had been studied in this research. Different percentages of Antimony were added to know the effect of modifier on the properties. Since there are plenty of data on traditional Al2O3 or Sic reinforced Al-alloys in the recent years, science is seeking for new materials to be used.

The aim of this research is to analyses the effect of using different weight fractions of Y2O3 as a material which is not used widely in that field of materials on the hardness and wear rate of modified Al-12%Si alloys.

2. Experimental Work

2.1 Composite Preparation

Commercial eutectic modified (Al – 12% Si) alloy with good bearing properties, good fluidity and low coefficient of thermal expansion is used as the matrix. This alloy is commonly used in the production of pistons. Table (1) shows the chemical composition of the alloy. In this study, the modification process had been performed on the matrix alloy. By a different additions percentage of Antimony (0.1, 0.2, 0.3, 0.4 and 0.5)wt % to specify the better percentage of addition which gives better properties through microscope examination and hardness test. A measured amount of the matrix alloy was melted at 700 Cº in an electrical furnace (carbolite type), Antimony powder is added. After that, the melt was stirred inside the furnace at 300 r.p.m speed and 3 min times to make a vortex in order to disperse the modifier in the melt. The melt temperature was controlled and checked with thermocouple (K type) before pouring into a carbon steel die. Then reinforcement particle Y_2O_3 with grain size (-75 +50)µm with addition percentages (3,6,9and12Wt%) was added to the new modified alloy with the best ratio of addition of modified to produce a composite materials, and

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this was done by using with the same casting parameters that used with the modification of the base alloy.

2.2 Composite test

For performing the microstructure examination, the specimens were prepared by using grinding papers with different particle size (500, 800, 1000 and 1200) micron, after that the surface is grinded by using polishing clothes and Al_2O_3 suspension, then etching the surface by a solution consist of 0.5% HF and 99.5%water.For hardness test, the equipment used to measure the hardness is Brinnel with ball penetration tool , on the specimen surface three measures were taken for each specimen, then calculating the average value for the modified alloy and composite materials. Wear test was performed on Pin – on – disc equipment. Carbon steel disc had been used with hardness of 35 HRC and the average disc speed was 510 r.p.m. After the specimen was put in the holder and ensuring the touching between the surface of specimen and steel disc in an acceptable manner before the starting of testing each specimen. The grinding for the disc in the touch area after each test is applied by using grinding papers with particle size (500 and 1000) micron, for keeping uniform roughness level and cleaning the disc from the rest of specimen test. The applied loads for testing are (10, 15 and 20) N and the time of sliding that are used to measure the wear rate are (15, 30 and 45) minutes. The wear rate (wr) for specimens is calculated from measuring the weight of each specimen before starting the test (wo), and then measuring the weight after the test (w1). The sensitive scale used is with accuracy (0.0001 gm). The wear rates which have units (cm3/cm) are calculated from the following equation:

Wear rate (wr) =Δw / лρDNt

Where:-

wr = wear rate (cm^3/cm), Δw = lost weight after the test

ρ = density of the material, D = distance from the centre of specimen to the centre of disc, N = average disc speed (510 r.p.m), t = time of test in minute

3. Results and discussion

3.1 Microstructure of Modified alloys

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Figures (1-6) show the micrographs of the unmodified and modified Al-12%Si alloys. The different forms of Si in the Al-Si alloys are a function of temperature gradient (G), the interface velocity (R) and the alloy chemistry. The presence of alloying elements leads to increasing the G/R ratio which will prevents constitutional under cooling of Al phase by Si phase (i.e Si phase grows in a faceted manner from the eutectic). Additives such as (the modifier Sb) and ceramic Y_2o_3 particles leads to decreasing the G/R ratio and so easier for Si phase to be refined and reconnected with Al phase as was mentioned by Guthy(10).

The figures above show the effect of Sb addition on the microstructure of Al-Si alloys. It can be seen that by increasing the Sb percent. From 0.1% to 0.3%, the microstructure became more refined. This is due to the effect of Sb in increasing the eutectic concentration as a consequence of increasing the surface area of silicon phase, as well as the transformation of eutectic silicon from flake-like to fibrous. Increasing the Sb to 0.4% and 0.5% had led to less refinement in the microstructure as shown in figure (5,6). This is due to over modification. The better refinement was found in figure (4) for 0.3% Sb[8].

3.2 Hardness

Hardness, is described as the resistance to surface indentation of the material, in figures (7 and 8) are show the hardness curves for specimens after carrying out the modification. From figure (7), the higher value of hardness was reached when the percentage of addition was 0.3% Antimony. The reason for this is due to the refining which leads to decrease the stresses concentration on faceted second phase silicon, this belongs to transformation the flake – like of silicon to fibrous – like which increases the properties especially the mechanical.

A figure (8) shows the hardness versus Y_2O_3 content. It can be seen that the hardness of the composite specimen is increased with increasing the percentage of particulates. This increase in hardness is expected since Y_2O_3 particles being a very hard dispersed

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particle and contributes positively to the hardness of the composites. The increased hardness is also attributable to the hard Y_2O_3 particles acting as barriers to the movement of dislocation with in the matrix.

3.3 Wear rate

A figure (9) to (11) illustrate the relation between wear rate and reinforcement particle volume fraction. It can be seen from these figures that the wear rate was decreased with increase the percentage of the Y_2O_3 particles, where it reaches to low levels comparing to the base alloy. This is because of the more refinement in the microstructure and high hardness results from the higher Y_2O_3 particles and the role of the particles for bearing the applied loads because of the high hardness and toughness, but at the small percentage of Y_2O_3, it is not enough to bear all the applied loads, therefore the particles are starting separating and collecting on wear paths. When the applied load and test time increase, the deformation will be high in the base material. And the increase in the wear rate for composite material, so the added particles especially with total percentage will be starting separating.

4. Conclusions

1- The using of Sb as a modifier to the Al-12%Si leads to refining the microstructure, But to a limited value up to 0.3%Sb.

2- The using of Sb as a modifier to the Al-12%Si leads to increasing hardness due to microstructure refinement, But to a limited value up to 0.3%Sb.

3- The addition of Y_2O_3 leads to an increase in the composites hardness and a decrease in wear rate.

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Table (1) Chemical composition of commercial Al – Si alloy

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Si	Cu	Fe	Zn	Mg	Mn	Ti	Al
12.1	0.83	0.65	0.45	0.27	0.2	0.02	Rem.

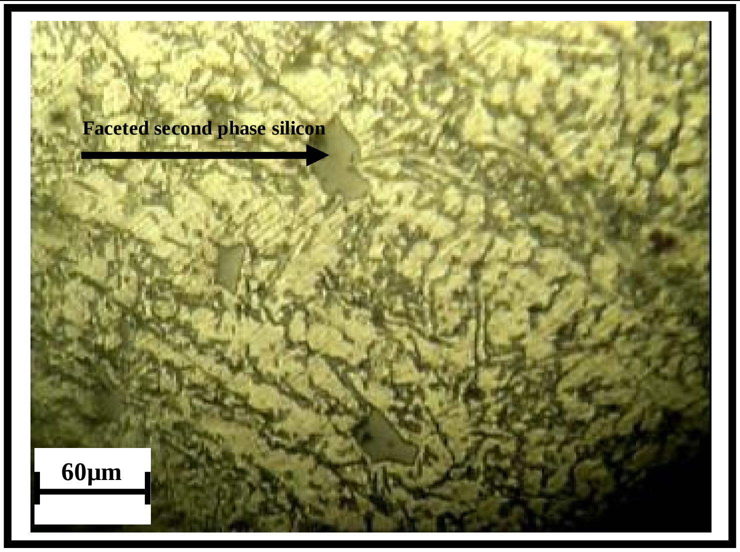

Figure (1) shows the micrographs of the unmodified Al-12%Si alloys

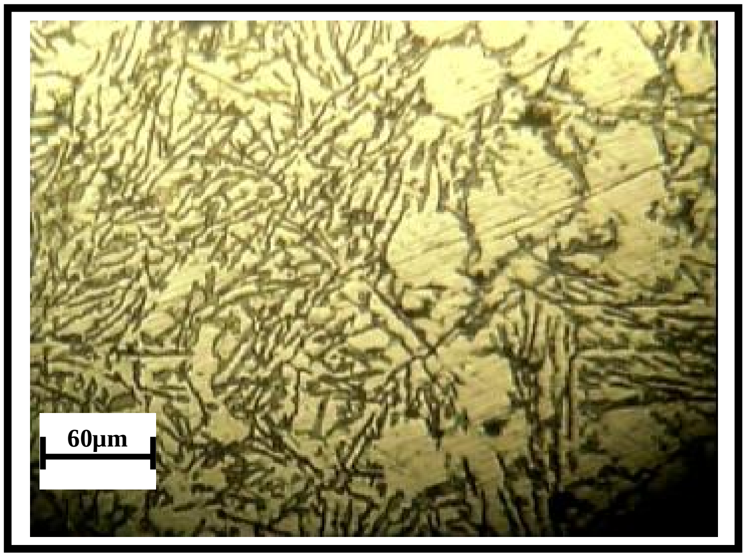

Figure (2) shows the micrographs of the modified Al-12%Si alloys 0.1%sb

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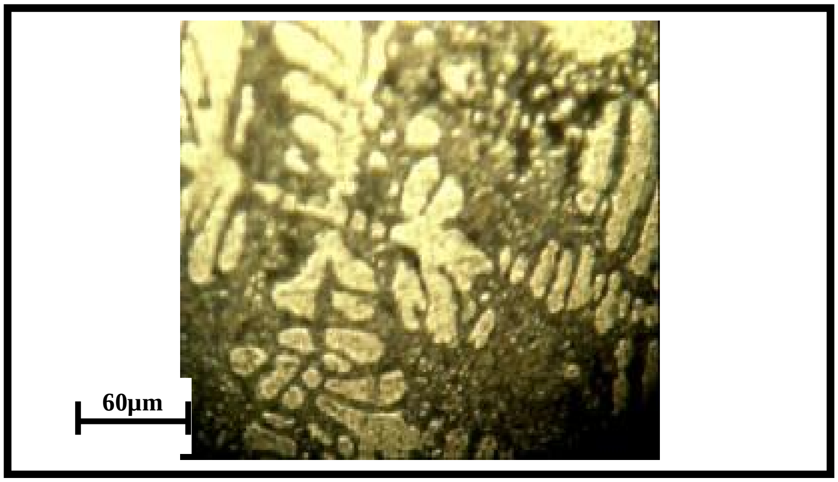

Figure (3) shows the micrographs of the modified Al-12%Si alloys 0.2%sb

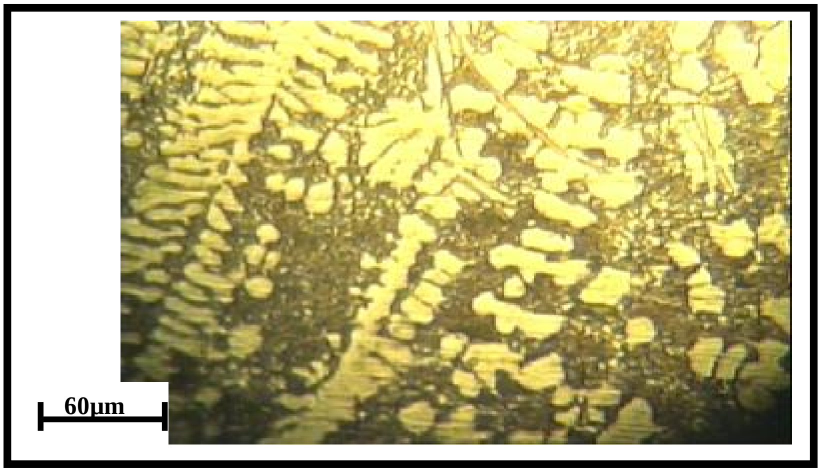

Figure (4) shows the micrographs of the modified Al-12%Si alloys0.3%sb

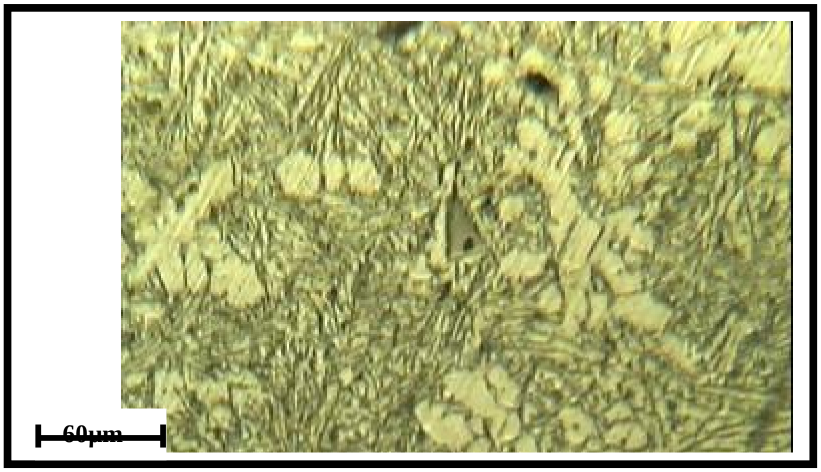

Figure (5) shows the micrographs of the modified Al-12%Si alloys0.4%sb

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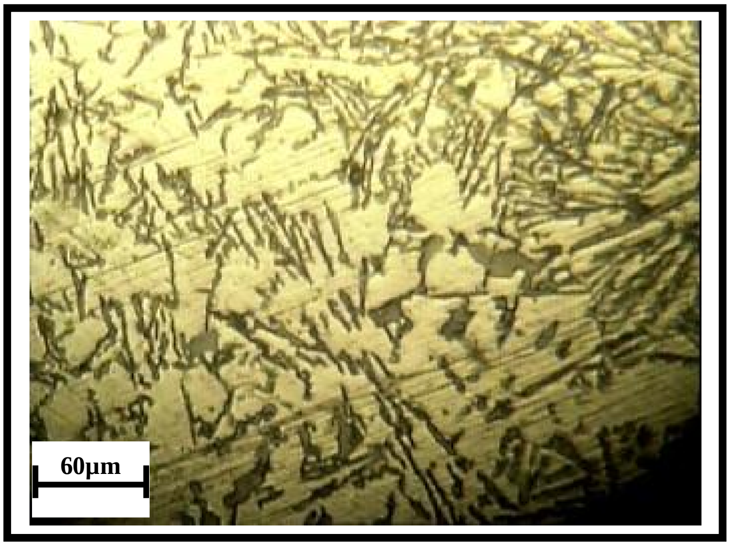

Figure (6) shows the micrographs of the modified Al-12%Si alloys0.5%sb

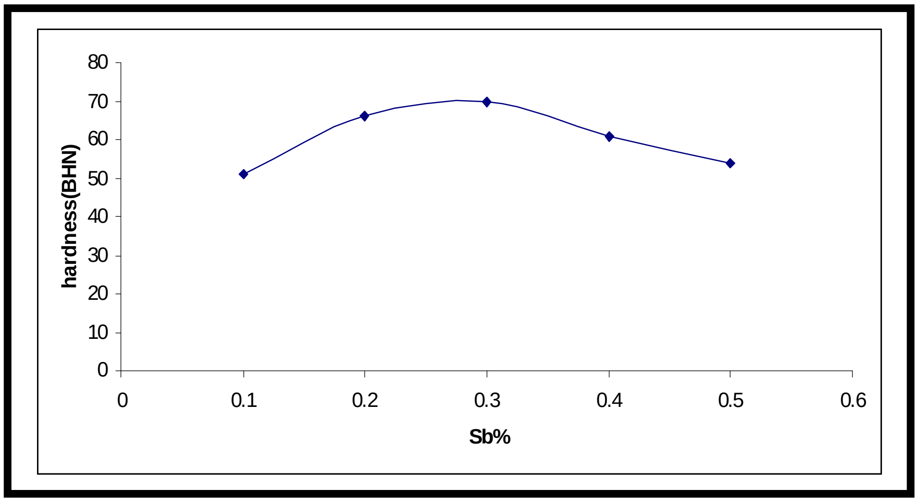

Figure (7) showing the relationship between the Sb% and Hardness (BHN) for the Al-12Si alloy

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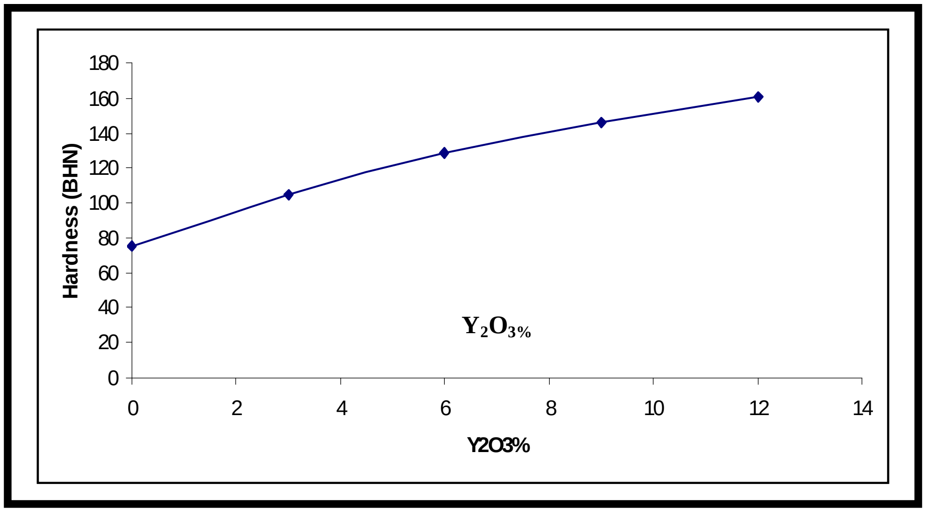

Figure (8) showing the relationship between the Y_2O_3% and Hardness (BHN)for the composite materials

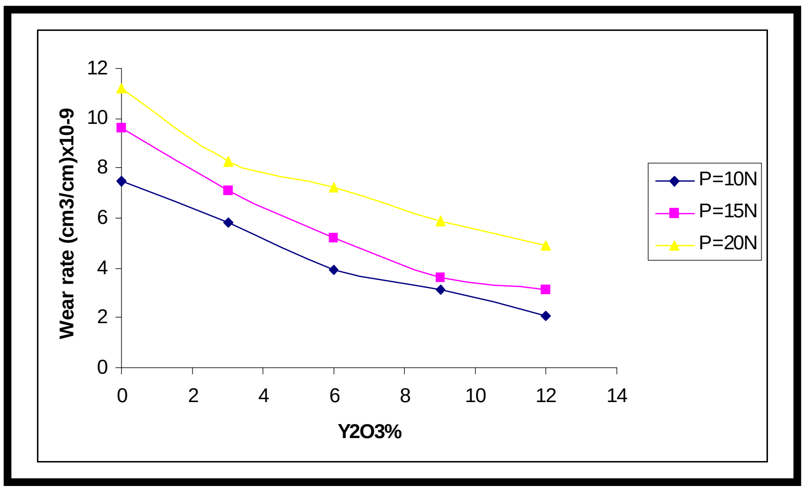

Figure (9) showing the relationship between the Y_2O_3% and wear rate at the 15 min time test.

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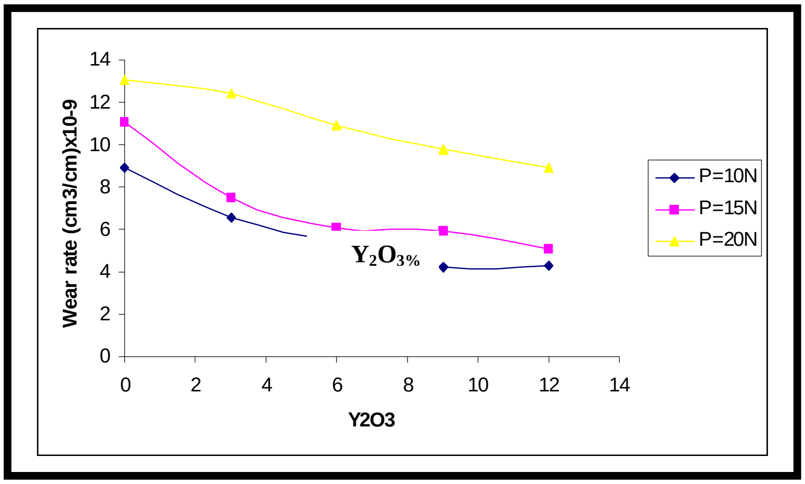

Figure (10) showing the relationship between the Y_2O_3% and wear rate at the 30 min time test.

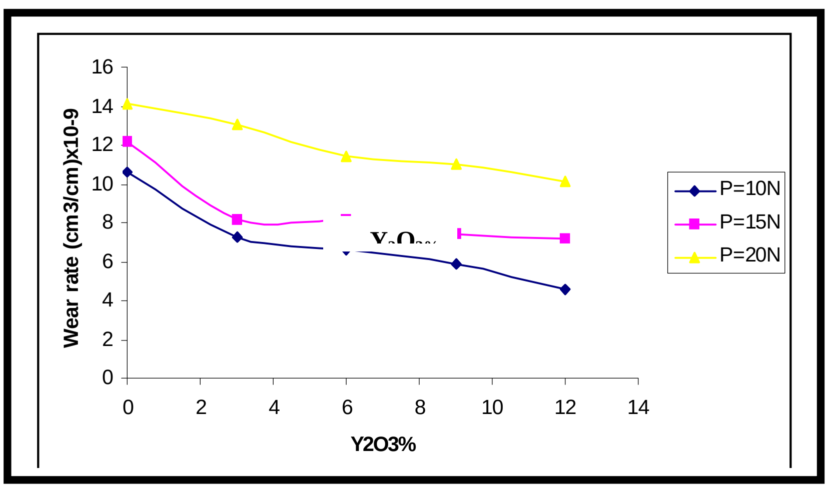

Figure (11) showing the relationship between the Y_2O_3% and wear rate at the 45 min time test.

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