PREPARATION OF COPPER-ALUMINA ELECTRICAL CONTACT MATERIALS

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ABSTRACT :

Electrical contact material are used in variety of application such as electrical switches ,contactors, circuit breakers, voltage regulators .In this paper copper with different weight percentage of α-alumina composite are prepared by using powder metallurgy technique. Disk samples of 14mm and 10mm in diameter and 5mm thickness. 5, 10, 15, 20, 30 weight percentage of α-alumina have been prepared. Tests including microstructure analyses by scanning electron microscope and optical microscope, electrical resistance, hardness, and dry sliding wear had been carried out. It's clear that the hardness and electrical resistance increase with increasing additive percentage while wear rate decrease with increasing additive percentage until 15% α-alumina where the wear rate increases .

Key words: electrical contact materials, Copper base, wear rate.

تحضير مواد موصلة كهربائيا نحاس-الومينا

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الخلاصة :

مواد التلامس الكهربائي تستخدم في عدة تطبيقات مثل المفاتيح الكهربائيه ، القواطع الكهربائيه ومنظمات الفولتيه . في هذا البحث تم تحضير مادة مركبة ذات اساس نحاس مع اضافة نسب مختلفة من الالومينا بأستخدام تكنلوجيا المساحيق. تم تحضير عينات اسطوانية بأقطار 14ملم و 10 ملم وذات سمك 5 ملم وكانت نسبة اضافة الالومينا (5، 10، 15، 20، 30) نسبة وزنية . تضمنت الاختبارات اختبار البنية المجهرية باستخدام مجهر المسح الالكتروني و المجهر الضوئي، المقاومة الكهربائية، الصلادة و البلى الانزلاقي الجاف . اشارت النتائج الى زيادة الصلادة والمقاومة الكهربائية بزيادة نسبة الاضافة من الالومينا بينما معدل البلى قل بزيادة نسبة الاضافة وصولا الى نسبة 15% الومينا بعدها يبدأ معدل البلى بالزيادة .

INTRODUCTION :

Copper has been used in electrical industry because it has the highest conductivity of commercial metal. A number of copper base alloys are used in electrical application because of their particular properties which suit them for the required application such as copper-alumina composite [Braunovic 2006]. In dispersion strengthened composite the second phase reinforced particles are finely dispersed in the soft ductile matrix. The strong particles restrict motion of dislocation and strengthen the matrix. Degree of strengthening depend upon several factors like volume, fraction of dispersed phase, size and shape of second phase particle, and inter particle spacing [Hazim 2014]. Copper- α- alumina has good electrical and thermal conductivity and less superior resistance to softening at high temperature. Alumina (or aluminum oxide) has been used due to their availability and low cost. Pure aluminum oxide,Al_2O_3, has one thermodynamically stable phase at room temperature, designated as alpha phase. The thermal shock resistance of alumina is low compared to other ceramics structure, because of the high an isotropic properties that depend on the crystallographic orientation of the alumina grains [Valefi 2012]. In order to keep the good conductivity the volume fraction and the size of reinforcement should be small [Edrees 2012]. Many papers were published in the field of reinforcing Cu-matrix by ceramic particles. In (2012) Edrees and muhsion studied reinforced copper matrix composite prepared by stir casting by adding, different weight percentage of alumina (0.1, 0.2, 0.3) to molten copper to study the effect of alumina content on hardness , tensile strength and electrical conductivity. In (2012) Chyad and his co-workers studied the effect of SiC particles with weight percentages of (1%, 1.5%, 2 %and 25%) on the wear resistance of copper graghite composite consisting of 90 wt% copper-10wt% graphite Dry sliding condition by using pin-on-disk technique was used. The structure was produced by powder metallurgy method (P/M). In (2014) Ritasalo and his co-workers studied the wear performance of Cu matrix composites which prepared by pulsed electric current sintering. The fully considered materials contained cuprite (Cu_2O), alumina (Al_2O_3), titanium diboride (TiB2) dispersoids in a coarse-graind Cu, submicron-Grained Cu, or nano grained Cu matrix. In (2014) Wankhede and shinde studied the use of Cu-Al_2O_3 composites for the applications which need materials with electrical and thermal conductivity and high wear resistance. The present work is aimed at studying and preparing copper base electrical contact material with increased mechanical properties by adding α- Al_2O_3 particles. The study will be achieved ،using P/M method with various percentages of reinforcing additives.

Experimental Work:

Fine powders of copper and α-Alumina were used as starting material to fabricate the samples with different weight percentage of α- Al_2O_3 (5, 10, 15, 20, and 30 %). The particle size of used powders, demonstrated in table (1), was determined by using the better size 2000, laser particles size analyzer see table (1). The powder mixture was mixed by using electro rolling mixer, type (STGQM-$1/_5$-2) for two hours to obtain a good homogenizing and distribution for the mix. The additive weight percentage of α- Al_2O_3 are demonstrate in table (2).

A Compacting pressure in uniaxial cold press at 550 MPa was used to prepare all samples. The pressure was determined basing on a maximum value for the density of the green compact for H_1 and H_5 . As show in figure (1) . Samples with 14 mm in diameter were prepared to be used in microstructure, electrical resistivity and hardness tests, while samples with 10 mm in dimeter were prepared for wear test. The sintering process was carried out by using vacuum furnace at 850 ᵒ c of (-760 $* 10^{-3}$ torr) for a sintering time of 4 hours. Figure (2) show the conventional powder metallurgy production sequence. The temperature of sintering was chose according to melting temperature of copper which it was below the melting temperature of copper. Figure (3) show sintering program. Sintered samples of 14 mm were ground by using paper grits as (180, 400, 800, 1000, 1200, 2000) then polished using diamond solution and etched. Microstructure was examined achieved by optical microscope and SEM. Resistance measuring device type (Applent AT512 High Precision Resistance ohmmeter) was used to determine the electrical resistance of the prepared samples. Brinell hardness test was achieved using 2.5mm ball diameter and 31.25 Kg/mm² load for 10 second. Samples with 10 mm diameter were used for dry sliding wear test depending on pin on disk concept. Steel disc of 5 mm radius was used with a rotational speed of 200 rpm, loads of 5and 10 N were used. Dry sliding wear determined according to equation (1). The test has been covered according to ASTM G-99-04.

Wear rate (cm^3) = weight loss (g) / ρ $\frac{g}{cm^3}$ (1)

Where:

$\Delta\ w$: Weight lost = weight before the test – weight after the test

ρ: theoretical density for Copper and alumina

Result and Discussion:

1. **Microstructure test**

The microstructure shown in **figure (4)** illustrates the existence and distribution of added particles to copper matrix. It’s clear that powders metallurgy technique gave an acceptable distribution of reinforcing particle.

2. **Scanning Electron Microscope Test**

It’s carried out for 30% α- Al_2O_3 – 70% Cu with different magnification power as shown in **figure (5)** The distribution and existence of added particles and pores through sample surface can be clearly noticed.

3. **Hardness Test:**

Figure **(6) shows** that by increasing additive percentage the hardness also increases because the reinforcing particles act as barrier to dislocation motion through the crystalline.

4. **Electrical Resistance:**

Results shown in **figure (7)** indicate that increasing the α-alumina percentage lead to increasing the electrical resistance, because added particle works as obstacles to the movement of electrons which is carrier electric charge lead to increasing the random and electrons welter and decrease the free flight time for the carrier electron.

5. **Wear Test:**

Figure (8) illustrate the effect of α-Al_2O_3 on the wear rate of the prepared samples. The wear rate decreases with increasing the percentage of added α-Al_2O_3 due to 15%, the increase in hardness. Adding more than 15% of α-Al_2O_3 causes the wear rate to increase because excessive increasing in α-Al_2O_3 percentage leads to increasing the friction of tested sample surface which is also lead to increasing in the removed particles from the sample surface.

CONCLUSIONS :

- Best compacting pressure is 550 MPa
- Hardness increase with increasing added percentage
- Electrical resistance increase with increasing added percentage
- Wear rate decrease with decreasing reinforcing particle until 15 % α- Al_2O_3 where the wear rate was 6.1 $*10^{-4}$

Table (1) Powders used in preparation of the samples for the present study and their sources

Powder	Particles size	Source
Copper	7.537 µm	HWNANO-Chania
α-Alumina	0.9 µm	HWNANO-Chania

Table (2): Prepared samples in the paper:

Sample Code	Weight percentage of the element %	
	Cu	α-Al_2O_3
B	100 %	----
H_1	95 %	5 %
H_2	90 %	10 %
H_3	85 %	15 %
H_4	80 %	20 %
H_5	70 %	30 %

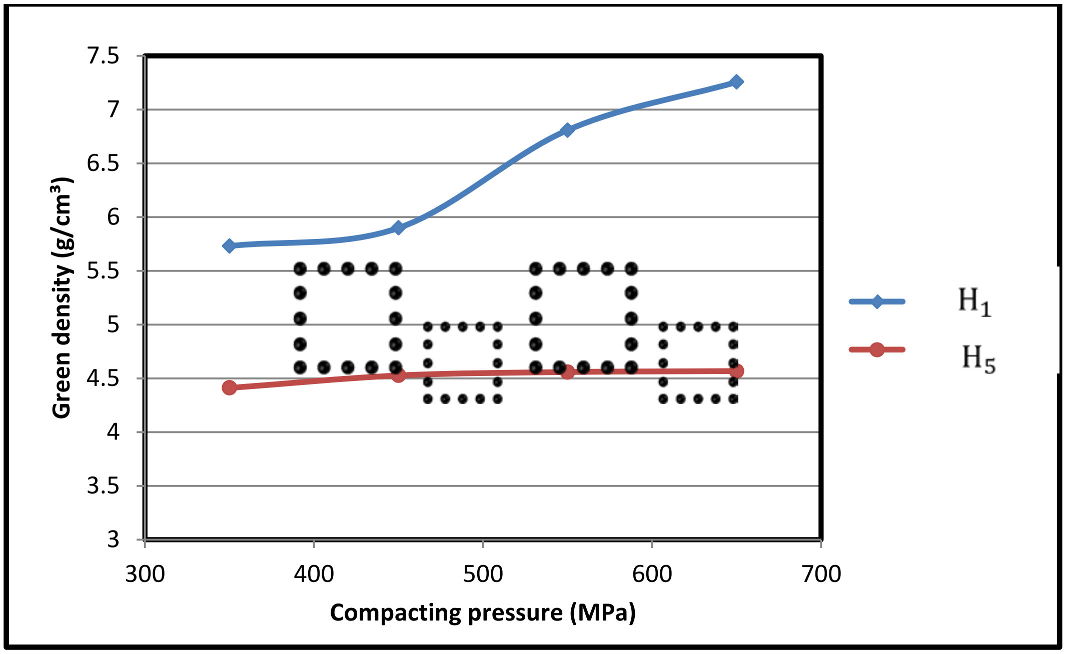

Fig (1): Effect of compacting pressure on green density of the samples

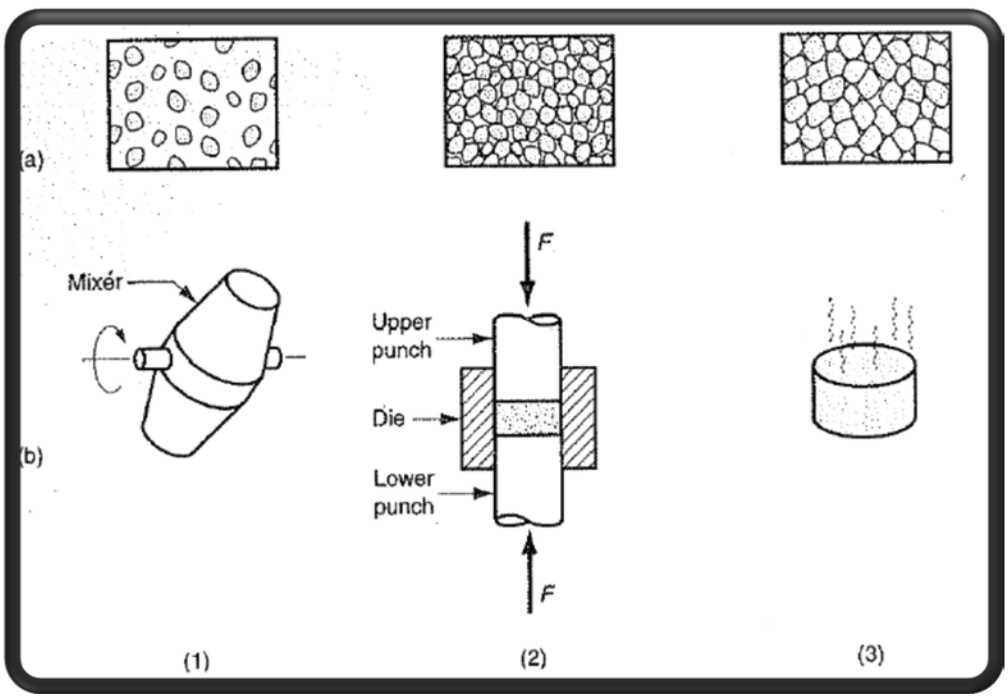

Fig (2): The conventional powder metallurgy production sequence:

(1) blending, (2) compacting, (3) sintering [Shashank 2014]

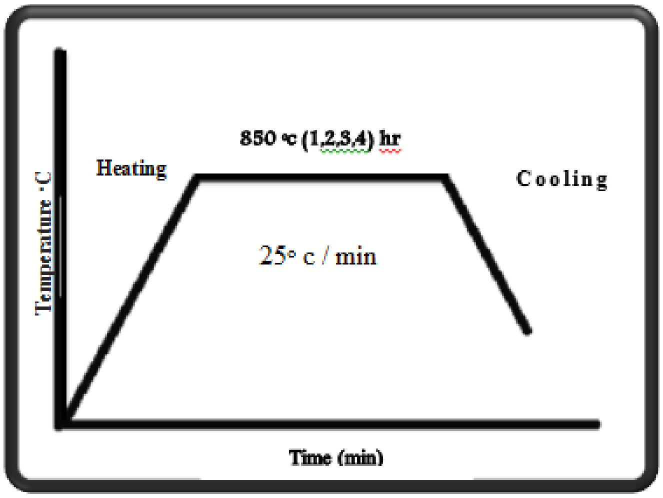

Fig (3): the program of sintering

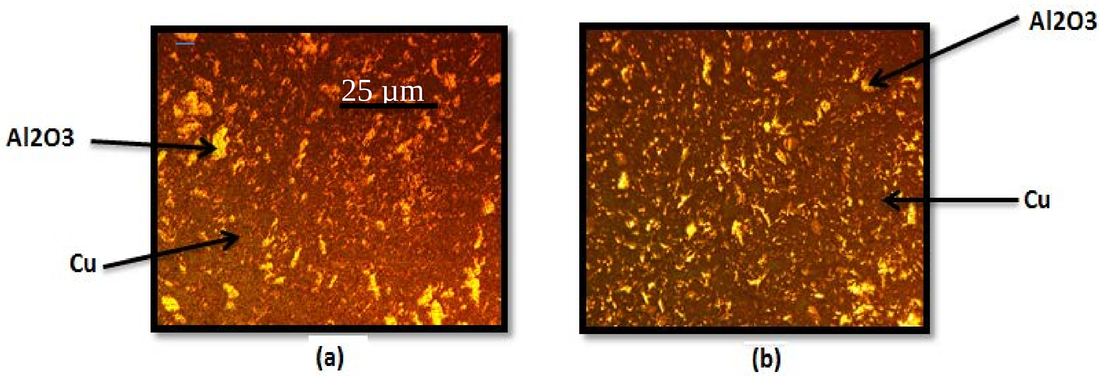

Fig (4): Microstructure of the sample prepared using a compacting pressure of 550 MPa (400X * magnification), (a) H_1, (b) H_5

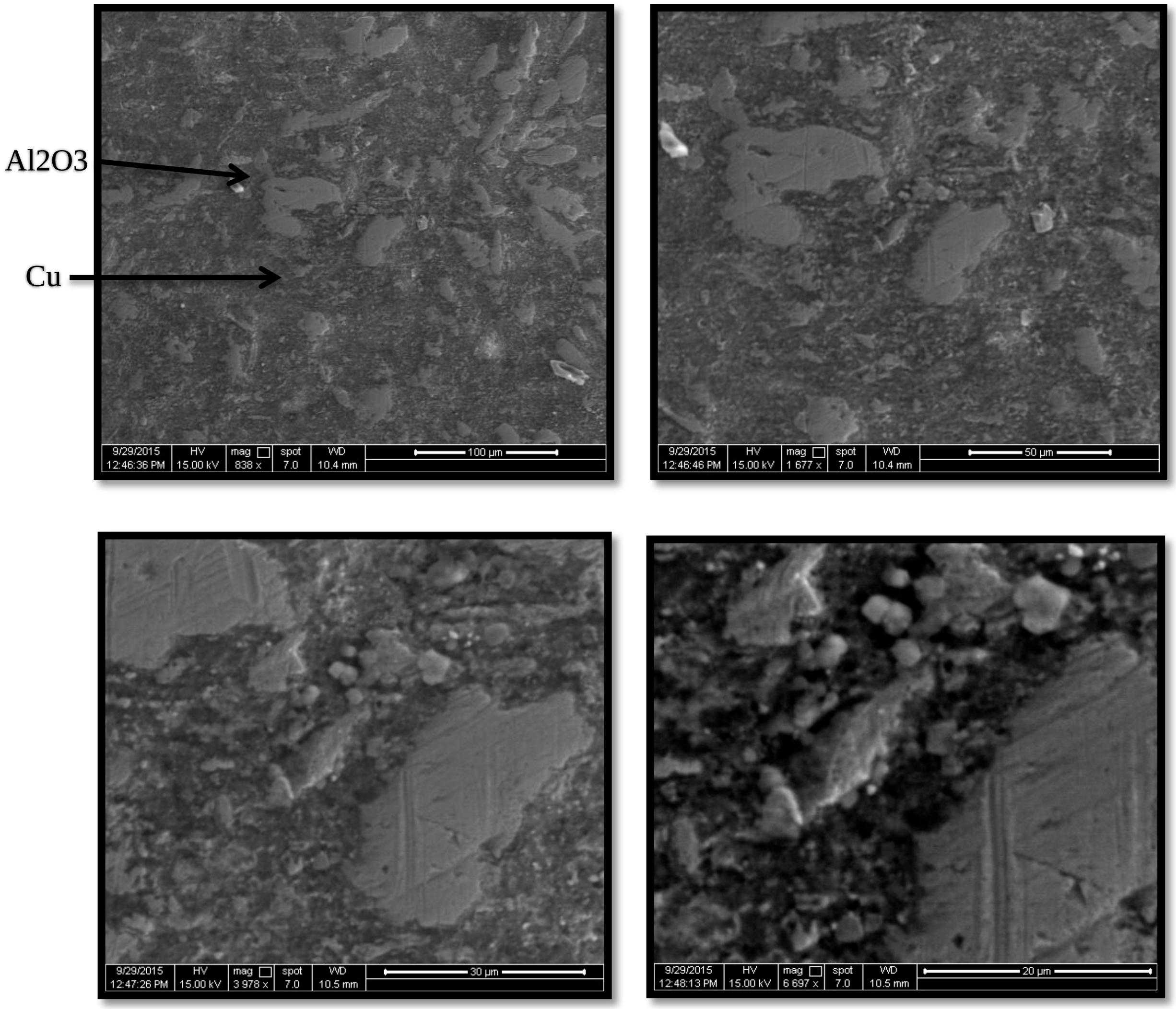

Fig (5): SEM images for H_5

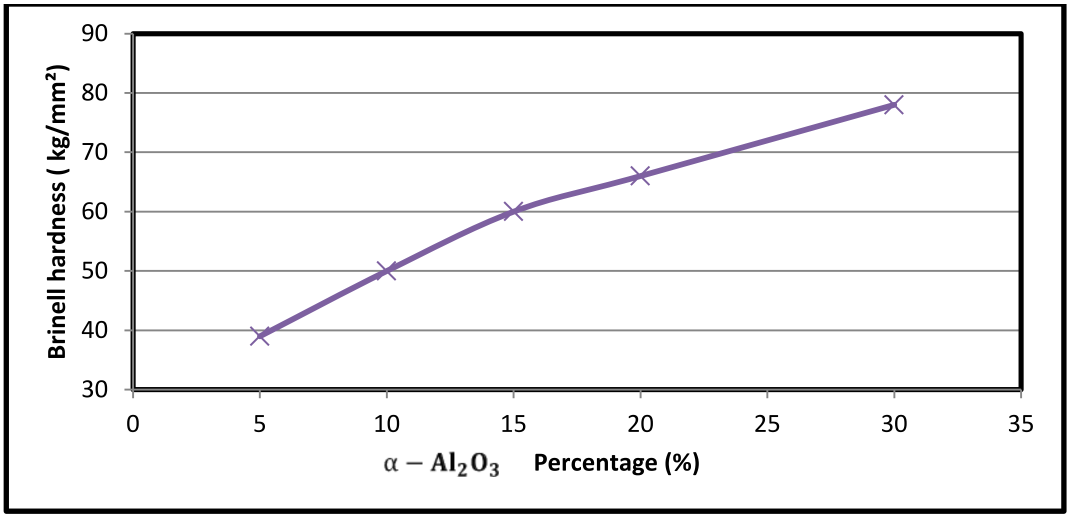

Fig (6): Effect of α-alumina additive on hardness of the prepared samples

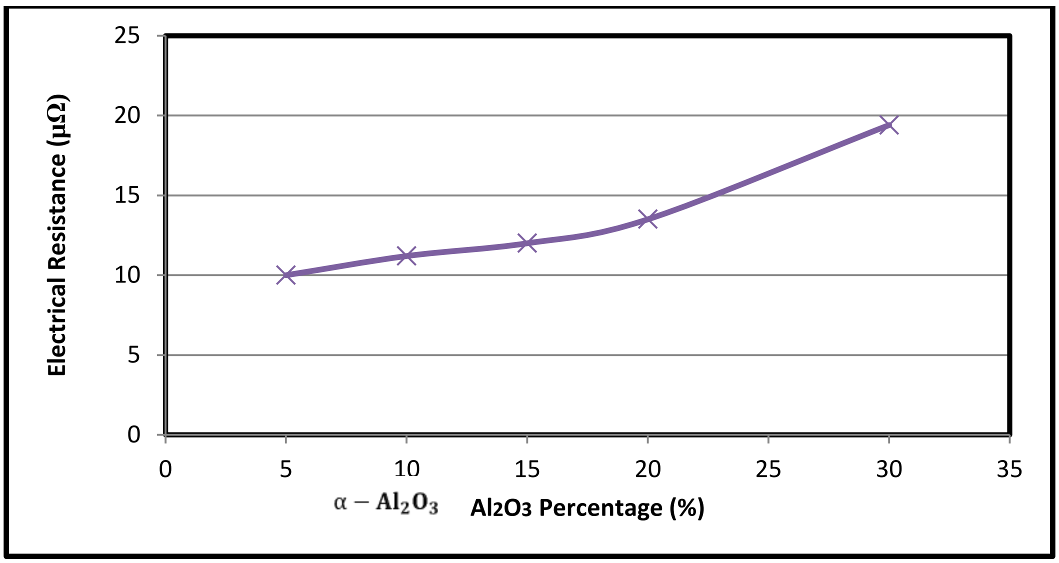

Fig (7): Effect of α-Al_2O_3 on electrical resistance

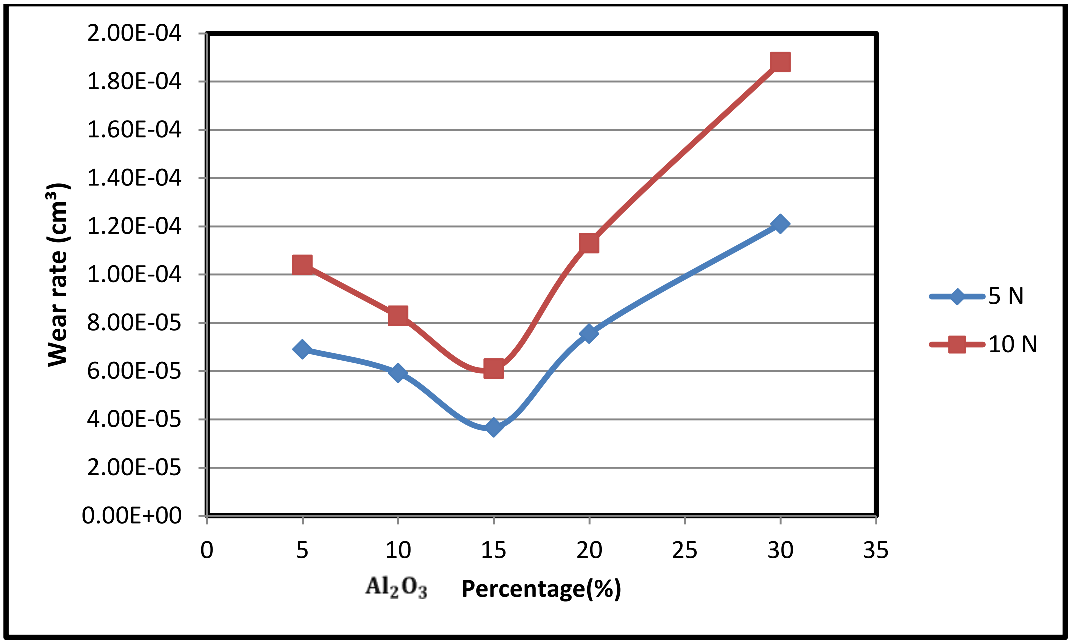

Fig (8): Effect of α- Al_2O_3 on wear rate of the prepared samples

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