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Study some of Mechanical properties of composite (Cu-Al_2O_3-Ni) prepared by powder metallurgy technology

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ABSTRACT
The present paper aims to study the properties of *(Bulk density*, *True density*, *Hardness* and *Wear)* of matrix composite material (based Copper) with (α-Alumina) Powder with different percentages (6, 4.5, and 1.3 %), and use the nickel at a constant percentage (0.7%). Manufactured by powder *metallurgy* to mix and compress the mixture by compressing (8 Tons) for three minutes, and then sintering temperature on the composite is (900°C) for one hour. So, the results referred to that there is a decrease in *Density* and *Wear* while there is an increase in *Hardness.*

Key words: Cu; Al_2O_3; Ni; Density; Wear; Hardness; powder metallurgy.

1. Introduction
The composite materials with all their kinds in all the practical scientific fields whether ceramic matrix composites "CMCs", Polymer Matrix Composite or metal matrix composite (MMC) are considered the materials in which the Copper is considered as one of the materials that used in many manufacturers shaped like composites with *Polymer*, *Metal* or *Ceramic* [1].
The composite materials is a system of materials that made up of two or three different components, these materials are different in their shapes i.e. one of them insoluble on one another, these materials are physically different and chemically heterogeneous. So, each of these different components maintains its structure and its properties, which differs by its practical features in the composite, which result in producing a composite that has components differ from the properties of its elements [2].
Composite materials made up of *Matrix Materials* and *Reinforcing Material*. These materials are characterized according to its base to composite materials with *Polymer*, *Metal* or *Ceramic* while the internal reinforcing may be *Polymer*, *Metal* or *Ceramic* [3].
Powder metallurgy (PM) is a process in which materials or components are made from metal powders. In early stages, PM is known as the processes that can be avoid, the use of MP is dating back to thousands of years ago, PM has been called a "lost art" [4].
Generally, reinforcing material must has mechanical properties more than the matrix material to be able to strengthening it, and preparing it to be used in a suitable way.
The present paper aims to improve the mechanical properties of (Cu- Al_2O_3- Ni) by reinforcing this composite with (Alpha-Alumina) Powder (α-Al_2O_3), by using Powder metallurgy.

2. Theoretical Framework
2.1 Physical Properties:
The physical properties of the bodies produced by the powder technology that resulting post-sintering is considered a measure of the success of the sintering process and potential product applications.

-Bulk density "apparent density":
The apparent density (A.D.) is the ratio between the mass and the apparent magnitude that includes (grain size of the material + the size of closed pores only) by using Archimedes' principle, we can find the apparent density A.D. through the following equation(1) [5]

$$A.D = \{W_d/(W_d-W_i)\} \times \rho_w \quad \ldots\ldots\ldots\ldots (1)$$

W_d: Dry Matter Weight, W_i: the weight of the model that is immersed with water according to Archimedes' principle, ρ_w: water density.

-The Theoretical Density
Density in general is a measure of mass per unit of volume. This density is measured by the following equation [6].

$$\rho th = \sum_{i=1}^{n} (\rho i \times Xi) \ldots\ldots (2)$$

ρ_{th} is the theoretical density, p_i is the theoretical density of element for one sample, X_i is the ratio of each element in the sample.

2-2 The Mechanical Properties :

-Hardness: Is known as the ability of a material to resist scratching and soft deformation during penetration, a certain amount of load is projected into a ball or a metal cone on the surface. Hardness is a measure of the resistance to localized plastic deformation induced by either mechanical indentation or abrasion. This measurement is not effect on the hardness which is suitable with the strength of tension [7]. Vickers hardness method (HV) is a method that commonly used in most of the research laboratories. The test is conducted by using diamond pyramid indenter i.e. a pyramid head and a square base and the head angle is 136°. Which leave a squared little mark, by measuring the diameters of this effect, using the following equation in order to the hardness is measured.[8]

$$H.V. = 1.8544 \frac{P}{D_v} \ldots\ldots(3)$$

-Wear: occurs between the contact surfaces that are metallic, non-metallic in the presence of a relative movement between them, i.e. Wear is the loss of material from the contact surfaces in the presence of a relative movement. This movement is whether rotation around, rectilinear motion or rolling motion. Wear also happens when the surfaces exposed to gases or liquid water that contain hardness parts. Wear takes place because of breaking the surface layers, so this is considered as one of Wear disadvantages, while the advantages of Wear are cutting as well as polishing. There are some effected factors that effect on Wear such as Chemical composition, microstructure, the mechanical properties, friction, slip velocity, corrosion, temperature and the pressure [8,9].

Wear rate is measured by the following equation [10]

Wear Rat = ΔW/SD .....(4)

SD = 2πr n t .....

ΔW:The weight difference of the model before and after the test. SD: Sliding distance. r: radius. t: Test time. n: The number of disk rotations (r. p .m.)

3. Practical Framework

3.1 Preparing and Mixing the Powders (Powders preparation):

The copper powder of high purity (99.9%), Nickel of high purity (99.9%), and Aluminums oxide of high purity (99.9%) have been used. The powders have been weighted by the percentages according to table (1), theses powders have been crushed up and mixed by using mortar and pestle (4.5) hour until these materials are mixed carefully.

Table (1) The proportion of materials used in the superposer

Sample	Sample Code
A	91.5% Cu - 1.5% Al_2O_3 -7% Ni
B	90% Cu - 3 % Al_2O_3 -7% Ni
C	88.5% Cu – 4.5% Al_2O_3 -7%Ni
D	87% Cu – 6% Al_2O_3 -7% Ni

3.2 Compacting Powders: The press was carried out with a (10 Ton) "hydraulic press" Prama press using a 1 cm diameter model. The compression process was performed in one way, using (8 Ton) for a period of (3 minutes) for compression. model compressed was obtained with height (0.6 cm).

3.3 Sintering of Compacts

The process of compacts sintering has been conducted by putting the compacts inside container that has covered by Silica (Sand) and irons filings in order to prevent the combination with oxygen, and then sintering by raising the oven temperature to (900°C) for one hour. The composites have been gradually cooled until it reaches room temperature.

4. Testes of Samples

4.1 Bulk density "apparent density" (A.D.)

The apparent density has studied according to Archimedes' principle by applying the equation No. (1) [6].

4.2 The Theoretical Density (T.D.)

The theoretical density of the models has measured by using the percentages and the densities of the composites components that have stated in table (1) by applying equation No. (2) [5].

4.3 The Vickers Hardness Test

The model is burnished by using sandpaper, polishing paste and cleaning clothes that have prepared to clean and polish up the model. The machine used Vickers hardness test that contains an accurate needle with empusa romboidea head, which puts in the model with (300 g.) for (5 minutes) for all the models separately. The effect of diameter is tested automatically after taking the load away. The Hardness value has been obtaining is displayed on the electronic screen of Vickers machine. Five samples have randomly selected that taken from the model surface, which included the surface area; the mean of the results has been taken [10].

4.4 Wear Test

Dry sliding wear has been selected in accordance with the global standard (ASTM G 99) by using a machine that used to test the wear, which found in material lab - Department of Mechanical Engineering - College of Engineering- Tikrit University.

After preparing the models with (10 mm.) that have polished by using sandpapers of (1000), then the model has weighted by an analytical balance that is incredible accuracy (0.0001g). The Machine has been cleaning, and then the model is placed on the special place on the turntable by a holder and put the vertical load (20 gm) on the model through Pin, whereas the hardness of the machine disk is (62HRC) with diamond (60 mm), the spin speed is (480 r.p.min) for thirty minutes. Then take out the model and weigh it again, thus, the wear and tear is calculated using the method of losing weight. That is, the difference between the two weights before and after a procedure corrosion process of the model, by applying equation No.(4)[10].

5. Results and Discussion

5.1 Bulk density (apparent density) (A.D.)

Throughout, the relationship between the samples (according to the increasing of α-Al_2O_3 in the sample), whereas the apparent density is decreased (6.8983 – 7.9965) g/cm^3, has shown in ,table (2) , figure (1).

5.2 True Density (T.D.)

The value of True density is decreased of (8.655-8.881) g/cm^3 in accordance with the table (3) as shown in figure (2).

The decrease of density is attributable to the low density of alumina reinforcement compared to the density of the remainder the other components. This decrease is consistent with the rule mixture.

$\rho_c = \rho_m V_m + \rho_p V_p$ .....(5)

P_c: The density of composite material, P_m: the density of basic materials, P_p: the density of reinforcement materials, V_m: the volume fraction of basic materials, V_p: the volume fraction of Matrix [11].

Also, the low density is associated with the high hardness of alumina, which makes it act as a barrier to compression in positions, the higher the percentage of Al_2O_3 Alumina, this phenomenon increases and the density decreases. The high difference in melting point between alumina and copper (melting point of Al_2O_3 is 2040 ^{o}C), (melting point of Cu is 1084 ^{o}C), this difference makes alumina create associations with copper, and then it will make a system with copper [12,13].

Table (2) shows the Apparent Density (A.D.) between sample (A, B, C and D)

Sample	Apparent Density (A.D.) g/cm^3
A	7.9956
B	7.5684
C	7.1990
D	6.8983

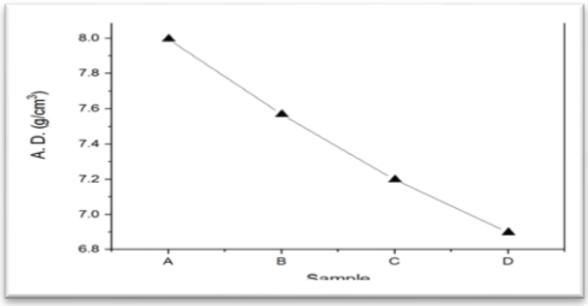

Figure (1) the relationship between the sample and (A.D.)

Table (3) shows the True Density (T.D.) between sample (A, B, C and D)

Sample	True Density (T.D.) g/c m^3
A	8.881
B	8.805
C	8.726
D	8.655

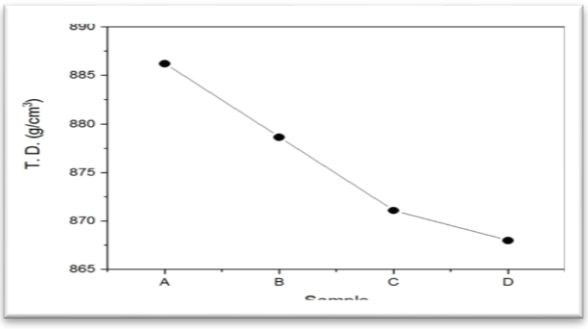

Figure (2) the relationship between the sample and (T.D.)

5.3 Vickers Hardness (VH)

Vickers Hardness of composites (A, B, C and D) that has shown in table (4), figure (3), which expresses about the relationship between hardness and the composites by increasing the percentage of reinforcement material (Al_2O_3) as it is known that alumina hardness (oxides) is higher than the copper hardness and Nickel (metal), this is considered as one of the reasons that leads to the increase of hardness due to its grains that act as barriers to misrepresent the base material, which leads to imapeding the movement of dislocations in greater proportions when its content in composites increases. As much as homogeneity in distribution between the basic material and the reinforcement grains play a significant role in increasing the hardness [14].

Table (4) shows the Hardness(HV) between sample (A, B, C and D)

Sample	Hardness g/mm^2
A	46.43
B	53.36
C	60.80
D	78.87

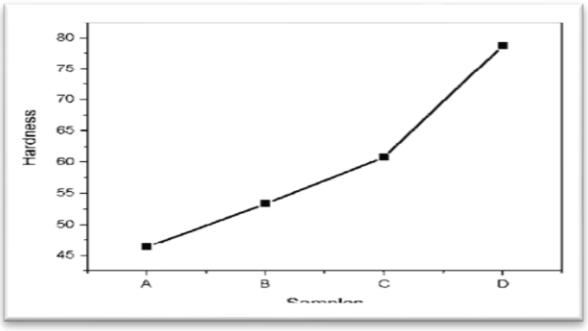

Figure (3) the relationship between the sample and Hardness(HV)

5.4 Wear Rate

The wear rate for the composites (A, B, C and D) has decreased with the increase of reinforcement rate Al_2O_3 (0.290×10^{-8} – 3.50×10^{-8}), whereas the results as in table (4) that shown in figure (4) shows that the loss of weight is decreased due to the reinforcement of base with ceramic particles, whereas ceramic hamper evacuations are provided so stresses that are harsh particles will be generated (Al_2O_3) [13]. Also, the particles of (Al_2O_3) go in the disk of wear test

machine because of its higher hardness that working on scratching it out. So, Most of the energy used to friction and leads to a decrease in the contact between the basic material and the disk, which leads to decrease the wear ratio.

Although wear is negatively correlated with hardness, according to the following equation:

$$V = K * \frac{WX}{Hv} \quad \ldots\ldots (6)$$

V: Wear Size, *K*: Wear Factor, *W*: Vertical Wear, *X*: Slipping Space, *Hv*: the Hardness of material (12)[9,12].

Table (4) shows the wear ratio and Sample (A, B, C and D)

Sample	The Wear Rate g/cm^3 $x10^{-8}$
A	3.50
B	1.99
C	1.47
D	0.290

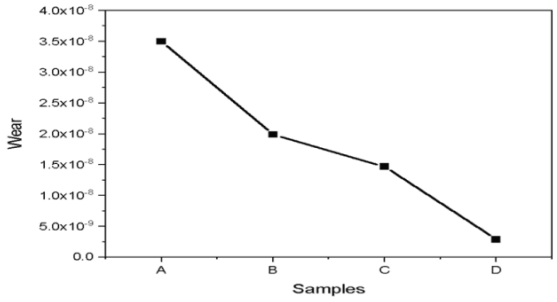

Figure (4)the relationship between the Wear ratio and Sample(A, B, C and D)

6. Conclusions

The increase of Alumina Ratio in the composite (A, B, C and D) in study reached the following conclusions:

1. increase of Vickers hardness.
2. decrease of Bulk (**apparent)** density, True Density and Wear ratio.

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دراسة بعض الخواص الميكانيكية للمتراكب ($Cu-Al_2O_3-Ni$) المحضرة بتقانة ميتالورجيا المساحيق"

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الملخص

يهدف هذا البحث الى دراسة خواص (الكثافة، الصلادة، والبلى) لمادة متراكبة ذات أساس معدني من مسحوق النحاس ومدعمة بمسحوق الفا–الومينا ($\alpha-Al_2O_3$) وبنسب وزنية (1.5, 3, 4.5, 6)% واستخدام النيكل بنسبة ثابتة (0.7%) ومصنعة بتقانة ميتالورجيا المساحيق بخلط، وكبس الخليط بضغط (8 Tan) لمدة (3min.)، ثم تلبيد المتراكب بدرجة حرارة (900^oc) ولمدة ساعة واحدة. وكانت نتائج الفحوصات نقصان في الكثافة وزيادة في الصلادة ونقصان في معدل البلى.