Influence of Thermo-Mechanical Treatment on the Microstructure and Wear Resistance of Cu-7Ag Reinforced by Y2O3

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Influence of Thermo-Mechanical Treatment on the Microstructure and Wear Resistance of Cu-7Ag Reinforced by Y$_2$O$_3$

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Abstract. Samples of electrical contact alloy (Cu-7Ag) without and with an addition of 4% V$_f$ of Y$_2$O$_3$ were prepared via powder metallurgy route. The green compacts of the samples were sintered at 850 °C for 4 hours. The heat treatments included homogenization at 777 °C for one hour, quenching in ice-water, and aging at 400°C for 8 hours. A pressure of 825 MPa was used to squeeze the alloy samples at room temperature 400 °C, and 600°C. Many Tests have been done before and after the thermo-mechanical treatments to study its impact on metallurgical, mechanical and electrical properties of the samples. The results indicated that the hot squeezing at 600°C and the 4% V$_f$ of Y$_2$O$_3$ addition evolved the best enhancement in physical and mechanical properties of the studied electrical contact material. By squeezing at 600 °C: the hardness of the base alloy was improved by 39%, the electrical conductivity was improved by 31%, and the porosity reduces by 54% while, the grain size reduced by 58% and the wear rate reduces by 90%. Adding 4% V$_f$ of Y$_2$O$_3$ enhanced the hardness and the electrical conductivity by 51% and 25% respectively. In addition, this additional reduced the porosity by 43%, the grain size and the wear rate by 83 % and 85% respectively.

Keywords: (Cu-7Ag) alloy, Thermo-mechanical treatment, hot squeezing, electrical conductivity, mechanical properties, recrystallization, warm squeezing.

1. INTRODUCTION

High conductivity and strength of the Cu-Ag alloys have garnered significant interest [1]. The combination of numerous strengthening mechanisms, which include work hardening, precipitation hardening, grain refinement, and solid solution hardening, determines the strength of the Cu–Ag alloy. The development of Ag precipitates is linked to the most significant strengthening a mechanism [2]. Knowing to the several phases of the cellular reaction is an extremely intricate issue. A driving force causes a reaction front to proceed into the supersaturated solid solution, where autocatalytic nucleation occurs during discontinuous precipitation. Most of the time, a grain boundary and the reaction front are identical, and the decomposition reaction happens by diffusion along the grain boundary. Grain boundary migration is known to result from plastic deformation because of a driving force in addition to the chemical force. The degree of plastic deformation has a significant impact on the grain boundary migration rate. Diverse values for the velocity of the reaction front motion during the cellular precipitation are provided by this dependence. The precipitation kinetics must be significantly influenced by the border migration rate if the latter is possible under these circumstances, when cell expansion and recrystallization processes are observed concurrently. In polycrystalline materials, enormous diffusion can be significantly boosted by diffusion along grain boundaries, which often serve as paths for fast atom transport [3]. The use of Cu-Ag alloys with an Ag concentration less than 8 wt % or the maximum
solubility at the eutectic temperature, has major benefit over equivalently treated Ag-rich alloys: the modest Ag content results in a better electrical conductivity [4-6]. The Cu-Ag binary system exhibits a simple eutectic phase diagram. Around 8% of both components are mutually maximally soluble at the eutectic a temperature of 780 °C. The composition of the eutectic is 72 weight percent Ag and 28 weight a percent Cu. The superposition of many strengthening mechanisms determines the strength of hypo-eutectic Cu – Ag alloys. The procedure of decomposition decreases the concentration of silver in the copper solid solution, which weakens the solid-solution hardening ability a [7]. Although Cu-7Ag alloy is regarded as a suitable electrical contacts material due to its high thermal and electrical conductivity, it has a relatively low wear resistance. The enhancement of this property and many other mechanical and physical properties can be achieved by a grain refinement and by adding hard particles or ceramic oxide. The impact of such procedures on the properties of many alloys were examined and published. Salah N. Alnomani in [8] got by raising density and decreasing porosity of brass samples (60% Cu-40% Zn) prepared using the hot iso-static pressing (HIP) sintering method. This resulted in a a notable improvement in hardness and strength compared to the comparable other cast alloys. The results demonstrated an 8.4% improvement in the values of the density due to the noticeable decrease in porosity values from 8.65% to around 0.43%. Rasha in her study [9] focused on improvement of Cu10Sn alloy prepared by stir casting by reinforcing with graphite along with hot squeezing at 600 °C. The added graphite was coated by copper. The results showed that 9Tons hot squeezing pressure applied on Cu-10Sn alloy with 5wt.% coated graphite reduced the grain size by 48%, decreased the porosity by 20%, increased the hardness by 94%, reduced the wear rate by (54%), and reduced the friction coefficient by 39%. Temel Varol et.al. in [10] astudied the characteristics of new Cu-Ag alloys enhanced with hot-pressed copper particles coated in silver. A thorough investigation was conducted into the impact of the amount of silver-coated copper particle content on the microstructure, density, hardness, and tensile strength of Cu-Ag alloys. The copper matrix had evenly spaced particles of copper plated in silver.

In [11] Al-Mhanna, M. A. M. H., et. al, got a discernible enhancement in the tensile and machining characteristics of 7075 Al alloy samples by warm squeezing resulted in a rise of 11% in the elongation percentage, 40% in the yield strength, and 19% in the tensile strength of the sample. In [12] Jaafar, et. Al, through statistical technique optimization of the composite's manufacturing process, An effort has been made to extend the anticipated life of the powder metallurgy-created copper graphite composite and enhance its multi-performance properties. The study's characteristics significantly influenced wear rate, densification, and electrical conductivity, according to the findings. The best combination of process parameters for achieving the best multi-performance characteristics was found at 750 MPa of compaction pressure, 950 °C of sintering temperature, and 10% of graphite content. In [13] , Al-Ethari. al, investigated the effect of warm squeezing on the microstructure, the hardness, the grain size, and the machinability of 2025Al alloy. The treatment included warm squeezing at 150°C by a pressure of 50, 100, and 150MPa. It has been noted that when the squeezing pressure increases, the hardness rises and the grain size falls. A maximum reduction of 56% in grain size and a maximum rise of 62% in Vickers hardness were achieved. Mu, et. al [14] shown that adding the appropriate amount of Y2O3 increases the samples' density and hardness. By adding 1.5 weight percent Y2O3, the sample's hardness reaches its maximum, and by adding 2 weight percent Y2O3, its density reaches its maximum. Yan et al.'s study from [15] demonstrated how ceramic particles can effectively improve copper's mechanical qualities, thermal expansion behavior, and high-temperature stability while retaining high levels of thermal and electrical conductivity. It also provided an explanation of the effects of ceramic particle content, size, morphology, and interfacial bonding on the mechanical behavior, electrical conductivity, and diathermancy of copper matrix composites. The current study will concentrate on the addition of a ceramic oxide and warm or hot squeezing to produce the Cu-7Ag alloy as an electrical contact material.
2-Materials and Tests Utilized in this Work:

The foundational materials for the base alloy and composite samples utilized in this investigation were 99.9% pure powders of copper (Cu), silver (Ag), and yttrium oxide (Y2O3). Particle sizes of the powders were investigated using (Better size 2000, laser particles size analyzer). Table 1) shows each powder's source and particle size.

<table>
<thead>
<tr>
<th>Powder</th>
<th>Supplier</th>
<th>Average Particle size (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>THOMAS BAKER (CHEMICALS PVT.LTD.B3&amp;B4, MIDC, CHEMICAL ZONE, AMBERNATH 421 501. INDIA.</td>
<td>19.26</td>
</tr>
<tr>
<td>Ag</td>
<td>Nanjing Nano Technology Co.,ltd.</td>
<td>11.64</td>
</tr>
<tr>
<td>Y2O3</td>
<td>Qingdao Hesiway Industrial Co. ,ltd.</td>
<td>4.6</td>
</tr>
</tbody>
</table>

3. Preparing the Samples:

3.1 The Fabrication Process

Two types of samples were prepared. The base alloy (Cu-7%Ag) represents the first type, while the alloy reinforced with 4 vol.% of Y2O3 is the second. In order to get the necessary percentage, the preparation began with mixing the powders. Four hours of mixing has been taken into consideration for the base alloy (Cu-7Ag), whereas six hours of mixing were employed for the composite samples. The powders were mixed using a STGQM-1/5-2 electro rolling mixer. A 10wt% alcohol was utilized in the mixing process. Using a double-action steel die, cylindrical samples with 12 mm-diameter and 15 mm-height were prepared via an electric-hydraulic press type (CT340-CT440). A compacting pressure of 825 MPa was applied to each sample according to the constancy of the green density. Figure (1) shows the program employed for the sintering process of the base alloy and the composite via a furnace type (MIT-GSL1600X).

The MIT-GSL1600X furnace was used to heat treat the sintered compacts in Argon gas atmosphere. Heat treatment of both types of the samples included homogenization at 777 °C for one hour, quenching in ice-water and then eight hours of aging at 400 °C according to [16,17].

3.2 Squeezing Process

The heat treated samples of the reinforced alloy (Cu-7Ag+4 Vl.% of Y2O3) and the (Cu-7Ag) base alloy had been subjected to the squeezing process. Squeezing was done at temperatures, 25 °C,400°C and 600 °C. A squeezing pressure of 825 MPa was applied to cylindrical samples of 12 mm in diameter and 14 mm in height, which was fitted without clearance inside a cylindrical steel die with a 12 mm internal diameter. Six minutes of squeezing were considered. An electric press
of the Carver type was used for the squeezing procedure. The equipment seen in Figure (2) was specifically designed and fabricated to carry out the heating process. The steel mold utilized for the squeezing procedure is shown in Figure (2b). After completing the hot squeezing at 600 °C samples had been quenched with ice water and heat treatment such as homogenization and ageing was also performed.

Figure 2: (a) The Controller of Temperature, Designed Heating Elemental (b) Image with a Geometric Design of the Steel die Used for Squeezing. (c)a Press Type (Carver) used to Perform the Squeezing of the Samples.

4. Test, Results, and Discussion

4.1 Microstructure

The heat-treated samples were ground using 400, 600, 800, 1000, 1500, 2000, 3000, and 4000 silicon carbide paper grits, polished using diamond paste, and then etched at room temperature in a FeCl3•6H2O solution [17]. The samples were etched, then dried using an electric dryer and cleaned with distilled water. The microstructure of the sample was captured using an optical microscope. The microstructure was examined after each squeezing process as shown in Figures (3) and (4). Compared to the sample squeezed at room temperature the warm squeezed sample at 400°C shows a grain refinement and the grain boundaries increase and get closer to each other as shown in Figures (3b) and (4b). Warm squeezing process led to equiaxed grains microstructure, point defects and pores were eliminated to a large extent. Figures (3c) and (4c) depict the model that underwent hot squeezing, the grain size became smaller as a result of recrystallization, and new, small, un-stressed grains formed adjacent to the numerous grain boundaries.

Figure 3: Optical micrographs of Cu-7Ag (a) At Room Temperature, (b) squeezed at 400 °C; (c) Squeezed at 600°C, then heat treated.
4.2. X-Ray Diffraction Analyses

The XRD-6000 generator type was utilized for the testing, with a Cu target of 40 N kV and 30 mA, a scanning range of \(30^\circ–85^\circ\), and a scanning speed of 6 (deg/min). The Cu-7Ag base alloy and Cu-7Ag+4vol.% \(Y_2O_3\) following heat treatments are shown in Figure (5), where the peaks correspond to the conventional reference codes (96-150-9080) for the silver-copper compound (0.04/3.96) and (00-005-0574) for the \(Y_2O_3\). The information gathered is listed in Table (2). These stages are created by heating the samples to a specific temperature. These specific phases are well-known for their exceptional hardness and strength, and they have a big impact on the qualities, especially the hardness, wear resistance, and strength.

![Figure 4: Optical Micrographs of Squeezed Cu-7Ag+4vol% Y2O3 (a) at Room Temperature; (b) at 400 °C, (c) at 600 °C, then Heat Treated.](image)

![Figure 5: XRD Pattern of: (a) Cu-7Ag; and (b): Cu-7Ag+4% Vf of Y2O3](image)

<table>
<thead>
<tr>
<th>Elements</th>
<th>h</th>
<th>k</th>
<th>l</th>
<th>d [Å]</th>
<th>2Theta[deg]</th>
<th>I [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>silver-copper compound</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2.08800</td>
<td>43.254</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1.80800</td>
<td>50.375</td>
<td>45.0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1.27800</td>
<td>74.007</td>
<td>22.0</td>
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<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3.06000</td>
<td>29.160</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 2: The Details Obtained by XRD.
4.3 Hardness Test

Specimens measuring 12 mm in diameter and 13 mm in height before squeezing and 12 mm in diameter and 11.5 mm in height after squeezing were meticulously prepared for this experiment. The (Wilson Hard REICHERTER UH 250) universal macro hardness tester type was utilized. The tests were carried out in accordance with ASTM (E10-15a) and used a ball with a diameter of 2.5 mm and a force of 31.25 kg for ten seconds. Only the base alloy sample was subjected to the Vickers hardness test. ASTM [E384] states that a 300 g force was applied for 10 seconds. For every specimen, the average of three hardness readings was used to record the hardness. The hardness test results are displayed in Table (3).

Table (3): Hardness Values after Treatments for each Sample

<table>
<thead>
<tr>
<th>Alloy/Composite</th>
<th>Before squeezing</th>
<th>After squeezing at room temperature</th>
<th>After squeezing at 400°C</th>
<th>After squeezing at 600°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu-7Ag</td>
<td>80 (95 HV)</td>
<td>103(129 HV)</td>
<td>116(138 HV)</td>
<td>132(146 HV)</td>
</tr>
<tr>
<td>Cu-7Ag+4% Y₂O₃</td>
<td>86</td>
<td>111</td>
<td>128</td>
<td>173</td>
</tr>
</tbody>
</table>

Table (3) shows how applying squeezing at the same pressure (825 MPa) at different temperatures increases the hardness of both the base alloy and the composite. As the squeezing temperature increases, the hardness also increases due to the gradual closing of the pores and gaps. The maximum hardness is achieved when the samples are squeezed at 600°C, as this leads to the closure of the largest number of pores. At a temperature of 600, recrystallization occurs in the base alloy and the composite. New fine, unstressed grains composed of Y₂O₃ particles can act as a nucleation agent. When Y₂O₃ is added to the basic alloy (Cu-7Ag), the composite becomes harder. The toughness of these additional particles is high. Samples have a long lifespan because it bears a portion of the applied force, which improves the material's strength and hardness and requires a large applied load to deform it. Since Y₂O₃ has excellent chemical stability and certain qualities, it was added to the copper alloy as a dispersion-strengthening phase [8, 12].

4.4 Electrical Conductivity

Figure (6) shows the results of electrical conductivity test. The surfaces of the samples were thoroughly cleaned before the test because contaminants, dust, and oxides might lead to inaccurate readings. Grits of SiC paper 400, 600, 800, 1000, 1500, 2000, 3000, and 4000 were used to grind the samples. Using an Applent AT512 High Precision Resistance Ohmmeter, a resistance measurement device, the readings were determined.
Electrical conductivity is proportional to the concentration of electrons and their mean free paths. The increased pore closure in the structure of the base alloy and composite leads to a decrease in resistivity. This, in turn, results in an increase in conductivity due to the increase in the mean free path of electrons. Grain refinement occurs at different levels: at room temperature, some grain refinement occurs, and at 400°C, further refinement takes place, resulting in equiaxed grains. The finest grains are obtained through hot squeezing at 600°C due to recrystallization. The electrical conductivity of the (Cu-7Ag) base alloy and composite increases due to the decrease in conductive electron scattering [17]. The application of squeezing pressure enhances the network structure of the matrix and enhances the bonding at the interface between the ceramic phase and the metallic matrix composed of Cu-7Ag. These effects collectively result in enhanced heat transfer, electrical conductivity, and load transmission, as stated in reference [15].

4.5 Grain Size Measurement

Atomic force microscopy (AFM) type (AA3000 Scanning probe microscope) was used in this test. Table (4) demonstrates the results of the grain size measurement. As the squeezing temperature increases, the fineness of the grains increases. The finer grain was achieved by hot squeezing at 600 °C for both the base alloy and the composite. It is observed that the ceramic oxide contents leads to increase in the number of grains (i.e. to small grains size) beside the effect of hot squeezing. This may be attributed to the higher number of nucleation center by the insoluble Y₂O₃ particles. In addition to the chemical force, it is well known that plastic deformation induces grain boundary motion. The degree of plastic deformation has a major impact on the migration speed of the grain boundary [9,12]. Because of this correlation, the reaction front speed during discontinuous precipitation can take on a wide range of values. Diffusion along grain boundaries, which typically operate as pathways of rapid atom movement, can significantly boost the mass transport in polycrystalline materials. Therefore, the hot squeezed at 600 °C composite specimen and the heat treated recorded the smallest grain size as illustrated in Table (4).

<table>
<thead>
<tr>
<th>Samples</th>
<th>Before squeezing</th>
<th>Squeezing at room temperature</th>
<th>Squeezing at 400°C</th>
<th>Squeezing at 600°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>base alloy</td>
<td>568 nm</td>
<td>504 nm</td>
<td>115 nm</td>
<td>100 nm</td>
</tr>
<tr>
<td>Cu-7Ag 4Vol.% +Y₂O₃</td>
<td>146 nm</td>
<td>122 nm</td>
<td>109 nm</td>
<td>61 nm</td>
</tr>
</tbody>
</table>

Table 4: The Grain Size Measured by AFM
4.6 Porosity and Density

The porosity of the specimens was determined according to an ASTM B328 [18] and according to Equation (1) to:

\[ P = \left[ \frac{B - A}{(B - F)D_0} \right] \times 100 \]  

\[ \text{Where: } P = \text{interconnecting porosity by volume, } \%; A: \text{ Mass in air of oil-free specimen, (g)}; B: \text{ Mass of oil-impregnated specimens, (g)}; F: \text{ Mass of immersed specimen in water at room temperature (g)}; D_w: \text{ Water density (0.9956 g/cm}^3\text{) at room temperature}; D^o: \text{ Oil density (0.634 g/cm}^3\text{). Figure (7) shows the results of the porosity test.} \]

![Figure 7: Porosity of (Cu-7Ag), (Cu-7Ag+4 Vf % of Y2O3) Specimens Before and After the Squeezing Process](image)

Figure 7: Porosity of (Cu-7Ag), (Cu-7Ag+4 Vf % of Y2O3) Specimens Before and After the Squeezing Process

Hot squeezing technology is a technique that significantly aids in reducing the pores within the structure of the final product, leading to a considerable improvement in mechanical properties [8]. Squeezing refines the grain which affects on the porosity formation with increasing the density. The lowest porosity was recorded as 0.89 % and 0.76% for (Cu-7Ag), (Cu-7Ag+4 Vf % of Y2O3) specimens respectively when squeezed at 600 °C. As a result, the strength and hardness of the material are expected to increase. The scattered particles exhibit a homogeneous distribution and collectively bear the applied load alongside the matrix. The interface between matrix and Y2O3 particles is transformed from non-coherent to semi-coherent [19].

Figure (8) represents the density of the tested specimens. The density was measured by Eq. (2).

\[ D = \left( \frac{A}{B - F} \right)D_w \]  

\[ \text{Where: } D = \text{ density; (g/cm}^3\text{)}; A: \text{ Mass in air of oil-free specimen, (g)}; B: \text{ Mass of oil-impregnated specimen, (g)}; F: \text{ Mass of immersed specimens in water room temperature (g)}; D_w: \text{ Water density (0.9956 g/cm}^3\text{) at room temperature.} \]
Recrystallization occurs within the range (0.5-0.7) Tm of the alloys. A high diffusion rate is achieved when employing hot squeezing at 600°C. Solid, insoluble ceramic particles Y2O3 behave as nucleation sites that led to the nucleation of new, unstrained nuclei, thus pores would have closed. Both of squeezing and heating simultaneously result in the production of high-density products with high static strength. Additionally, no segregation or grain growth can occur during squeezing, with repeated heat treatments such as homogenization and aging that followed the hot squeezing. This also enhances density and other mechanical properties while minimizing porosity. This process increases density and can further enhance the final samples density due to the diffusion rate between contacting particles. Since porosity has a significant impact on a material's mechanical and physical properties, porosity test analysis is a crucial method for evaluating the quality of alloys. In comparison to the sample that was not treated to hot squeezing, the results in Figures (7) and (8) demonstrate that the sample exposed to hot squeezing had higher density and lower porosity. Through plastic deformation and grain refinement, this technique modifies the microstructure and inhibits the creation of porosity. Overall, hot pressing of copper alloys is an effective method to decrease porosity and increase density, thereby enhancing the material's mechanical properties and suitability for different industrial uses. The hot squeezing procedure naturally closed the pores to the greatest extent feasible, which resulted to increased electrical conductivity values. Since porosity and density are strongly correlated, this also led to a notable increase in density.

4.7 Wear Test

The wear rate was measured based on a pin on a disk method according to ASTM G 99-04 [20]. The test specimens for the dry sliding wear test have dimensions of 10 mm for height and 12 mm for diameter. An electric balance with a precision of 0.0001 was used to weigh the specimens. For the evaluation, a wear tester (model MT-4003, revision 10.0) a weight of 10 Newtons was applied. The samples were weighed after 5, 10, 15, 20, and 25 minutes in order to determine the dry sliding wear rate using Eq. (3) [9]:

\[
(W_r = \Delta w/2\pi rnt) \quad ......... (3)
\]

Where: \(W_r\) - wear rate (g/mm); \(\Delta w\) - weight lost (g) which is the difference in weight of the specimen before and after the test; \(t\) - Sliding time (25min.); \(r\) - the radius of the specimen to the center of the disc (2mm); and \(n\) - disk rotational speed (200rpm).

In general, the wear resistance of samples improved after the squeezing. The decrease in the wear rate of the tested samples after squeezing, is attributed to the closing of the pores and the increase in the hardness, so it became difficult for the sample to lose.
layers of its surface when exposed to wear test. The wear resistance of the composite increases further due to the presence of ceramic oxide, which imparts an increase in composite hardness. Minimizing porosity is crucial for enhancing wear resistance, as pores can serve as points for crack propagation under stress concentration during wear testing [21]. Figure (9) shows the results of the test.

![Figure 9: Wear Rate for the Base Alloy and the Cu-7Ag+4vol% Y2O3 Samples Using 10 N loading: (a) After Squeezing at Room Temperature; (b) Squeezing at (400 °C); (c) Squeezing at (600 °C)](image)

The lowest wear rate is achieved when (Cu-7Ag+4vol% Y2O3) is squeezed at 600°C, which results in the closure of the largest number of pores. It is also noted that wear tends to reduce with increasing asperity hardness. Figure (10) shows wear trace on the tested surfaces. Time, load, and the tested specimen’s hardness all affect how deep the penetration goes. The wear rate increases with an increase in the applied load. The increase in hardness causes a decrease in wear rate and an increase in wear resistance. The wear rate decreases with time, albeit only little. The impact of hot squeezing on the (Cu-7Ag) base alloy's increased wear rate decrease was shown in Figure (9). The specimen that underwent heat squeezing at 600 C showed the biggest decrease in wear rate. The wear rate could be reduced by a maximum for 10N following a 25-minute wearing period. It is accurate because wear occurs more quickly and more materials tend to be removed from the surface over time [22, 23]. Additionally, friction at the surface increases as time passes. The loss of alloy size (with and without squeezed) rises as time increases [24].
At Room Temperature, (b) At 400 °C, (c) At 600 °C; squeezed (Cu-7Ag+4vol% Y2O3), (d) At Room Temperature, (e) At 400 °C, (f) At 600 °C.

4.8 Friction Coefficient

The addition of Y2O3 particles improved both the strength and the deformation ability, leading to gradually lower friction coefficient as showed in Figure (11). The relationship between the area of contact and the hardness is inversely proportional, meaning that as hardness increases, the area of contact decreases. Additionally, it is observed that wear tends to decrease as the hardness of asperities increases. The reducing of friction can be achieved through the squeezing for both of base and composite samples.

Figure (11) shows that the coefficient of friction gradually decreases with applied squeezing due to increased surface hardness and less contact between the pin and the sample surface. The
lowest coefficient of friction was obtained when applied hot squeezing at 600°C for both the base alloy and (Cu-7Ag+4V of %Y2O3) samples.

5. Conclusions

According to the findings cited earlier, most physical as well as mechanical properties of the base alloy and the composite material have been upgraded lead to the following conclusions:

- Hardness for both of (Cu-7Ag) base alloy and (Cu-7Ag+4V of %Y2O3) samples can be enhanced by squeezing process. The hardness of the (Cu-7Ag) base alloy increased about 19% after room temperature squeezing, 31% after warm squeezing and about 40% after hot squeezing, while the hardness of the (Cu-7Ag+4V of %Y2O3) increased by 23% after room temperature squeezing, 33 % after warm squeezing and about 51 % after hot squeezing.
- Better improvements of 25% and 17% in the electrical conductivity of the (Cu-7Ag) base alloy and the (Cu-7Ag+4%V of Y2O3) composite were recorded for the specimens hot squeezed at 600°C.
- Hot squeezing revealed that (Cu-7Ag+4%V of Y2O3) had reduced coefficient of friction and wear rate , also Additionally, hot squeezing results in a decrease in porosity, an improvement in mechanical and wear properties, and an improvement and refinement of the grain size of the composite materials.

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