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Effect of copper on friction and wear properties on copper-based friction materials

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ABSTRACT – The purpose of this paper is to investigate the effect of copper on the mechanical friction and wear properties of the copper-based friction materials. In this research, different composition of the copper, iron-oxide and graphite on the Cu-based friction materials were prepared through powder metallurgy process. Among of the assessment were porosity, hardness, and friction wear tests which follow the international standard test procedure. The results obtained shows that sample A3 with was composed of 85% of copper is the best formulation based on its mechanical properties and friction behaviors.

1. INTRODUCTION

There are three types of powder metallurgy friction materials which are based on iron, copper and both copper-iron materials [1]. Powder metallurgy friction materials are made of ingredients in powder form and are composite of friction components which composed of solid lubricant and metal matrix [2]. Based on the research done by previous researchers, copper-based powder metallurgy is preferable due to its higher wear resistance and better thermal conductivity [3]. These attractive properties have made it broadly used in automobiles and aircraft braking system [3]. Copper based materials have a braking performance similar like iron and it is cheaper.

Copper based powder metallurgy friction materials can be formulated by using the correct combination of chemical composition. Friction and wear characteristics are the most critical aspects of friction material that need to be highlighted during the development of its formulation. Besides that, volume percentage and type of ingredient used in the formulation can affect the friction and wear characteristics [4]. Therefore, this research will be directly focused on improving the formulation of copper-based powder metallurgy specifically on the mechanical and tribological properties.

2. METHODOLOGY

2.1 Sample preparation

Graphite, copper and iron oxide are obtained from the local supplier company in Selangor, Malaysia. Three samples with different volume percentages (vol. %) of ingredients as presented in Table 1 were prepared through powder metallurgy process. All these 3 samples will be compared with commercial available powder metallurgy friction materials. The ingredients were mixed for 30 minutes in a turbula mixer with a rotating speed of 50 rpm. The weight ratio of 30:1 was set between the tungsten carbide ball to the ingredients weight. The samples were obtained by compacting dried and granulated powder in a mold with a dimension of 25 mm x 30 mm x 5 mm at a pressure of 625 MPa (18 ton). The compacted samples were sintered at temperature of 960ºC under nitrogen based (95%N2, 5%H2) in a tube furnace.

Table 1 Sample composition.

Ingredients	Graphite (vol. %)	Copper (vol. %)	Iron oxide (vol. %)
A1	7	65	28
A2	5	75	20
A3	3	85	12
Total (%)	100	100	100

2.2 Testing and analysis

Each developed sample was subjected to microhardness, porosity test and the coefficient of friction and wear behaviours. The data for microhardness of the samples was obtained according to American Standard Test Method ASTM D2240 using Durometer hardness tester scale D. The porosity of the samples was measured using hot bath in accordance with Japanese Industrial Standard JIS 4418. The coefficient of friction and wear behaviours data were obtained in accordance with American Standard Test Method ASTM G 99. This test was performed on CSM Pin-on-Disc Tribometer with 10 N load applied on a 6-mm diameter alumina ball for a sliding distance of 1000 metre and rotating speed of 0.035 m/s.

3. RESULTS AND DISCUSSION

3.1 Material properties

Table 2 shows the mechanical and tribological properties of the test samples. It is shown that sample A3 with the highest volume percentage of copper produces the highest porosity and decreasing hardness compared to than other test samples. Figure 1 shows the relation between the porosity properties with vol.% of copper in the composition.

Table 2 Test results.

Sample	Hardness (Shore D)	Porosity (%)	Weight loss (10^{-3} gm)
COM	86.2	26.1	29.1
A1	81.1	27.3	19.7
A2	82.7	29.3	23.2
A3	82.1	35.3	6.4

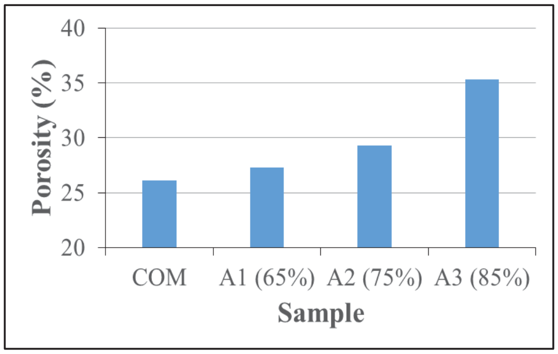

Figure 1 Effect of copper on porosity behaviours.

3.2 Coefficient of friction

The results of coefficient of friction (COF) for all the test samples over the sliding distance are shown in Figure 2. Sample A3 which contains highest copper powder in the sample composition produce higher and stable COF compared to other samples having less copper powder. According to the Society of Automotive Engineer standard SAE J661, the sample A3 with minimum COF of 0.216 has already meet the minimum requirement of COF. The sample with composed of 85% vol. percentage of copper could be the optimized material composition as it shows highest and stable COF.

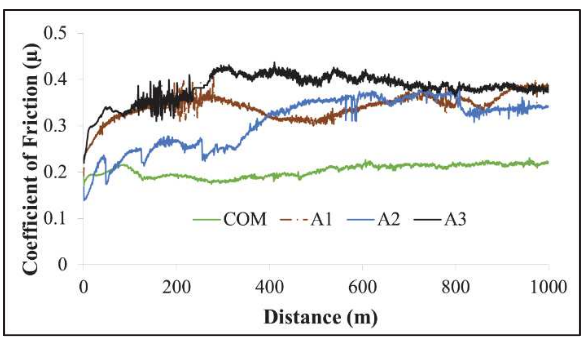

Figure 2: Effect of carbon on COF behaviours

3.3 Weight loss

The lowest weight loss was observed for sample A3 which composed of higher vol. percentage of copper in the composition. Higher copper vol. % in the composition would increase the thermal conductivity of the sample, thus reduce the surface temperature during braking process. This is supported by the findings that the rapid weight loss occurs above the temperature of 260°C was due to oxidative decomposition [5]. Thus, it can be concluded that sample A3 which composed of 85% vol. percentage of copper is the optimum percentage to be used in the formulation.

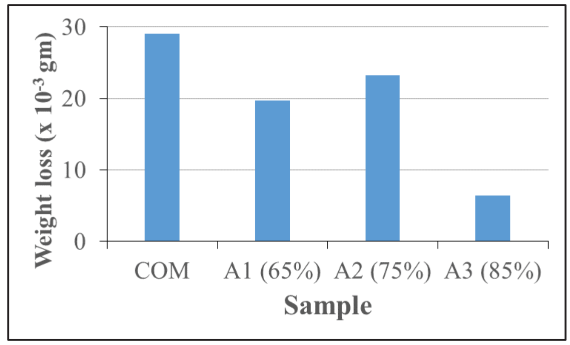

Figure 3 Weight loss characteristics of different vol. % of carbon in the formulation.

4. CONCLUSIONS

The tribological and material characteristics for copper-based friction materials were found to be better at composition of 3% graphite, 85% copper and 12% Iron oxide. The results demonstrate that this composition relatively have stable COF as well as the lowest weight loss. Thus, it could be postulated that the vol. percentage of the copper ingredients influence the tribological and material properties if Cu-based material.

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