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WEAR CHARACTERISTICS OF SINTERED ALUMINIUM (AL)- COPPER (CU) POWDER PRE-FORMS TESTED AT DRY ATMOSPHERIC CONDITION

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***Abstract*-Abrasive wear behaviour of Aluminium (Al) – Copper (Cu) powder pre-forms were investigated in this work. Three different compositions of Al–Cu pre-forms were tested considering two compacting pressures. The wear tests were conducted using a pin-on-disc apparatus against silicon carbide abrasive paper under multi-pass condition at dry atmospheric condition. Wear test was conducted under various testing conditions such as sliding distance, applied load, sliding velocity and abrasive grit number. The wear is measured by means of loss in weight. Relationships between the weight loss and the sliding distance, sliding velocity and applied load were established. It was observed that a higher amount of copper in the matrix reduces the wear of specimens irrespective of the compacting pressures. Also a higher compacting pressure reduces the wear of specimens for all the parameters considered. Also the relationship between the specific wear rate and the abrasive grit number were established.**

***Keywords:* Abrasive Wear, Pin on Disc, Preform, Specific Wear Rate.**

I. INTRODUCTION

Powder metallurgical (P/M) processing provides much finer and homogeneous microstructure and near net shape parts producibility for aluminium alloys in comparison with ingot metallurgy (I/M). Sintered aluminium P/M parts compete with other metal powder parts in applications where some of the attractive physical and mechanical properties of aluminium can be used. Though Aluminium alloys are desirable for variety of reasons like Light weight, Corrosion resistance, Good ductility, Nonmagnetic properties, Conductivity, Machinability etc., their low density, poor wear resistance limits their application in critical service conditions. Since last many years, a wide spread attention has been paid by many researchers in the area of improving the wear resistance of aluminium alloys and its composites. Several investigations have demonstrated improved wear resistance of Al alloys reinforced with hard ceramic phase. Dwivedi evaluated the wear behaviour of cast Al-13.5% Si base alloy on sliding conditions, microstructure and heat treatment [1]. Gurcan et al. conducted pin on disc wear tests on AA6061 composites containing Saffil, SiC, and mixtures of both ceramics against SiC grit and steel counter faces [2]. Bhansali & Mehrabian [3] reported that in their studies, the wear resistance of Al/ Al_2O_3 composites was reported to be superior to those of Al containing SiC as the dispersed phase. Srivastava et al. [4] studied the wear characteristics of Al base composites containing 5 to 20 vol. % of Al_2O_3 and in dry sliding condition. Barrie S. Shabel et al. [5] reported the friction and wear properties of aluminium – silicon alloys. Bialo and Duszczyk [6] studied the wear of Al_2O_3/Al composites fabricated by liquid phase sintering using a pin on disc apparatus. The existing literature mainly dealt with wear behaviour of aluminium and its alloys reinforced with hard ceramic particles and hard particles as a first phase and a soft metal as a second phase. [7] A. Ravikiran has discussed the quantification of tribological properties. He focused on the scatter created while calculating the tribological properties and he made an attempt to quantify the wear more appropriately.Without conducting additional tests, the existing data can be re-represented using the variable “wear index". Sliding wear tests were conducted on SS 304L and the influence of test duration on material damage have been investigated [8]. The damage to the contact zone have been evaluated by Van Herpen et al. They have developed a methodolgy to test slidng wear. [9] Maatta et al. have conducted adhesion wear test on tool steels and reported that the surface roughness and topography of the tool affect the friction between tool and work piece. They also concluded that local contact pressures cannot break the oxide layers on the mating surfaces [10]. Sumitha et al have discussed the importance of the nickel free stainless steel. They have reviewed the improvement properties by nitrogen addition in stainless steel. Hubner et al. have investigated that stainless steel Cr-Ni steel has phase stability at low temperatures [11]. Also the use of inert environment eliminates the chemical influences. The phase transformation at operating temperature 4.2 K during wear had been reported [12].Koji Kameo et al. studied the wear behaviour characteristics under self- mating; dry sliding conditions using a pin-on-disk type wear configurations. They reported the wear characteristics in SS316L, precipitated stainless steel and ball bearing steel. Yong-suk Kim et al. have investigated that the high wear resistance of the steel was attributed to the solid solution strengthening and high strain hardening effects of the nitrogen. Also, they have reported that precipated nitrides exhibites low wear rate at higher loads [13]. [14] Magnus Hansen et al. have made an attempt to understand the surface oxides effects in the sliding experiments performed. The tests were conducted in SS304 material.They also reported that the austenitic stainless steel is a very sticky material in sliding contact. They concluded that there is no material transfer for the SS 304 when the test is conducted at 800^{o}C. [15] Staffan Jacobson et al. have elucidated with few examples that the tribofilms and modified surfaces have an influential effect on the performance of various mechanical components and tools. A.Devaraju et al., [16] have analyzed tribological behaviors of the plasma nitrided AISI 316 LN type austenitic stainless steel specimens (both pins and rings) in the year of 2010. The wear resistance of plasma nitrided (CrN) 316LN has been assessed by mating itself (CrN coated pin against CrN coated Ring) in air and its result has been compared with the result of self-mating of untreated 316LN. Many researchers attempted to find the optimum wear parameters and some others found the optimum process parameters for good surface finishing in machining processes. Only a very few papers had discussed with the wear behaviour of metal – metal matrix. The objective of present investigation is to study the abrasive wear performance of Al - Cu powder preforms. The effect of addition of Cu on Al and the compacting pressure of preforms were reported.

II. EXPERIMENTATION

A. *Preparation of Specimens*

Atomized aluminium powder and copper powder were obtained from the Metal Powder Company Ltd., Thirumangalam, Tamilnadu, India. The properties of powders were given in the table 1. Commercially available water proof silicon carbide (SiC) abrasive papers of different grit sizes of 80,100,120,150,180,220,320 and 400 were selected as abrasion counter face. The three different compositions selected for the wear tests were, (i) Al 90 % - Cu 10 % (ii) Al 80 % - Cu 20 % and (iii) Al 70 % - Cu 30 %. The samples were prepared by conventional powder metallurgy process. The compacts of two different densities were prepared for all the three compositions. Zinc stearate of quantity 1 % to the mass of the powders was added to act as the lubricant during compacting. A die was designed and fabricated to prepare solid cylindrical specimens of diameter 20.27 mm. Compacting was done using the hydraulic compression testing machine of capacity 200 tonnes at room temperature. Compacts were prepared with two different compacting pressures of 147.15 MPa and 177.58 Mpa on the given mass of the powder. Before compacting, Zinc stearate dust was applied on the inner surfaces of the die and the outer surfaces of punch. The green compacts thus obtained were measured for density using Archimedes’s principle.

The green compacts were coated with alumina paste to prevent the oxidation of preforms during sintering. The preforms were sintered to a temperature of 400 ±10^{0}C and maintained at this temperature for an hour. Then the preforms were air cooled at room temperature. The diameters of the sintered preforms were reduced from 20.27 mm to 15 mm by turning operation.

TABLE 1
PROPERTIES OF ALUMINIUM AND COPPER POWDERS

Particulars	**Aluminium**	**Copper**
Purity (%)	98.5	99.5
Apparent Density (g/cc)	0.7856	5.19
Average Particle size (μ)	15	12
Sieve	Retention 75, 3% max. Retention 45, 10% max.	Retention 15, 3% max. Retention 45, 55% max.

B. *Abrasive Wear Test*

Abrasive wear tests were conducted on a purpose built pin on disc apparatus at multipass condition. The schematic diagram of the apparatus is shown in figure. 1. Abrasive paper was cut to the diameter of the disc and pasted over it. The pin was fixed in the holder at proper height to ensure uniform contact of its flat surface at the other end. This height was maintained constant for all the tests. The wear tests were carried out at various sliding distances (12 m to 96 m), loads

(0.5 kg to 3 kg), sliding velocities (1.5 m/min to 12 m/min) and different abrasive grit sizes (80 to 400). The initial weight of the test pin was measured using a single pan digital balance of accuracy 0.1 milligram. At the end of each run, the specimen was removed, thoroughly cleaned of worn particles and reweighed. The difference in weight gives the weight loss. The wear was measured by this loss in weight, which was then converted to wear volume using density data [7] and equation 1.

$$V = \frac{W}{\rho} \qquad (1)$$

Where, V is the Wear volume in m^3, W is the weight loss in Kg and ρ is the density in Kg/ m^3.

The specific wear rate was calculated from the equation 2.

$$K_o = \frac{V}{L\,D} \qquad (2)$$

Where, K_o = Specific wear rate (m^3/Nm),
V = Wear volume (m^3) and
L = Applied load (N).

After each wear test, the setup was balanced and the abrasive paper was replaced with a fresh one. The tests were carried out at a room temperature of 28 to 31°C and a relative humidity of 70 to 76%.

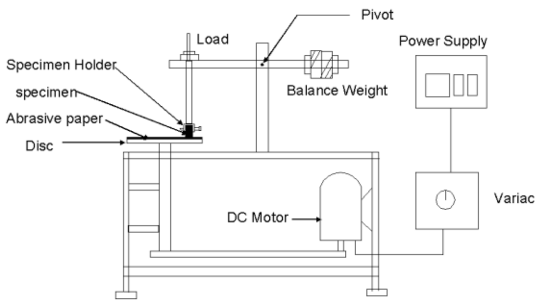

Fig. 1 SchematicDiagram of the Pin on Disc Apparatus.

III. RESULTS AND DISCUSSION

The fig 2(a,b), shows the weight loss as the function of abrading distance for the three compositions experimented and the two compacting pressures considered. A non linear increase in weight loss is observed as the abrading distance is increased. This behaviour is noticed irrespective of the compositions and the compacting pressures taken for the study. However it was observed that a higher compacting pressure reduces the weight loss. It is also noticed from the graphs established, that the higher amount of copper in the matrix yields a lesser weight loss irrespective of the Compacting pressures. It is noted that in the beginning, the increase in weight loss is rapid and subsequently it is stabilized to a steady value. The reason may be attributed to the repeated sliding over the circular track on abrasive paper, the circular path tends to become clogged with wear debris and causes reduced abrasive capacity and hence the weight loss is stabilized. The clogging is due to the collection of wear debris in the crevices or depression, on the paper and after a certain number of traverses, abrasion of materials reduces and reaches to equilibrium conditions. Fig 3 (a,b), shows the weight loss as the function of sliding velocity for the three compositions experimented and the two compacting pressures considered. It is noted that in the beginning, the increase in weight loss is rapid and subsequently it is stabilized to a steady value. The reason may be attributed to the repeated sliding over the circular track on abrasive paper, the circular path tends to become clogged with wear debris and causes reduced abrasive capacity and hence the weight loss is stabilized. The clogging is due to the collection of wear debris in the crevices or depression, on the paper and after a certain number of traverses, abrasion of materials reduces and reaches to equilibrium conditions. Fig 3 (a,b), shows the weight loss as the function of sliding velocity for the three compositions experimented and the two compacting pressures considered.

A non linear behaviour in weight loss is observed as the sliding velocity is increased. The weight loss initially decreases with increasing sliding velocity and reaches an optimum value, beyond which there is a slight increase in it. This behaviour is noticed irrespective of the compositions and the compacting pressures taken for the study. Further, it was observed that a higher compacting pressure reduces the weight loss. It is also noticed from the graphs established, that the higher amount of copper in the matrix yields a lesser weight loss irrespective of the compacting pressures. At low sliding velocities, the frictional force generated on the wear surface is large enough to abrade the surface of pins. As the sliding velocity increases, the coefficient of friction reduces and thus the frictional force decreases. Subsequently the weight loss decreases until the abrasion becomes the major wear mechanism. At high sliding velocity, the weight loss of materials becomes high. The weight loss starts to increase due to severe abrasion. The optimal sliding velocity, before the abrasion takes its active role is found to be 9 m/min. Fig 4(a, b), shows the weight loss as the function of applied load for the three compositions experimented and the two compacting pressures considered. A linear increase in weight loss is observed as the applied load is increased.

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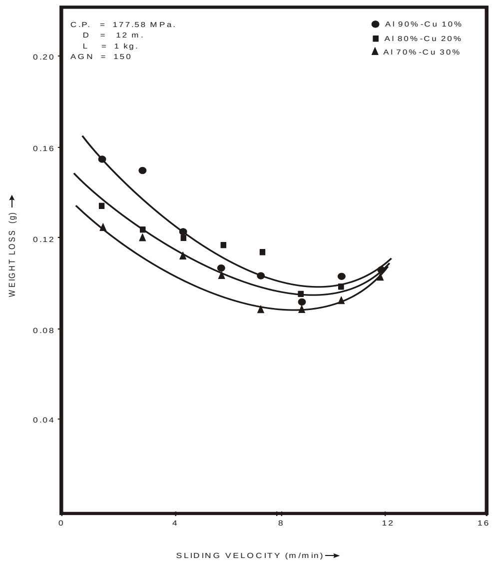


Fig 2-a. Weight loss as a function of sliding distance

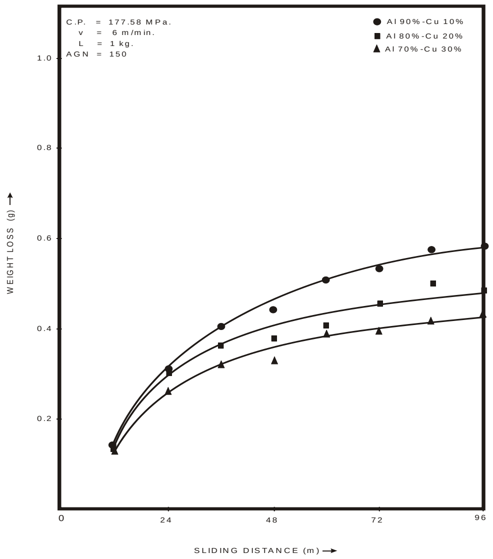


Fig. 2-b. Weight loss as a function of Sliding distance

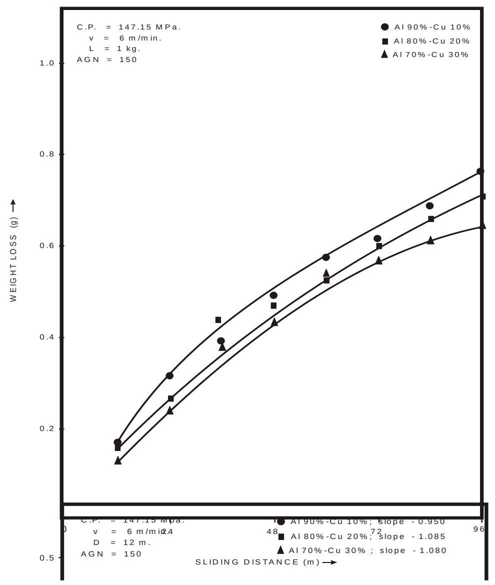


Fig 3-a Weight loss a function of sliding velocity

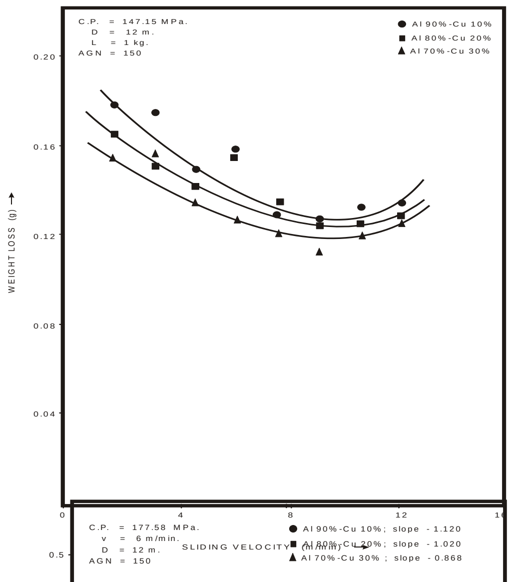
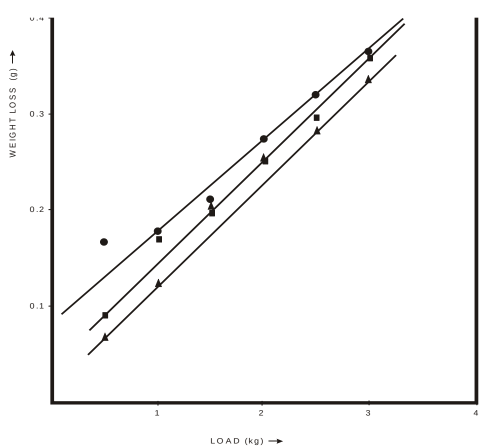
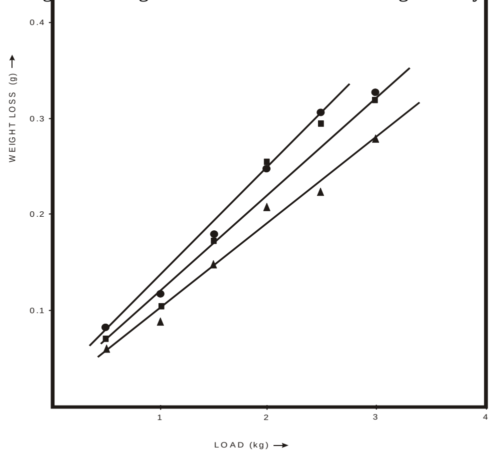


Fig. 3-b. Weight loss as a function of Sliding velocity





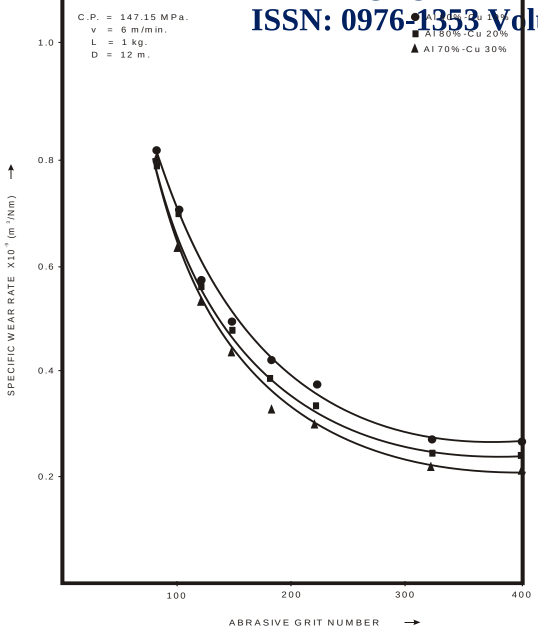


Fig. 5-a Specific Wear Rate as a function of Abrasive Grit Size.

A non linear behaviour in weight loss is observed as the sliding velocity is increased. The weight loss initially decreases with increasing sliding velocity and reaches an optimum value, beyond which there is a slight increase in it. This behaviour is noticed irrespective of the compositions and the compacting pressures taken for the study. Further, it was observed that a higher compacting pressure reduces the weight loss. It is also noticed from the graphs established, that the higher amount of copper in the matrix yields a lesser weight loss irrespective of the compacting pressures. At low sliding velocities, the frictional force generated on the wear surface is large enough to abrade the surface of pins. As the sliding velocity increases, the coefficient of friction reduces and thus the frictional force decreases. Subsequently the weight loss decreases until the abrasion becomes the major wear mechanism. At high sliding velocity, the weight loss of materials becomes high. The weight loss starts to increase due to severe abrasion. The optimal sliding velocity, before the abrasion takes its active role is found to be 9 m/min. Fig 4(a, b), shows the weight loss as the function of applied load for the three compositions experimented and the two compacting pressures considered. A linear increase in weight loss is observed as the applied load is increased.

This straight line behaviour is noticed irrespective of the compositions and the compacting pressures taken for the study. This straight line behaviour suggests a power law relationship between the weight loss and the applied load. The power law relation is expressed as equation 3.

$$W = C_1 L^{-m_1} \quad (3)$$

Where, W - Weight loss, L- Applied load and

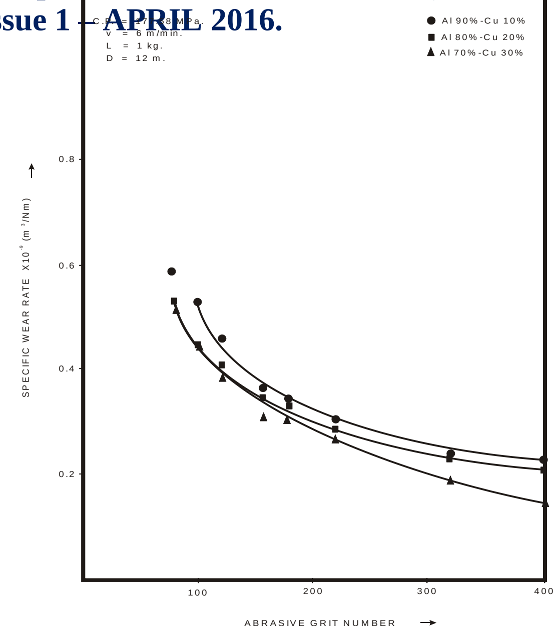


Fig. 5-b Specific Wear Rate as a function of Abrasive Grit Size

$C1, m_1$ - Empirically determined constants.

It was observed that a higher compacting pressure reduces the weight loss. It is also noticed from the graphs established, that the higher amount of copper in the matrix yields a lesser weight loss irrespective of the compacting pressures. The abrasive particles are of irregular in shape rather than ideally spherical and their cutting tips are approximately conical in shape. At higher applied loads, the cutting tips of the abrading particles penetrate deeper into the surface of the pin and the width of the ploughing furrows increases due to the conical shape of the cutting tip. In addition to this, a larger length of he perform is sliced when the penetration is more. Thus, the wider ploughing furrows and larger sliced length of the preforms result in the increase of weight loss at higher applied loads. Fig 5(a,b), shows the specific wear rate as the function of abrading distance for the three compositions experimented and the two compacting pressures considered. A non linear decrease in specific wear rate s beh e compacting pressures taken for the study. However it was observed that a higher compacting pressure reduces the specific wear rate. It is also noticed from the graphs established , that the higher amount of copper in the matrix yield a lesser specific wear rate irrespective of the compacting pressures. With decrease in size of the abrading particles, wear rate first decreases rapidly and then decreases slightly. In general, the wear of materials against abrasive papers is proportional to the ploughing component of friction and depends on the physical properties of the materials. When using very rough abrasive paper, the individual grains penetrate deeply into the surface of the pins, subsequently removing material by extensive micro ploughing process.

During this process, large amount of plastic deformation takes place.

When using a smaller particle size, it is found that, the clogging of wear track with wear debris took place rapidly and hence abrasive capacity is reduced.

IV. CONCLUSION

The following conclusions can be drawn from the present investigation

- A non linear relationship was observed between the weight loss and the sliding distance.
- The weight loss initially decreases with increasing sliding velocity, reaches an optimum value, and then increases.
- A power law relationship exists between the weight loss and the applied load.
- The relationship between the specific wear rate and the abrasive grit number is found to be non linear in nature.
- Higher amount of copper in the matrix reduces the weight loss of specimens irrespective of the compacting pressures for all the parameters considered.
- Higher compacting pressure reduces the weight loss of specimens for all the parameters considered.

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