Proceedings of Malaysian International Tribology Conference 2015, pp. 115-116, November 2015

Dry sliding wear behavior of Al-SiO_2 composites

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Keywords: Composites; powder metallurgy; sliding wear

ABSTRACT – An Al-Silica based composites having four different compositions 5, 10, 15 and 20 wt. % Silica in aluminium matrix is developed using powder metallurgy rout. The developed composites have been characterized for compositional, microstructural, mechanical and sliding wear behavior. Wear behavior of different composite was studied with different parameter like sliding distance and applied loads. It has been observed that the Al- 10wt. % SiO_2 composites exhibits an optimum mechanical and wear resistance properties.

1. INTRODUCTION

Monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements [1-3].

Advances in the science of MMCs present us an opportunity to design light-weight aluminum based materials with precise balances of mechanical, physical properties and essentially tribological characteristics. Now a days the particulate reinforced Al matrix composite are gaining importance because of their low cost with advantage like isotropic properties. The strengthening of aluminum alloys with dispersion of fine ceramic particulate composite materials were developed as an alternative of unreinforced alloy, for obtaining materials with high stiffness (high strength/modulus) and low density with special interest for the wear resistant and structural applications [4-7]. In the present investigation Al-Silica based composite have been developed for a optimum mechanical and wear resistance properties for applications of aero-space, auto mobile and marine engineering field.

2. METHODOLOGY

For the development of composite commercially pure aluminium (99%) used as matrix and silica with 50 µm size was added as reinforcement to get the improve properties.

Commercially pure Aluminium (99%) powder (Loba Chemie) and silicon dioxide powder were mixed with varying wt.% of silicon oxide from 5% to 25%, at an interval of 5%. The powders were mechanically mixed with the help of mortar pestle up to 45 minutes. After mixing powders filled it into die of 10 mm diameters and compressed up to 15 ton with the help of universal testing machine (UTM). Zinc stearate was used as lubricant to prevent sticking of powder with the die walls and easy removal to compacts from the die. Then dimensions of the compacts were measured by a Vernier's caliper, they were weighted in a weighing machine (having least count 0.001 gm), to calculate green density of the compacts. After compaction sintering was done at 550°C for 2 hours in a tube furnace in Argon atmosphere to prevent oxidation. After sintering of different compositions, compacts were again weighted and their dimensions were measured to calculate sinter density at different temperatures. After sintering compacts samples were characterized for microstructure by using scanning electron microscopy (SEM). Then sintered compacts were tested for bulk hardness, uniaxial compression test and dry sliding wear properties.

3. RESULTS AND DISCUSSION

The scanning electron microscope (SEM) sintered at 550^0 C for the holding time 2 hours with different %wt. are shown in Figure 1.

(a) 5%wt (b) 10%wt (c) 20%wt

Figure 1 Scanning Electron Microscope of compact composites.

By comparing the micrograph of Al-SiO_2 composites of different composition we can observe that the porosity is least in 10% sample. It indicates that porosity decreases on increasing the wt. % of SiO_2 from 5% and reaches minimum at 10%. Again on increasing the wt. % of SiO_2, the porosity of composites increases.

Table 1 shows the variation of hardness and uniaxial compressive strength (UCS) of composite materials. It has been observed that the hardness and uniaxial compressive strength increasing with increasing the wt. % of silica up to 10%wt. Further on increasing the wt. % of silica, the hardness and uniaxial compressive strength decreasing. This may be attributed due to the variation of porosity. Initially on increasing the wt. % of silica, the porosity reduced and further addition increasing the porosity.

Table 1 VHN of compacts made by P/M route of Al & SiO_2 powders.

Sl. No.	Wt% SiO_2	Vickers Hardness (HV)	UCS ($\times 10^5$ N/m^2) of length 6 cm
1	5	46	187.16
2	10	52	243.31
3	15	40	162.21
4	20	33	134.13

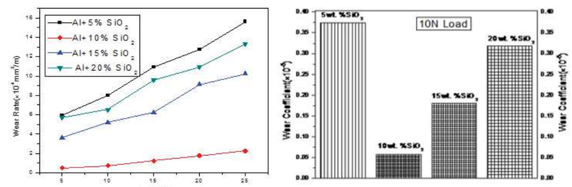
Figure 2(a) to (d) shows the variation of cumulative volume loss with sliding distance for different compositions having 5, 10, 15 and 20 wt. % and at different normal loads of 5N, 10N, 15N, 20N respectively. It is observed that variation of cumulative volume loss is linear with all loads and it is increasing with increasing normal load. Here it is also observed that initially on increasing the wt.% of SiO_2, the cumulative volume loss decreases and it achieved minimum at 10%. However, on further increasing the wt.% of SiO_2 , the cumulative volume loss increases, it is mainly due to increase in porosity.

Figure 3(a) shows the variation of wear rate at different load and different composition. It has been observed that as the load increases the wear rate also increases. However, variation with respect to compositions is different. Here 10wt. % composition has minimum wear rate relative to other wt. % composition. Wear coefficient has been also calculated with the help of Archard's law and shown in Figure 3(b). It is observed that the 10 wt. % compositions have better wear resistant property than any other because it has relative less value of wear coefficient.

4. CONCLUSIONS

From the above results and discussion the following conclusions has been drawn:

a) Hardness of commercially pure aluminium is increased from 29 VHN to 52 VHN with addition of Silica. Sintered composite yields better result of ultimate compressive strength.
b) Optimum wear resistance properties up to the addition of 10 wt. % SiO_2.
c) The sintered composite exhibits a better wear resistance due to compaction.
d) Cumulative volume loss increases with increasing the sliding distance and normal load.
e) Wear rate is minimum for Al-10wt.% SiO_2 composites.



(a) (b)

Figure 3 (a) Variation of wear rate with normal load (b) wear coefficient.

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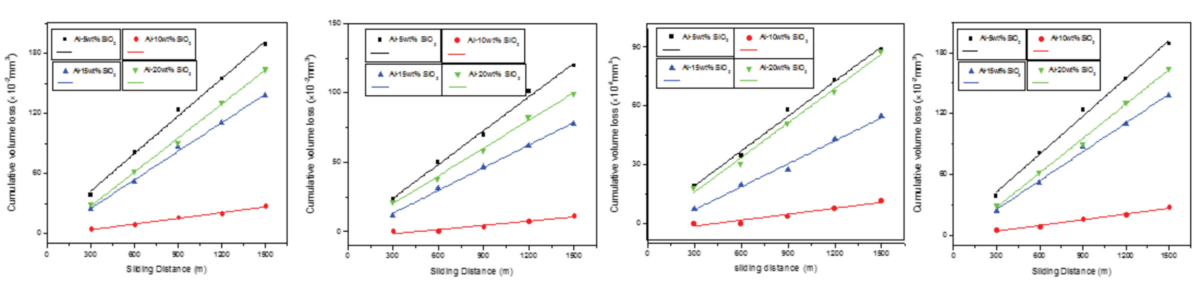

(a) 5N (b) 10N (c) 15N (d) 20N

Figure 2 Variation of cumulative volume loss with sliding distance.