WEAR CHARACTERISTICS OF DOUBLE CERAMIC PARTICULATE HYBRID ALUMINIUM MATRIX COMPOSITE

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Abstract: - Metal matrix composites got popularity due to their light weight and high strength and replacing metal parts from various applications like aerospace, automobile and biomedical. Aluminum matrix composites (AMC) are suitable for the aerospace industries and still the research is going on to use it for other applications. In this research work, a double ceramic particulate AMC was synthesized. The ceramic powders used were alumina (Al₂O₃) in wt. % of 0.5, 1.0 and 2 and silicon dioxide (SiO₂) in wt. % of 0.5 and 1.0. The synthesis of composites was done by stir casting method. SEM analysis showed that porosity was reduced and the distribution of reinforcement particles were uniform throughout the matrix. Wear test was carried out using pin on disc wear testing machine, results showed reduction in wear. SEM analysis of worn out specimen showed transition from adhesive wear to abrasive wear for hybrid composites.

Keywords: AMC, Al₂O₃, SiO₂, Stir casting

1. Introduction

In the present scenario, a composite is a multiphase material can be prepared artificial or natural way by adding the constituent phases, which is chemically dissimilar and have separate distinct interface. Basically, the composite materials have been identified by two phases namely, matrix and reinforcement. Matrix phase is characterized by continuous phase whereas other phase is reinforcement which is dispersed phase [1]. The development of metal matrix composites made significant change in the aerospace and automotive industries. MMCs have been made by using most of the metals and their alloys as the matrix material, but only few metals and alloys are available for high and low temperature applications. In air craft industries, the material selected should be light weight and high strength. The popular matrix materials such as titanium, magnesium and aluminum and its alloys are popular materials suitable for aircraft components. The reinforcement material selected for making MMC should have high modulus and the resulting composite material possess better properties than the most of the alloys. The suitability of composites at different service temperatures depends on its melting point, physical and mechanical properties. Some metals have low melting point and the reinforcement materials should improve the melting point. Aluminum and its alloys can be a one good choice as matrix material which is light in weight and high strength to weight ratio. Discontinuous reinforced aluminium matrix composites (DRAMCs) are the composites in which discontinuous fibers are used like whiskers, particulates etc., which strengthen the aluminum matrix. Most of the researchers concentrated on the overall performance of the composites by selecting the proper reinforcing material. The performance of DRAMCs can be improved in three different ways. First way is to find the cheaper reinforcement material to reduce the overall production cost and to tackle the limited availability of the ceramic reinforcement material. This can be achieved by using the materials from industrial wastes and agro waste derivatives. Some of the investigations showed the usage of alternative reinforcements in the preparation of composites exhibits improved properties than
the unreinforced alloy. However, the developed composites show inferior properties than the conventional synthetic reinforced DRAMCs [2]. Second way the small size ceramic materials selected for the preparation ranges from micron scale to nanoscale. The nano size ceramic particulates shows better fracture toughness and ductility of DRAMCs reported in some studies, but the major limitation is high cost and availability of the reinforcement materials. Also, there is still inconclusive evidence to substantiate the mechanisms of ductility and fracture toughness improvement in nano particulate reinforced composites [2]. Third way is to use two or more reinforcing materials to produce DRAMCs hybrid composites. The objective of this approach is to produce DRAMC at lower cost coupled with optimized property. Some authors show the way to produce better performance hybrid AMCs at lower cost when compared with single reinforced AMCs [2].

Kenneth Kanayo Alanemeetal et al. prepared Al-Mg-Si alloy matrix hybrid composites by using rice husk- alumina as reinforcement and its corrosion and wear behavior have been studied. The method used was double stir casting. The percentage of alumina used was 2, 3 and 4 wt% while the Rice husk ash (RHA) was added in such a manner that the total reinforcement addition remains 10%. Corrosion and wear behavior were analyzed by open circuit corrosion potential and potentiodynamic polarization measurements methods respectively. Scanning electron microscope was taken as for characterizing corrosion and wear mechanisms. Superior corrosion resistance was seen by single reinforced Al-Mg-Si/10 wt.% Al₂O₃ composites from the other hybrid composites in 3.5% NaCl solution. Also increase in corrosion rates was due to increase in RHA reinforcement. The reason for increasing corrosion rates was increase in population of reinforcements. In wear test also, wear rate and coefficient of friction was seen to be increased because of the increased percentage of RHA reinforcement [3]. K. Umanath et al. investigated metallic worn surface of Al 6061 hybrid composites produced by stir casting method. Aluminium oxide and silicon carbide reinforcements were varied together from 5 to 25% vol. Fractions. Wear behavior showed much rougher surfaces of composites than the as cast alloy indicates abrasive wear. SEM results also revealed uniform mixing of reinforcements inside the aluminium matrix [4]. T. Hariprasad et al. investigated wear characteristics of Al₂O₃ and B₄C reinforced with Al 5083 metal matrix based hybrid composites. Al₂O₃ with 5% and four different proportions of B₄C with (0 wt%, 3 wt%, 5 wt%, 7 wt%) were used as reinforcements. Composites were synthesized by stir casting method. Wear test results concluded improved wear resistance properties because of high percentage of boron carbide and alumina particles [5]. A. Saravanakumar et al. investigated mechanical behavior of AA6063 Al₂O₃-1%, Gr (3, 6, 9, 12 wt.%) hybrid composites which was fabricated by stir casting method. One set is taken in as caste condition while other one was treated with hardening and testing was carried out on both materials. Mechanical properties were improved as addition of alumina had increased but only up to 6%. At higher percentage of alumina, agglomeration was seen as stated by SEM micrographs. The maximum improved properties were seen in 6% of alumina addition [6]. Aniruddha V. Muley et al. highlighted mechanical and tribological studies on nanoparticles reinforced hybrid aluminum based composite. Reinforcements were SiC and Al₂O₃ nanoparticles. LM 6 alloy was considered for the study. For fabrication stir casting was used and reinforcements were added in equal proportion for wt% of 0.5, 1.0, 1.5 and 2. Improvements in tensile and hardness were characterized by optical and SEM images. Hardness was improved by 17% while tensile strength was improved by 39%. Both were seen for 2wt% of reinforcements. Wear reduces by 80% compared to LM 6 alloys [7].

2. Experimental details

2.1 Materials

In the present work, AA 2014 was taken as a matrix material and the chemical composition of AA 2014 is presented in the Table 1. Alumina (Al₂O₃) particles of size 70-240 mesh and Silicon Dioxide (SiO₂) particles of size 40-150 mesh were selected as reinforcement materials for composite preparation. X-ray diffraction (XRD) test was performed to check the distribution of Al₂O₃ and SiO₂ particles. XRD phase evaluation was performed by Analytica006C X’ Pert3 Powder XRD machine and confirmed that the used Al₂O₃ particles were γ-Al₂O₃.
Table 1. Chemical composition of As Cast AA2014 Al alloy

| Elements | Cu   | Mg   | Si    | Fe    | Mn    | Ti    | Zn    | Cr    | Al    |
|----------|------|------|-------|-------|-------|-------|-------|-------|-------|
| %Wt.     | 4.723| 0.354| 0.755 | 0.197 | 0.771 | 0.012 | 0.048 | 0.062 | REM   |

Figure 1. XRD images of Alumina and Silicon dioxide particles

2.2 Fabrication of hybrid composites
The hybrid composites of $\text{Al}_2\text{O}_3$/SiO$_2$ AA 2014 were synthesized by stir casting. For comparison AA 2014 was also synthesized. The reinforcement materials $\text{Al}_2\text{O}_3$ and SiO$_2$ were kept in small pot and preheated to 240°C in a muffle furnace for 30 minutes. This improves wettability of the reinforcement with the matrix and remove the moisture content. After preheating, the molten metal of AA2014 was produced at 750°C in a graphite crucible using electric resistance furnace. The unwanted gases entrapped in the melt were removed by using degassing tablets of Hexachloroethane ($\text{C}_2\text{Cl}_6$). The reinforcements were added to the molten matrix and stirred completely for 5 minutes at 300 rpm. During stirring, complete mixing of the reinforcement particles of $\text{Al}_2\text{O}_3$ and SiO$_2$ inside the vortex was formed. The prepared molten mixture was poured into the preheated permanent moulds.
Table 2. Composition of hybrid composites prepared

| S.No. | Castings                   | Codes |
|-------|----------------------------|-------|
| 1     | AA 2014                    | Ascast|
| 2     | AA 2014 + 0.5% Al₂O₃ + 0.5% SiO₂ | A     |
| 3     | AA 2014 + 0.5% Al₂O₃ + 1.0% SiO₂ | B     |
| 4     | AA 2014 + 1.0% Al₂O₃ + 0.5% SiO₂ | C     |
| 5     | AA 2014 + 1.0% Al₂O₃ + 1.0% SiO₂ | D     |
| 6     | AA 2014 + 2.0% Al₂O₃ + 0.5% SiO₂ | E     |
| 7     | AA 2014 + 2.0% Al₂O₃ + 1.0% SiO₂ | F     |

2.3 Wear test
Dry sliding wear was carried out on specimen to know the wear behavior. Standard wear specimen of 8 mm diameter and 30 mm height were prepared as per ASTM standard. The wear tests were conducted at a fixed 1200 rpm of disc for track radius of 50.4 mm for 5 minutes, 10 minutes and 15 minutes.

2.4 Scanning electron microscope (SEM)
Scanning electron microscopy (SEM) was used to characterize the synthesized composites. The specimens were polished using standard metallographic. The hybrid composite and as-cast specimens were examined using Tescan Vega-3 LMU High Resolution Scanning Electron Microscope (HR-SEM) to study the distribution of reinforcement in the matrix.

3. Results and Discussions

3.1 Microstructure analysis
Scanning electron microscope images show uniform mixing of reinforcements inside the matrix.
Figure 2 shows the SEM micrograph of the specimens at 200X magnification. Agglomerated line structures are formed as shown in images of hybrid composites. Porosities can be observed in Ascast alloy. Image of hybrid composites show that reinforcements are more uniformly distributed in matrix than aluminium alloy. Hybrid composites A, B and C images show less segregation of line structure than hybrid composites D, E and F because of less reinforcement content. Line – line structure may be due to agglomeration of lesser density of SiO$_2$ particles.

3.2 Wear behavior
Figure 3 shows variation of wear with time at 1200 rpm for Ascast and hybrid composites. It can be observed from the graph that wear increases with increase in time. Ascast specimen wears out faster than hybrid composites. Low wear was observed for hybrid composites having better combination of reinforcements. Similar trend can be observed for the loads of 0.5kg, 1.0kg and 1.5kg.

3.3 Wear surface analysis

Figure 4 shows the SEM micrograph of the specimens at 500X magnification. Ascast image shows adhesive wear because of friction force given by hard EN-31 steel disc. Composite A image shows abrasive wear mechanism observed as hard particles are introduced inside matrix. Small grooves can be also observed. Composites B and C images shows track lines of wear test and reinforcement particles are forced out from matrix due to abrasive action. Composites D, E and F images shows accumulation of wear debris and partial welding of debris on surface of composite [8].
Figure 4. SEM images of worn out specimens (a) Ascast (b) Composite A (c) composite B (d) composite C (e) composite D (f) composite E (g) composite F, at magnification 500X

4. Conclusions
In the present work a hybrid aluminium matrix composite has been synthesized. The effects of reinforcements (alumina and silicon dioxide) with different percentages have been examined for wear properties of aluminium 2014.
SEM images show successful incorporation of reinforcements inside the metal matrix.

- Decreased trend for wear was noticed for more addition of reinforcements at higher loads and higher speeds.
- The scanning electron microscope images of worn out specimens showed transition from adhesive wear to abrasive wear as reinforcement percentage increases.

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