

Effect of SiC and Graphite Particulates Addition on Wear Behaviour of Al2219 Alloy Hybrid Composites

Madeva Nagara¹, B K Shivananda², Jayachandran³, V Auradi⁴, S A Kori⁵

^{1,4}R&D Centre, Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumkur-572103, Karnataka, India

²PG Scholar, Department of Mechanical Engineering, UVCE, Bangalore-560001, Karnataka, India

³Manager, Aircraft Research and Design Centre, Hindustan Aeronautics Limited, Bangalore-560037, Karnataka, India ⁵R&D Centre, Department of Mechanical Engineering, BEC, Bagalkot-587116, Karnataka, India

Abstract. In this investigation wear behaviour of Al2219 alloy reinforced with SiC and graphite particulates were studied. The percentage of silicon carbide and graphite as reinforcements were varied from 2 wt. % to 4 wt. % in steps of 2. Energy dispersive spectroscopy and scanning electron microphotographs were used to confirm the presence of SiC and graphite particulates and its uniform distribution over the aluminum matrix. Wear behaviour of aluminum alloy Al2219 reinforced with silicon carbide and graphite fabricated by stir casting process was investigated. The wear properties of the metal matrix composites were studied by performing dry sliding wear test using a pin-on-disc wear tester. The experiments were conducted at a constant sliding velocity of 1.73m/s over a load of 2kg. The results showed that the wear resistance of Al2219-2%SiC-2% graphite and Al2219-4%SiC-4% graphite composites were better than the unreinforced alloy. The wear in terms of weight loss and wear rate was found to decrease with the increasing the weigh percentages of SiC and graphite. To study the dominant sliding wear mechanism worn surfaces were analyzed using scanning electron microscopy.

1. Introduction

Metal matrix composites (MMCs) are gaining more importance mainly in automobile and aircraft sectors because of their high specific strength, high specific stiffness and low weight, where weight reduction is critical. As compared to light weight conventional monolithic alloys, MMCs have better structural applications and superior mechanical properties. Basically conventional alloys have disadvantage over stiffness, strength, density, wear resistance, fatigue etc. hence there is demand for new material and this is one of the driving force for the fabrication of newer and newer matrix materials(composites) in the field of aerospace, transport, turbine compressor engineering, automobile, marine, construction and material science [1-3]. These engineering fields need superior and enhanced weight reduction, mechanical and physical properties such as hardness, tensile strength, fatigue, stiffness, coefficient of friction, resistance to high temperature, toughness at room and elevated temperature[4].

Due to advancement in technology, there is enlarged demand for an economical, light weight, harder, stronger and energy saving material in the area space, aircraft, defence and automotive applications and aluminium matrix composites (AMCs) found applications in these areas [5]. In the field of composite materials there is wide exploration and pioneering development is going on. Many researchers tried to reinforce monolithic metal and alloy with ceramic phase to enhance their physical and chemical properties [6]. AMCs when compared to unreinforced alloy have better properties such as improved high temperature properties, improved stiffness, enhanced and tailored electrical performance, reduced density, good corrosion resistance, heat management, increased damping capabilities and improved wear resistance.

The most familiarly employed Metal Matrix Composites consists of aluminium alloy reinforced with ceramic particles usually alumina, silicon carbide and soft particles usually graphite [7]. Silicon carbide (SiC) are generally accepted for high strength, low density, high elastic modulus, low thermal expansion, high hardness, excellent thermal shock resistance and better chemical inertness. The accent has been given on improvement of affordable Al-based Metal matrix Composites with various hard



and soft reinforcements like SiC, graphite, zircon, Al₂O₃, and Mica[8]. Graphite in the form of fibres or particulates has long been identified as a low friction and self-lubricant, low wettability by liquid metals, high thermal and electrical conductivity, low density material. Al/graphite particulate composite was used as a material for engine cylinder which exhibit higher seizure resistance and low frictional coefficient and wear rate. Aluminum, graphite and SiC particulate Metal Matrix Composites produced by solidification techniques represent a class of inexpensive tailor-made materials for a various engineering applications [9].

As revealed in the so far carried out research, the particulate graphite increases wear resistance and using a method of hybrid reinforcement addition performance of SiC contributes to improvement of mechanical properties also at high temperatures. The presence of SiC could effectively prevent the matrix deformation, to carry the load and lock the micro cracks that often develop along the friction direction. Investigation of wear behaviour of aluminum alloys reinforced by micro particles such as SiC and Graphite is an absorbing area of research [10, 11]. Therefore, the objective of this research is to examine the effect of SiC and Graphite particulates content on the wear behaviour of Al2219–SiC and graphite particulates reinforced hybrid composites made by stir casting method.

2. Experimental Details

2.1 Process parameters-Matrix and Reinforcement

2XXX series includes copper as the alloying elements, Magnesium (Mg), Silicon (Si), Zircon (Zr), Iron (Fe), manganese (Mn), Titanium (Ti), vanadium (V), Zinc (Zn) were added to the alloys of 2XXX class series as minor alloying elements.

The percentage of silicon carbide and graphite as reinforcements were varied from 2 wt% to 4 wt% in steps of 2 and particles were produced by liquid metallurgy route. For the production of MMCs, an Al2219 alloy was used as the matrix material while SiC and graphite particles with an average size of 80-100µm were used as the reinforcements.

2.2 Synthesis of composites

In order to achieve better wear behaviour in the composites, a good interfacial bonding (wetting) has to be obtained between the dispersed phase and the liquid matrix. Hence the hybrid composites Al2219-SiC-Graphite used in this work were prepared by stir casting or vortex method. In stir casting method before the casting reinforcements, stirrer, permanent mould preheated to 500°C to remove moisture and gases from the surface of the reinforcements and equipments before casting. The Al2219 alloy melts at a temperature of 730°C in a graphite crucible in induction furnace and degassing was carried out using hexa-chloroethane degassing tablet. The tablet helps in the removal of entrapped air in the melt and thus prevents casting defects like porosity and blow holes. In order to reduce the temperature gradient and to improve wetting between the molten metal and the reinforcements, the reinforcements were preheated prior to their addition in the aluminium alloy melt. The superheated molten slurry (Al2219-SiC-Graphite) was stirred in graphite crucible at 300 rpm using a twin blade mild steel impeller which is coated with zirconia and stirred for 15 min until a clear vortex is formed. The melt with reinforced particulates was instantaneously poured into dried, coated, preheated cast iron permanent finger mould die. The melt was then allowed to solidify in the moulds.

2.3 Testing

Prior to microstructural analysis and wear testing the metallographic samples were cut from ingots, ground and the face of the specimen to be examined is prepared by polishing through different sized grit emery papers. The specimen is etched with a solution of HF and HNO₃ in volume ratio 1:12 at room temperature (for 10s) before it is examined using scanning electron microscopy and Energy dispersive spectroscopy, EDX analysis were used to determine the chemical compositions of the

composites. To ensure the reliability and the quality of anti-wear properties of the cast MMCs was analysed in detail in order to achieve a good reproductively.

3. RESULTS AND DISCUSSION

3.1 Microstructures of as-cast and Al2219-SiC-Graphite hybrid composites

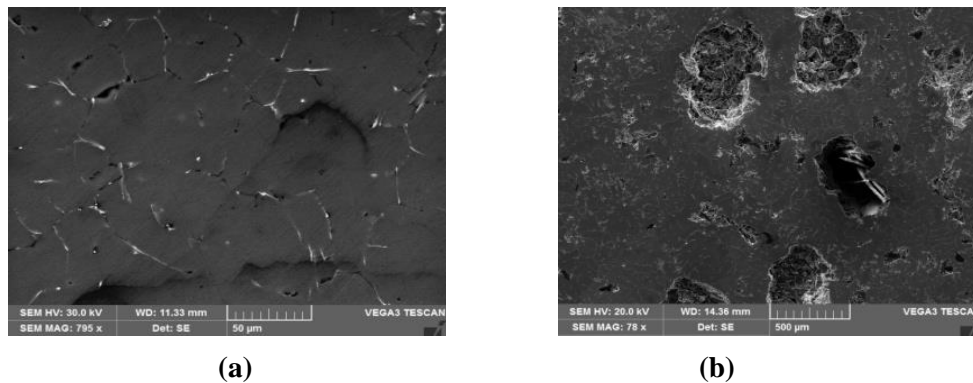


Figure 1. Showing SEM micrographs of (a) as cast Al2219 (b) Al2219-4% SiC-4% Graphite composite

The scanning electron micrographs of as cast Al2219 and its composites are shown in fig.1 (a-b). It is noted that the SiC and Graphite particulates were mainly distributed along grain boundaries in the hybrid composites. The reason for this is that the SiC and graphite particulates were pushed ahead by liquid solid interface during the solidification process.

The scanning electron micrographs of Al2219 as cast alloy (fig. 1-a) and Al2219-4%SiC-4% Graphite particulate composites (fig. 1-b) are shown. This reveals the uniform distribution of SiC and graphite particles and very low agglomeration and segregation of particles, and porosity. The vortex generated in the stirring process breaks solid dendrites due to higher friction between particles and Al matrix alloy, which further induces a homogeneous distribution of particles.

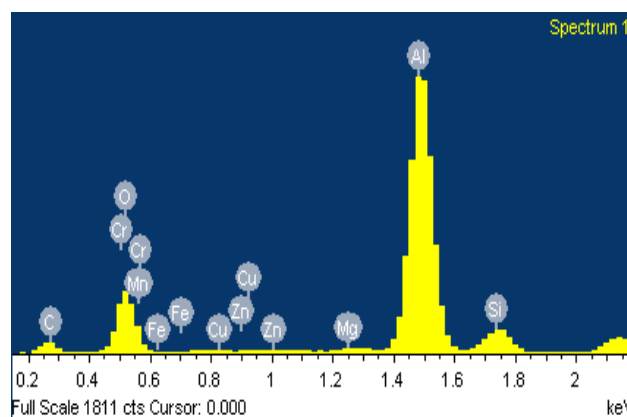


Figure 2. Showing EDS image of Al2219-4%SiC-4%Graphite composite.

The fig.2 showing energy dispersive spectrograph of Al2219 alloy reinforced with SiC and Graphite particulates. The graph reveals the presence of SiC and graphite particulates in the matrix alloy Al2219.

3.2 Wear studies and worn surface analysis

The dry sliding wear tests were conducted According to ASTM: G99 a DUCOM pin-on-disc wear testing machine. A pin on disc test apparatus was used to investigate the dry sliding wear behaviour of Al2219-SiC-Graphite hybrid composites. Pin specimens of 6mm diameter and 25mm height for wear test were prepared from the above hybrid composites. The experiments were conducted at a constant sliding velocity of 1.73m/s and time 54min over a load of 2kg and varying sliding distance of 2000m, 4000m, and 6000m.

Fig.3 and 4 shows the weight loss and wear rate of Al2219 alloy and its composites reinforced with SiC and Graphite particulates. Both weight loss and wear rate is more for as cast Al2219 alloy at a load of 2kg and sliding velocity of 1.73m/sec for the sliding distance of 6000m. Further, from the fig. 3 weight loss and wear rate (fig. 4) decreases as weight percentage of SiC and Graphite particulates increases from 2 wt. % to 4 wt. %.

The increase in wear resistance of Al2219-SiC-Graphite composites is mainly due to presence of hard SiC particulates and soft graphite particulates in the Al2219 alloy matrix.

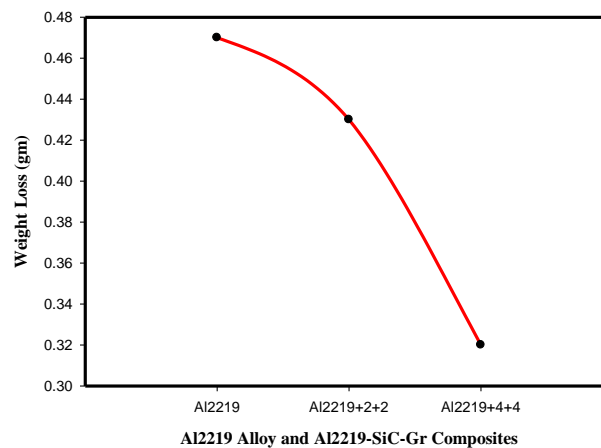


Figure 3. Showing the weight loss of Al2219 alloy and its composites at 2kg Load and 1.73 m/sec sliding velocity and for 6000m sliding distance.

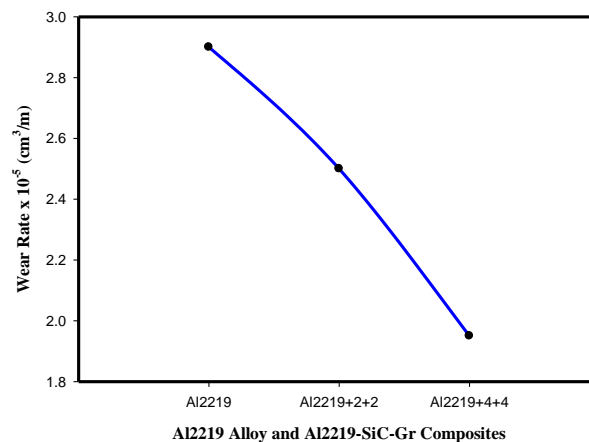


Figure 4. Showing the wear rate of Al2219 alloy and its composites at 2kg Load and 1.73 m/sec sliding velocity and for 6000m sliding distance

The improvement in the wear resistance of the composites with increased contains of SiC reinforcements can be attributed to the improvement in the hardness of the composites and improved

hardness results in the decrease in the wear rate of the composites. Increase in hardness results in improvement of wear and seizure resistance of materials. Further, increased wear rate with increased sliding speed is due to high strain rate subsurface deformation. The increased rate of subsurface deformation increases the contact area by fracture and fragmentation of asperities. Therefore this leads to enhanced de-lamination contributing to enhanced wear.

The graphite content in the Al2219 alloy decreases the wear rate due to presence of graphite on the mating surface during sliding. The graphite acts as a solid lubricant which is smeared on to the sliding surface thereby preventing a metal to metal contact. Such a mechanism of graphite smearing over the sliding surface has also been observed to operate in Al-alloy-Gr, particulate composites containing up to 50% by volume of graphite [12].

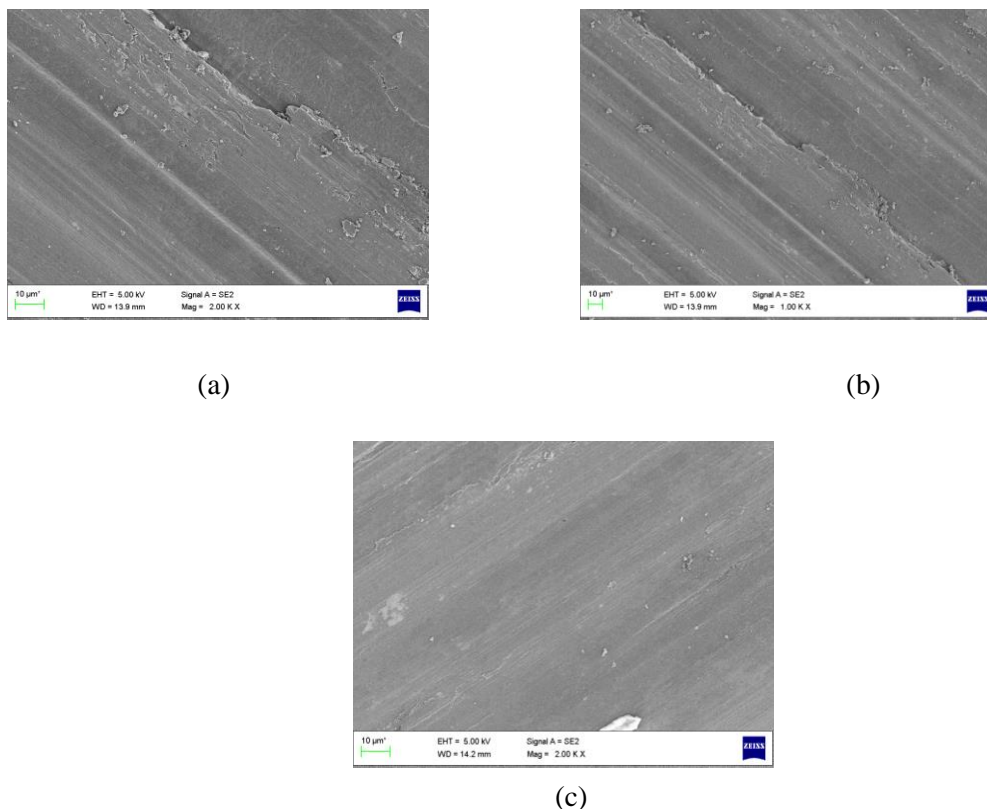


Figure 5. Showing the SEM worn surfaces of (a) as cast Al2219 alloy (b) Al2219-2% SiC-2% Graphite (c) Al2219-4% SiC-4% Graphite hybrid composites

The examination of worn surfaces from Fig. 5a showed that the worn surfaces of base alloy are much rougher than composites. SEM micrographs from Fig. 5b & fig. 5c it is seen that the width of scratches or cavities on the worn surfaces decreases with increase in volume fraction of reinforcement.

The images indicate the role of hard particles in increasing the wear resistance of the composites. The wear track observation shows that abrasion is the major wear mechanism at lower loads with small amount of de-lamination. Adhesion and de-lamination are dominant wear mechanisms observed at higher loads and lower speeds. This is supported by the large sized de-lamination flakes and severe adhesion resulting in bulk removal of material at higher loads.

It is observed that some cracks are formed/ originated at the grain boundaries of composite. This might due to the strain hardening of aluminium during sliding with applied load and due to pulling up of hard phase particles and also due to improper matrix-reinforcement interface leading to crack nucleation under higher loads.

As the ceramic particles resist the de-lamination process, composites are found to have greater wear resistance. Wear resistance of the composites increases with increase in the weight % of reinforcement.

4. CONCLUSIONS

The present work on SiC and graphite particulate reinforced Al2219 composite by two stage addition using melt stirring method has led to the following conclusions.

- SiC and Graphite particulate reinforced Al2219 composites with 2 and 4 wt. % of SiC and graphite were successfully fabricated by melt stirring method involving two stage additions.
- Two stage addition method adopted for introducing SiC and graphite particulates during melt stirring has resulted in homogeneous distribution of SiC and graphite with no clustering or agglomeration as evident from SEM microphotographs.
- Energy Dispersive Spectrograph shown the presence of SiC and Graphite particulates in Al2219 alloy matrix.
- Weight loss and Wear rate is more for Al2219 alloy compare to Al2219- SiC-Graphite hybrid composites.
- Weight loss and wear rate decreases with wt. percentage of SiC and Graphite content increases from 2 to 4 wt. %.
- Worn surface analysis revealed the presence of hard SiC and soft graphite particles in the matrix alloy, which decreased the wear rate and weight loss of base matrix.

5. REFERENCES

1. Dora Siva Prasad and Chintada Shoba 2014 *Journal of Materials Research and Technology* vol 3(2) pp172-178.
2. Gaohui Wu Xi Wang Longtao Jiang and Boran Ma 2014 *Materials and Design* vol 61 pp141-145.
3. Shin J H Choi H J and Bae D H 2014 *Materials Science and Engineering A* vol 607 pp 605-610.
4. Vijay Ramnath B Elachezhian C Jaivignesh M Rajesh S Parswajinan C and Siddique Ahmed Ghias A 2014 *Materials and Design* vol 58 pp 332-338.
5. Shouvik Ghosh and Prasanta Sahoo 2012 *Journal of Minerals and materials Characterization and Engineering* vol 11 pp1085-1094.
6. Rahika N Subramanian R and Venkat Prasat S *Journal of Minerals and Materials Characterization and Engineering* vol 10 pp 427-443.
7. Vinoth Babu N and Moorthy T V 2014 *Applied Mechanics and Materials* vols 592-594 pp 760-764.
8. Vinod Lakshminarayana Madhav Nagaral Suthan Rajendran and Auradi V 2015 *International Journal of Applied engineering research* vol 10.
9. Hartaj Singh and Sarabjit 2011 *Journal of Engineering Research and Studies* vol 2 pp 72-78.
10. Rana R S and Rajesh Purohit 2012 *International Journal of Scientific and Engineering Research* vol 3.
11. Hai Zhi Ye and Xing Yang 2004 *Journal of materials Science* vol 39 pp 6153-6171.
12. Ilyas Uygur and Mustafa Kemal 2002 *Turkish J* vol 26 pp 265-274.