Investigation of Mechanical and Tribological Properties of Aluminium Metal Matrix Composites - A Review

Arun Kumar Rajamanickam¹, Uvaraja V C² & Babu Narayanan³

¹,³ Assistant Professor, Sri Krishna College of Engineering and Technology, Coimbatore, Tamilnadu, India.
² Associate Professor, Bannari Amman Institute of Technology, Erode, Tamilnadu, India.

Abstract
Aluminium based metal matrix composites (AMCs) plays a major role in the demand for good quality materials for automobile and aeronautical applications which leads to production of best structural composite materials. Due to the grander strength to weight ratio, simple manufacturing of AMCs and wear resistance of aluminium based composites achieving better results. Reinforcement like alumina, boron carbide (B₄C), titanium carbide, silicon carbide (SiC), graphite and graphene etc., can be easily mixed in molten metal. Addition of titanium carbide and titanium di boride can improve the wear resistance of AMCs. Graphite and Graphene has self-lubricating property due to this machinability of AMCs will improve. This article presents the effective way of preparing the AMCs and its properties.

Keywords: Aluminium, Silicon carbide, Graphene, Titanium carbide, Titanium boride, Boron Carbide, Mechanical properties, etc.

1. Introduction
Polymer matrix and metal matrix composites has utilized to solve technological problems in industries. A composite material is a mixture of two or more constituents that are differ in form. In the past decades AMCs have drawn most of the attention due to its superior mechanical and tribological properties like tensile strength, fatigue, fracture, wear resistance and corrosive resistance etc. as compared to the un-reinforced composites. To achieve the desired properties of the materials, type of reinforcement, composition and shape of the reinforcement, location of the reinforcement and fabrication method can be varied. The aim is to achieve the desired properties of the AMCs by combine the desirable attributes of metals and ceramics. Composites can be very strong and stiff, yet very light in weight, so ratios of strength-to-weight and stiffness-to-weight are several times
greater than steel or aluminium. The hard material is mixed with reinforcement to improve the mechanical and also tribological properties. That composites are very well suitable to automobile components such as engines, brake disc, rotor etc.

Thirumal Azhagan et al the automotive and aerospace sectors develops the need of squeeze casting process due to its improved mechanical properties. E. Hajjari et al squeeze cast specimen with the presence of nickel coating on the carbon fibers improves the tensile strength of the composites, also the effect of nickel layer is improving the wettability and also protecting the fibers against reaction with liquid aluminium during processing the composite. J. I. Song et al the wear resistance of AMC reinforced with aluminium oxide and carbon fiber composites was extraordinarily improved over AMC reinforced with aluminium oxide composites. It was found that better result was obtained at the intermediate sliding speed. A. Urena et al addition of silicon carbide particles with aluminium matrix gradually increase the hardness of the composite. Processability of composite were improved by coating of SiC particles with silica layer by deposition by sol-gel process. The main drawback of developing AMCs lies in fabrication cost and of the reinforcement material. This paper presents a review of AMCs regarding their improved mechanical and tribological properties.

2 Effect of Reinforcements in Mechanical and Tribological Properties of Aluminium Metal Matrix Composites

Thirumal Azhagan et al (2014) has produce three squeeze cast components of AA6061 as per ASTM standard by varying the process parameters such as squeeze pressure at three levels (35 MPa, 70 MPa, 105 MPa), die preheat temperature was maintained at 200 °C and pressure applied duration was maintained at 15 seconds respectively. Impact strength of the specimens were tested by charpy impact pendulum tester. The authors observed that the high impact value has obtained in the third specimen by applying maximum squeeze pressure 105MPa. In the investigation of micro hardness of AA6061 alloy under three different squeeze pressures shows that the third specimen by applying maximum squeeze pressure 105Mp has the highest micro hardness of 74 Hv. The results shows that the mechanical properties like impact strength and micro hardness has improved with increasing squeeze pressure.

E. Hajjari et al (2010), prepared the 2024 aluminium specimens using squeeze casting method under 30, 50 and 70 MPa pressures by adding nickel coated polyacrylonitrile (PAN) based carbon fibers as reinforcement. Tensile strength of the AMCs significantly has the improvement due to the presence of nickel coating layer around the carbon fibers. With the help of scanning electron microscope the effect of applied pressure and nickel coating on the microstructure of the components were observed and also the fracture surface of tensile specimen was found. Fracture surface of tensile specimen nickel coated carbon reinforced with 2024 aluminium under 30 MPa applied pressure, is typically of fiber pull out type and long and numerous fiber pull outs were observed. Applying high pressures will leads to separate the nickel coating layer from the carbon fiber and also damage the
distribution fiber particulate and then it will reduce the strength of the component. Specimens prepared under 30MPa pressure shows no separation of nickel coating layer in carbon fiber also it has the higher strength compared to the specimens which made above 30 MPa pressure. The study shows that the different applied pressure of casting process has significant impact on the properties of the aluminium alloy.

J. I. Song, et al (1997), investigates the fabrication of Al/Al2O3/C hybrid composites, an AC2B aluminium alloy was used as a matrix. The composite specimens were fabricated in the following composition were chosen, Al2O3, (20 vol. %), and Al2O3/C at 18/2, 16/4, 14/6, 12/8, and 10/10 vol. %. By the direct squeeze infiltration method, Al/Al2O3/C specimens were obtained. To improve the mechanical properties of specimens an age hardenable aluminium alloy used as matrix material. The effect of wear resistance of Al/Al2O3/C hybrid composites were analysed with the different sliding speed on weight losses (volume) of AC2B Al alloy, Al/A&O3 and Al/Al2O3/C hybrid composites under final load of 3.2 kg, with sliding distance of 400 m at various sliding speeds of 0.5, 1.14, 1.97 and 3.62 m/set. During the wear test the wear resistance of the specimen were improved with sliding distance of 1.14 m/set. The above wear behaviour of Al/Al2O3/C hybrid composites were identified with microstructure analysis of the specimen with SEM.

Urena et al (2009), have been studied the effect wear behavior of an AA 6061 alloy reinforced with both modified SiC particles and metal coated carbon fibres. SiC particles are used to increase the hardness of the composite specimen and short carbon fibers are used as a solid lubricant. SiC particles coated with silica layer by sol-gel method to improve the processability of composite specimen. Nickel phosphorus or copper will be coated on carbon fiber through electroless process. The coating results wetting of the fibres during processing and then dissolved in the aluminium matrix leads to increasing the hardness of the specimen. The wear behaviour of AA 6061–20%SiC, AA 6061–20%SiC–2%C were compared with same reinforcement but using coated and particles fiber. The wear resistance of the specimen were increased when the carbon fiber were added as a secondary reinforcement. Specimens are fabricated by means of melting tests of cold compressed (520MPa during 5min) powder pellets of 13mm diameter and 3mm height. Specimen with coated and uncoated reinforcement were prepared to analyse the wear behaviour of the material. Uncoated reinforcement specimens has better wear behaviour. Coated SiCp favours the resistance of the composite and reduces the tendency of reinforcement being dislodged from composite.

Subramanya Reddy et al (2015), has investigated the mechanical properties of aluminium alloy with varies composition of boron carbide and silica carbide. The tensile, flexural, hardness and impact tests were conducted to evaluate the performance of hybrid composite. Tensile test for the specimens were conducted by Universal Testing Machine as per the ASTM standard. Flexural test was carried out to analyse the behaviour of the specimen under bending load. Sample 1 contains higher percentage of aluminium undergoes maximum displacement comparing to other samples. Higher tensile strength were obtained in sample 4. Sample 1 contain
least amount of SiC absorbs more energy than other samples so it makes it ductile for absorbing more energy. Sample 4 has higher hardness value compared to the other samples due to the presence of higher percentage of silicon carbide and boron carbide.

Baradeswaran A et al (2014), has prepared a AA 6061 and 7075 composite specimen were reinforced with 10 % weight fraction of (B4C) and 5 wt.% of graphite the characterization of composites are analysed with the help of SEM. Microstructure of the specimen shows distribution of the reinforcement with the aluminium matrix material. The following parameters were selected to conduct the wear test are applied load (10, 20, and 30 N), sliding speed (0.6, 0.8, and 1.0 m/s) and sliding distance (1000, 1500, and 2000 m). Investigation results of AA 6061 and 7075 shows that high hardness and good percentage of elongation is obtained in the AA 7075 hybrid composite. Wear resistance of the composite specimens were increased with the addition of 10 % weight fraction of B4C and 5 % weight fraction of graphite particles.

Baradeswaran, A et al (2014), Investigated the influence of graphite on the wear behaviour of Al 7075/Al2O3. Graphite has the self-lubricating property it providers significant improvement in wear resistance of the Al 7075 hybrid composite specimen. Al 7075 hybrid composite were prepared with 5 wt. % graphite particles addition to 2, 4, 6 and 8 wt.% of Al2O3. Wear resistance of the hybrid composite specimen were gradually improved with addition of graphite. Superior wear resistance properties were obtained in specimen containing higher percentage of Al2O3 and graphite particles.

Dunia Abdul Saheb et al (2011), evaluate the performance of AMCs with addition of SiC particle and graphite. The main objective of the research is to develop a conventional low cost metal matrix composites which leads to the demand of AMCs in automobile sector. By using stir casting method the composite specimens were fabricated by adding graphite and silicon carbide as a reinforcement material in following composition, graphite has been added in the weight fraction of 2%, 4%, 6%, 8% and 10%. The hardness test results of the hybrid specimens indicate that the maximum hardness has been obtained at 25 % weight fraction of SiC and at 4% weight fraction of graphite.

Kulkarni et al (2014), studies the mechanical and tribological properties of aluminium hybrid metal matrix composite. The specimen were prepared by stir casting process by adding Al2O3, SiC and graphite as reinforcement particles. The Al2O3 and SiC particles were added in the constant weight fraction of 1% and 3% in addition to that 0 to 6% weight fraction of graphite. The research of the results is the homogeneous distribution of the reinforcements in the aluminium matrix, which leads to obtain the better mechanical and tribological properties of the hybrid composite. The test results shows that the addition of graphite improve the tribological property of the specimen.

Prabagaran et al (2013), in this study AA6061 aluminium matrix were reinforced with B4C and graphite to improve its mechanical properties. Wear behaviour of AA6061, AA6061-B4C composite and AA6061-B4C-Gr hybrid
composite was investigated. The investigation result shows that AA6061-B4C composite had a higher hardness compared to AA6061. Wear resistance of the AA6061-B4C-Gr hybrid composite is higher than that of the AA6061-B4C composite and much higher than that of the AA6061.

Suresh et al (2014), prepared the aluminium metal matrix composites by adding the graphite and TiB2 particles as reinforcement. The test results shows that addition of 2% weight fraction of graphite shows the greatest improvement in mechanical behaviour. Also significant improvement in tensile strength and elongation with the addition of TiB2 and graphite.

Viney Kumar et al (2014), prepared the aluminium metal matrix specimens by casting process. AL6061 as taken as matrix material, 4% of magnesium and 10%, 15% and 20% of graphite was taken as reinforcement to prepare the hybrid composite specimen. The investigation results indicate that tensile strength of the specimen were increase with addition of fly ash upto 15%. Further addition of fly ash decrease the strength of the specimen. Graphite addition smoothens the machining. Fly ash increases hardness whereas graphite decreases hardness in a little amount but improves machining.

3. Conclusion

The above study reveals the following conclusions: stir casting and squeeze casting method can be successfully used to fabricate the metal matrix composites with desired properties. The mechanical and tribological properties of aluminium alloy has significant improvement with addition of ceramic particles. Addition of silica, silicon carbide, alumina and boron carbide particles with aluminium matrix evidence the improvement in their mechanical property. Addition of graphite and graphene particles with aluminium matrix results in increasing the tensile strength of the AMCs also it decrease the hardness of the material. Stir casting process has proper reinforcement particle distribution in the matrix material. Addition of titanium boride and titanium di boride particles with aluminium shows the improvement in wear resistance of the AMCs.

References


