A review on mechanical properties of aluminium metal matrix composites

A.A.Bagade[a], Dr. Shriramshastri Chavali [b], Dr.Abhijit Dandavate [c]

[A] Ph.D .Scholar, *Department of Mechanical Engineering, D Y Patil School of Engineering & Technology Ambi, Pune 410506,India*
[b] *Department of Mechanical Engineering, D Y Patil School of Engineering & Technology Ambi, Pune 410506,India*

[c] *Department of Mechanical Engineering,Dhole Patil college of Engineering,Pune 412207, India*

Abstract

Aluminium metal matrix composites is the most popular material because of light in weight, resistive to corrosion, low density, higher strength and thermal conductivity. Due to these Al MMC have become choice material in various application like aerospace, construction, and marine industries and automotive. By using different methods various experiments were carried out on Al MMC 6061, 7075, 5058 series. The qualities of stiffness, wear, creep strength, and fatigue are improved by the addition of reinforcement to the metal matrix.Al2O3, silicon carbide, fly ash, zircon, boron carbide, red mud, and other types of reinforcement are taken into consideration to improve the mechanical and tribological properties of Al MMC. Dependent on the distribution of the reinforcements are mechanical and tribological properties. The mechanical and tribological characteristics of aluminium MMC are discussed in this article

Keywords: Aluminium, Stir casting, wear

DOI: 10.53555/ecb/2022.11.10.68

1. Introduction

In current competitive market, large demand for the material having different properties in one material. The required demand such as high core toughness, high surface hardness, high corrosion resistance, better weldability and machinability. And these requirement can be fulfilled by composite material. The matrix phase and the reinforcing phase are combined to form a metal matrix composite. It is widely utilized in industry to modify the characteristics of base metals as needed .These composites can aid in improving the tribological and mechanical characteristics of metal. Different reinforcements are used to strengthen the parent metal, giving it additional strength[1].A Aluminium metal matrix composites are employed in a range of industries despite their many attributes, which include a relatively low density, enhanced corrosion resistance, strong abrasion and wear resistance, significant thermal conductivity, and a high specific modulus, including the automotive, aerospace, and marine industries. These composites can be made using a variety of fabrication methods, including the squeeze casting, stir casting, powder metallurgy, and spray codeposition. Selection of particular process depends on type of MMC to be produced, distribution of reinforcement which is in the form of fiber or particulate. It also depends upon the application for which it is manufactured [2]. Using the stir casting method, J. Hashim et al. produced metal matrix composites and study that the mechanical properties of metal matrix composites are enhanced by reinforcement of composites, particle dispersion, and adequate mixing of reinforcements with matrix.[3].Powder metallurgy is another technique for production of particulate-reinforced Al metal matrix composites. The impact of various process parameters via powder metallurgy for the production of particulate-reinforced composites of aluminium metal matrix, according to Vijayvani et al. The degree to which reinforced particles are distributed uniformly depends on critical process variables like temperature of process, duration sintering, type of reinforcement, reinforcement weight % and particle size. Homogeneous particle distribution can be obtained with less interfacial reaction by reducing sintering time [4].

The effects of stir casting on the mechanical properties of SiC reinforced with Al MMC were examined by Md. Habibur et al. with an increase in SiC content, mechanical qualities and wear resistance improved [5].B. Anil studied at the Al-SiC-B4C MMC's mechanical characteristics. Kumar et al. using a powder metallurgy approach, and they came to the conclusion that As the amount of B4C weight decreased the hybrid composite's hardness decreased[6].By using the Al6061 matrix alloy and reinforcing it with volume percentages 5%, 10%, 15%, and 20% of red mud as a reinforcement. Gangadharappa M. et al. study the effect of red mud in Al6061 for hardness, co-efficient of friction and wear rate. The study came to the conclusion that wear rate decreased as the percentage of red mud increased and that hardness increased[7].The Aluminium Metal matrix composite can be created using a variety of techniques. Many researchers favour the stir casting process over the others.

In this paper study is carried out on Mechanical and tribological properties of AlMMCs.

2. Mechanical Properties

The mechanical properties of Al MMCs are influenced by a number of variables, including the distribution of non-uniform reinforcement particles, the features of the reinforced element, the porosity between the metal matrix and the reinforced element and others. The following are the mechanical parameters of the aluminium metal matrix composites that have been examined:

2.1 Hardness

R.Pandiyarajan et al. studied the metallurgical and mechanical properties of SiC/B4C reinforced with Aluminium composites created by varying the SiC and B4C percentages. The homogeneous combination of matrix and reinforcement particles in composites is identified via SEM and EDX analyses. The study found that at 20 weight percent B4C and 10 weight percent SiC, the hardness parameters of the composite were improved by 20.48% [8].

Shakil Hossain et.al has study experiment on Al-Al2O3-SiC metal matrix composites mechanical behaviour and microstructure. In the present study the SiC percentage was changed from 0 to 8 wt% while the Al2O3 content remained constant at 1 wt%. As the amount of reinforcement materials rises, composite materials get harder. A maximum hardness of 84HRB is discovered for AK05.

Al2O3-SiC reinforced composites resist material deformation as a result of the hardness of the ceramic particles, which increases the composites' hardness during mechanical evaluation [9]. The mechanical behaviour of titanium carbide-reinforced Al Metal Matrix composites was studied by K. Ravikumar et al. Variations in the weight percentage of TiC added were the cause of hardness variations in the aluminium alloy (Al 6063). The amount of titanium carbide particles used resulted in a maximum 20% improvement in hardness. As TiC weight percentage increases, hardness increases [10]. Sumesh Narayan et al. conducted experiments to determine how aluminium MMC would behave mechanically. The reinforcements under consideration include titanium carbide ,tungsten carbide, iron carbide and Molybdenum carbide. When the reheat procedure was used before final cooling, the hardness increased [11]. The current study highlights the impact of reinforcing particles on the mechanical characteristics of the metal matrix composition composites made of aluminium (Al 6063) that have been friction stir welded. Initially, stir casting technology was used to successfully create composites with varying weight percentages and combinations of reinforcements (graphite,B4Cand SiC). The friction stir welding technique was used to join all sets of composite specimens through solid state process, and the fabricated composites were then characterised using parameters including tool rotational speed (800, 1000, and 1200 rpm), welding speed (20 and 40 mm/min), and axial loading (10 and 20 KN). Mechanical and microstructural characterizations were used to investigate the effects of friction stir welding settings. Using an optical microscope, the microstructure of the composites and the dispersion of the reinforcement were analysed. The study concluded that Al 6063 matrix composites have been successfully fabricated using the friction stir welding method and stir casting method. When compared to the Al 6063 matrix, the particles SiC, B4C, and graphite have greater wettability and interfacial bonding. All composite specimens having higher hardness values, particular B4C reinforced composites having a greater hardness value. Hard B4C particles prevent atoms from dislocating within the composites, increasing their hardness in comparison to other composites and base alloys [12] Siddique et al. investigated that the hardness of the Al-SiC composite was affected by SiC reinforcement. Hardness increases with the number of silicon carbide particles added [13]. The mechanical properties of Al7075 hybrid nano composite was studied by C. Kannan et al using stir- and squeeze-casting . The three samples that were considered were Al 7075 reinforced with 4% SiC, Al 7075 reinforced with 2% Al2O3, and Al 7075 reinforced with 4% SiC for single and hybrid reinforced nano composites was study and found that the hardness value increased to 63.7% and 81.1%, respectively[14].Al 7075 reinforced with hybrid composites made of Al2O3 and graphite has been examined for its mechanical properties by Baradeswaran et al. When more reinforcement is added, the hardness increases. The hardness value rises with the addition of alumina. The inclusion of graphite reduces the hybrid MMCs' hardness value.[15]

As shown in Fig. 1, the proportion of alumina added increased the hybrid Al 7075/graphite/Al2O3 composite's hardness. The distribution of particles inside the matrix, the kind of reinforcement used, and the kind of matrix all have an impact on the hardness.

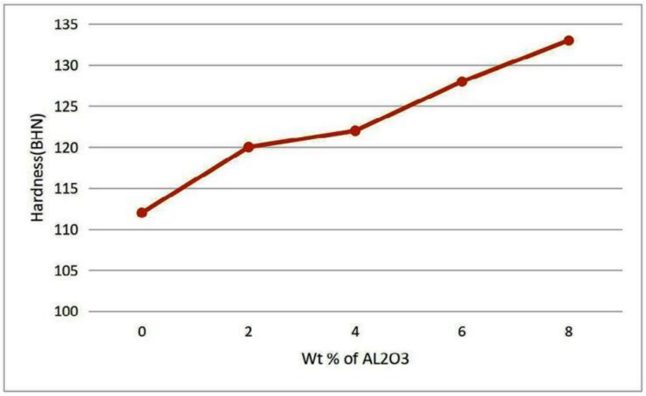

Fig.1 Hardness varies depending on the weight percentage of Al2O3

2.2 Tensile Strength

In their research, Amit Raturi et.al. investigated The fabrication and mechanical performance of aluminium 7075 enhanced with nanoalumina particles. The double stir casting method is used to carry out the fabrication process. When compared to base alloy, MMC has greater tensile strength. Due of cluster formation, too much porosity, and non-uniform nanoparticle distribution, adding reinforcement yields a decrease in tensile strength [16]. Rahman et al. examined the reinforcements that were added to Al 6061. In comparison to Al 6061 reinforced with silicon carbide, Al 6061 reinforced with graphite was found with a greater tensile strength [17]. The mechanical characteristics of Al 7075 reinforced with 3-6% SiC/red mud/fly ash were examined by Vinitha and Motgi. In comparison with Al7075 reinforce with SiC and fly ash, Al7075 reinforced with red mud and SiC has a higher tensile strength [18]. S.Sulaiman et al. examined how modifiers affected the mechanical characteristics of Al-SiC composites. Due to the weak bond between the matrix phase and particles, the increase in tensile strength is negligible. Before tensile testing, the sample must undergo a heat treatment to increase its tensile strength [19].

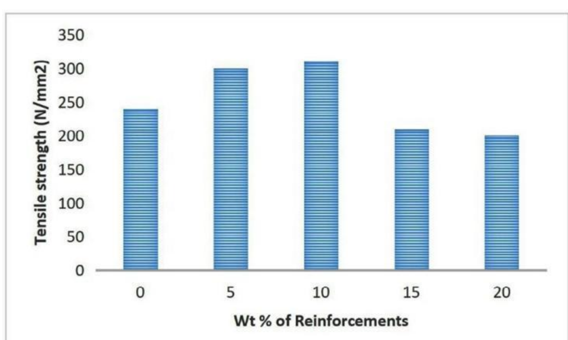

Fig. 2 Tensile strength varies depending on the SiC weight percentage.

Tensile strength of Al-SiC composites increases with increases the percentage of SiC but it then declined due to an uneven distribution of particles of reinforcement and an increase in cluster formation (Fig. 2). [5]

2.3 Compressive Strength

The aluminium alloy LM 25 was used as the basis for the addition of various silicon carbide compositions, graphite,fly ash. Fly ash particles are the best reinforcement for increasing compressive strength since they are known to harden the base alloy.

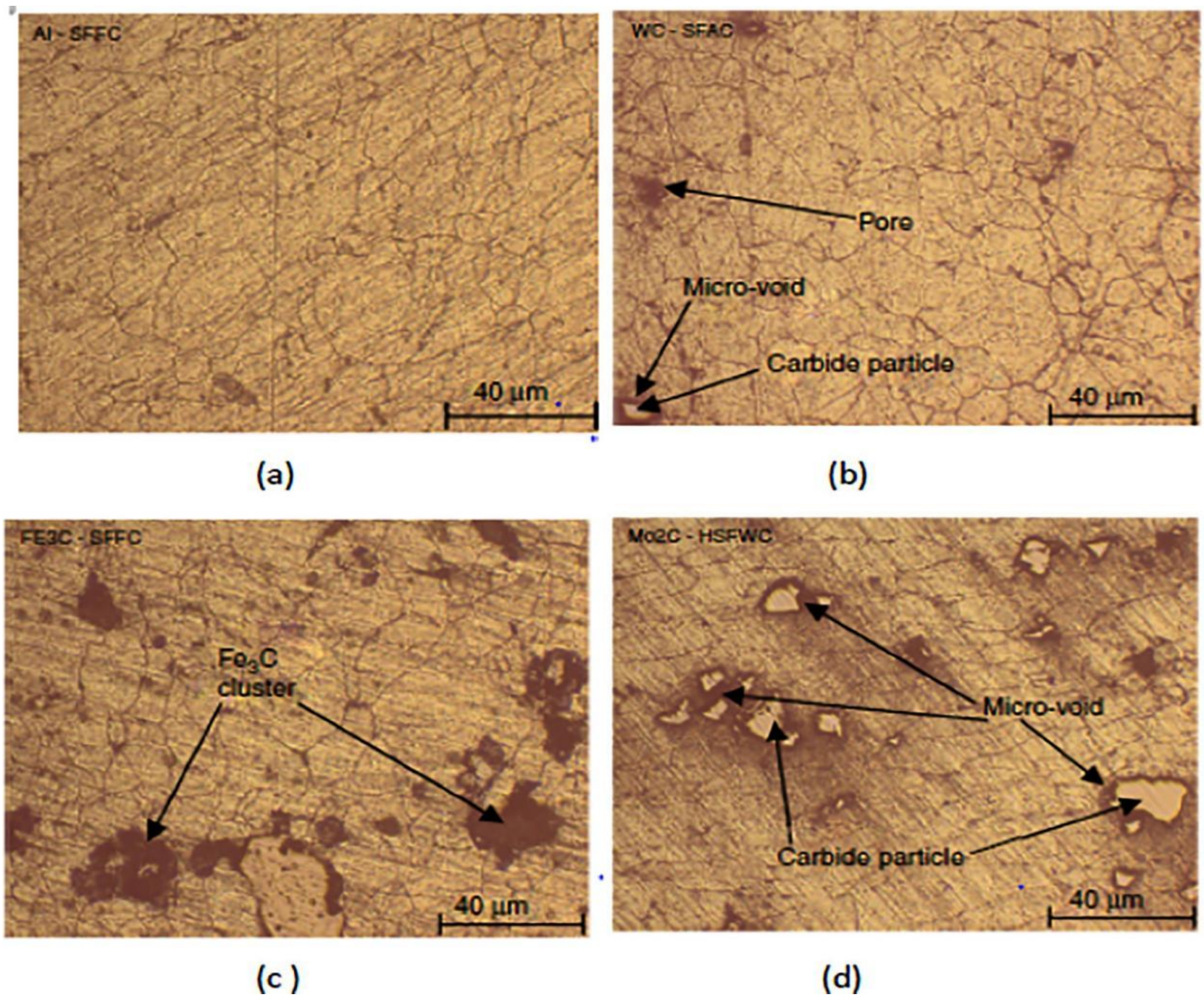

Fig.3 Aluminium preform and composite microstructures.

Saravanan and Kumar used rice husk ash as reinforcement in their experiment on aluminium (AlSi10Mg).The alloy had additions of rice husk at 9 and 12 weight percent. Since fly ash and rice husk have comparable characteristics, using rice husk increases the metal matrix composite's compressive strength.

2.4 Microstructure

The microstructure study revealed the reinforcement in the matrix phase and grain formation and the properties of composite can be enhanced using these finding. As seen in Fig. 3, Sumesh Narayanan et al.that examined the microstructures of powder-metallurgy-fabricated MMCS and the as-cast aluminium preforms. The microstructures of the aluminium alloys Al4WC, Al4FE3C, and Al4MO2C are shown in Figures (b),(c) and (d) respectively. While a pure aluminium preform's microstructure is depicted in Figure (a). The granules of pure aluminium have spherical, clearly defined shapes and little porosity. The reinforced particles are evenly dispersed throughout the matrix as can be seen from the composite microstructures. The heat treatment process in carbide composites causes the grains to enlarge. The matrix also exhibits micro-voids and clusters of reinforced particles, which may weaken the composite and result it to start splitting under tension [15]

3 Tribological properties

Tribological qualities include the coefficient of friction, specific wear rate, wear loss of manufactured materials, and frictional force produced during wear testing A thorough analysis of the reinforced metal matrix composites must be done.These characteristics are also examined after production in addition to mechanical properties. These materials have important uses in the biological area, among other things, and wind turbines.

3.1 Wear Rate

Kok et al. have investigated the wear resistance of aluminium and its composites with added Al2O3 particles. Sliding wear experiments were performed utilising composites made of the 2024 aluminium alloy, which was created using the vortex process, and 10, 20, and 30 weight percent of Al2O3 reinforcement. It is discovered that the composite has higher wear resistance than the base alloy. It rises as Al2O3 particle concentration and size increase, but wear load and sliding distance increase, causing it to reduce. The composite's wear resistance is largely influenced by the size of the reinforcement [21].Veeresh Kumar et al studied Particulate Reinforced Aluminum Metal Matrix Composites on Tribological behavior and Mechanical behaviour. The research results include a review performance of wear of hard ceramic reinforced aluminium matrix composites with considering mechanical, physical, and material variables as well as work hardening, mechanical mixed layer, impact of lubrication, mechanical mixed layer and heat treatment, etc. Al-MMCs with ceramic reinforcement will have greater wear resistance than alloys without reinforcement. There is bright scope for research in the field of methodology of soft computing for Tribological and Mechanical properties evaluation of particle reinforced metal matrix composites[22]. Al MMCs that have SiC and Al2O particles as reinforcement have been developed by Prasada et al. [32]. Finally, it was found that particles would lighten vehicles, improve engine performance, and cut down on fuel use and pollutants. By dispersing Al2O3,SiC, or graphite particles in Al, the seizure resistance and poor adhesion of Al can be overcome, allowing engine components of cast iron to be replaced with lighter-weight Al alloys. By using these particles, a significant reduction in friction is achieved. Additionally, since Al MMCs can withstand high thermal and mechanical stresses , and decrease heat losses by allowing closer fit that can be achieved because of lower thermal expansion coefficient of Al MMCs [23]. Fig. [4] show the loss of wear for various SiC weight fractions. Studying these composites exposed that the amount of wear loss lowers as reinforcement is added to the metal alloy. Wear characteristics are more affected by the composite's hardness than by the base alloy. [5]

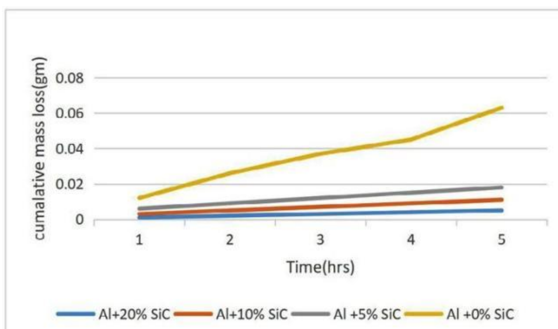

Fig. 4. loss of wear for Al-SiC composites.

3.2 Coefficient of friction

Ranganathan et al.'s tests involved a nano composite with an aluminium silicon carbide matrix. At all applied loads, it was observed that the friction coefficient of nano composites was lower than that of unreinforced alloy, and it decreased to 0.324 under the load of 40 N while sliding speed is 0.5 m/s [24]. Marwaha et al. examined the wear characteristics of aluminium composite with graphite and silicon carbide reinforcement. Using ANOVA method, effect of parameters like sliding speed ,track diameter and applied load on coefficient of friction are investigated [25].responses were calculated by S/N ratios and mathematical model was created. Track diameter has a largest effect on the coefficient of friction subsequently applied load and sliding speed .The study indicates that the coefficient of friction not affected by mechanical parameters. It is totally depends on contents of based on the metal matrix composite.

The mechanical , wear , and corrosion properties of Ti-6Al-4V alloy when reinforced with boron carbide ceramic particles were studied by Soorya Prakash et al. Three samples are initially created, each of which includes reinforced materials of various compositions. They came to the conclusion that when boron carbide's weight % increased, there was a decrease in density, an increase in hardness, and a greater resistance to corrosion. When examined under a scanning electron microscope, the material's exceptional wear resistance was discovered.Senthil Murugan and colleagues described the tensile, compressive, and impact properties of stir-cast Al6061-T6 reinforced with alumina (7% constant) and SiC (10, 15 and 20%). According to the outcomes of all these mechanical tests, the Al6061-T6 composite with 20% SiC reinforcement had greater tensile, compressive, and impact strength than other composite combinations. The mechanical properties are improved as a result of increased interfacial bonding between the matrix and reinforcement caused by increased ceramic (SiC) content.

Conclusions

The following conclusions were derived from the present review

- With the variation of Silicon Carbide composition MMC hardness changes. Hardness increases with increases in SiC weight fraction.
- By adding silicon Carbide, fly ash and Graphite, tensile strength of the composite can be improved.
- Compressive strength can be increases by adding the fly ash particles.
- The wear resistance can be increases by addition of different composition of silicon carbide.

References

[1] Praveen Kumar R, Periyasamy P, Rangarajan S, Sathish T. League championship optimization for the parameter selection for Mg/WC metal matrix composition. Mater Today Proc 2019.

[2] U. K. Karl, Basics of Metal Matrix Composites, Wiley-Vch Verlag Gmbh and Company Weinheim, 2006, pp.1- 6

[3] J. Hashim, L. Looney, et al., Metal matrix composites: A production by the stir casting method, J. Mater. Process. Technol. 92–93 (1999) 1–7

[4] Vemula vijaya vani, Sanjay kumar Chak, ‘‘ The effect of process parameters in aluminium metal matrix composites with powder metallurgy”, Manuf. Rev. 5, 2018

[5] M.d. Habibur Rahaman, H.M. Mahun, Characterization of Silicon carbide reinforced aluminium matrix composites, Procedia Eng. 90 (2014) 104–109

[6] B. Anil Kumar, K. Eswaraiah, et.al, ‘‘ Fabrication of Al-SiC-B4C metal matrix composite by powder metallurgy technique and evaluating mechanical properties”, 8,2016, 428-431.

[7] Gangadharappa M,Reddappa H.N.Ravi KumarM,Suresh R , Mechanical and wear characterization of Al6061 red Mud composites, Mater Today Proc 5(2018)22384-22389.

[8] R. Pandiyarajan *, M.P. Prabakaran b, T. Rajkumar, K. Vetrivel Kumar, R. Manikandan,Metallurgical and mechanical properties of SiC/ B4C reinforced with aluminum composites synthesized by mechanical alloying.Mater Today Proc 2020.

[9] Shakil Hossain, MD Mamunur Rahman, Devesh Chawla, Alip Kumar, Prem Prakash Sethb, Pallav Gupta, Devendra Kumar, Rajeev Agrawal, Anbesh Jamwal, Fabrication, microstructural and mechanical behavior of Al-Al2O3-SiC hybrid metal matrix composites. Mater Today Proc 2019

[10]. K. Ravi Kumar, K. Kiran, et al., Microstructural characteristics and mechanical behaviour of aluminium matrix composites reinforced with titanium carbide, J. Alloy. Compd. 723 (2017) 795–801.

[10] Sumesh Narayanan, Rajeshkannan, Hardness, tensile, impact behaviour of hot forged aluminium metal matrix composites, J. Mater. Res Technol. 6 (2017) 213–219.

[11] Suresh Babu B*, Chandramohan Gb, Boopathi C, Pridhar T and Srinivasan R, Production and characterization of mechanical and microstructural behaviour of friction stir welded A16063 composites reinforced with Gr/B4C/SiC particles,Journal of Ceramic Processing Research.Vol 19 No.1,pp69-74 (2018).

[12] T.A. Siddique, M.T. Islam, M.S. Kabir, M.N. Haque, Effect of SiCp addition on the indentation hardness of as-cast Al metal matrix composites, Int. J. Innov. Sci. Res. 11 (2014) 433–438.

[13] C. Kannan, Ramanujam Radhakrishnan, et al., Machinability studies on Al 7075/BN/Al2O3 squeeze cast hybrid nano composite under different machining environments, Mater. Manuf. Processes (2017).

[14] Sumesh Narayanan, Rajeshkannan, Hardness, tensile, impact behaviour of hot forged aluminium metal matrix composites, J. Mater. Res Technol. 6 (2017) 213–219.

[15] Amit Raturi, K.K.s.Mer,, Synthesis and characterization of mechanical, tribological and microstructural behaviour of Al 7075 matrix reinforced with nano Al2O3 particles, Mater. Today Proc. 4 (2017) 2645–2658.

[16] M.H. Rahman, H.M.M.A. Rashed, ‘‘Characterization of Silicon Carbide Reinforced Aluminium Matrix Composite”, Proceedings of the 10th International Conference in Mechanical Engineering 2013: 103- 109

[17] Vinitha, B.S.Motgi, Evaluation of mechanical properties of Al7075 alloy, fly ash, SiC and red mud reinforced metal matrix composites, Int. J. Sci. Res. Dev. 2 (2014) 190–193

[18] S. Sulaiman, Z. Marjom, et al., Effect of modifier on mechanical properties of aluminium silicon carbide (Al-SiC) composites, Procedia Eng. 184 (2017) 773– 777.

[19] S.D. Saravanan, M. Senthil Kumar, Effect of mechanical properties on rice husk ash reinforced aluminium alloy (AlSi10Mg) matrix composites, Procedia Eng. 64 (2013) 1505–1513

[20] M. Kok, Kamil Ozdin, Wear resistance of aluminium alloy and its composites reinforced by Al2O3 particles, J. Mater. Process. Technol. 183 (2007) 301–309.

[21] S. Basavaraju, K. Arasukumar, et al., Studies on Mechanical properties and Tribological Characteristics of LM25-Graphite-Silicon carbide and LM25-Fly ash-silicon carbide hybrid MMCs, Int. J. Innov. Sci. Eng. Technol. 1 (2012) 107– 112.

[22] P. Shanmugasundaram, Wear behaviour of As-cast and heat treated Al-7075iC composites, IJRASET 3 (2015) 433–436.

[23] I. Manivannan, S. Ranganathan, et al., Mechanical properties and tribological behaviour Al6061-SiC-Gr self-lubricating hybrid nano composites, Trans. Indian Inst. Met. 71 (2018).