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STUDY OF ALUMINIUM BASED METAL MATRIX COMPOSITES WITH VARIOUS REINFORCEMENTS – A REVIEW.

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Abstract
Aluminium alloy based metal matrix composites (AMMC) due to their excellent mechanical properties with high strength to weight ratio are widely used for aerospace, automobile, marine industries, etc. The Aluminium matrix is strengthened when it is reinforced with hard ceramic particles like SiC, Al2O3, B4C, etc & it is always a challenge to achieve accurate percentage distribution of the reinforcement particles inside the matrix, resulting in enhanced wear resistance and improved strength, and more fatigue life. This review paper is broadly focused on the effect of the different reinforcements like SiC, B4C, Al2O3, graphite, graphene nanoplates, industrial waste materials like fly ash and bagasse ash, TiC, ZrO2, TiB2, WC etc on the microstructure, mechanical, tribological & corrosion properties of the Al and Al alloys. This paper also discuss to optimize the wt. % of reinforcement in the metal matrix by using stir casting route which is the most economical, simple & flexible method used for synthesizing particulate composites.

Keywords:
Metal matrix composites, Reinforcements, stir casting, tribological, corrosion.

1. Introduction

Composites are the materials in which metals like aluminium, titanium, magnesium copper etc are used as the matrix phase reinforced with the other material i.e. ceramic [1]. Aluminium Metal Matrix Composites (AMMC) reinforced with other materials like SiC, Al2O3, B4C, Ti_2B , fly ash etc has enhanced mechanical properties and relatively low production cost having superior properties such as high specific strength and stiffness, increased wear resistance, enhanced high temperature performance and are used for various applications such as brake rotors, pistons, cylinder liner[2, 3]. Manufacturing of particulate reinforcements composites are done either by powder metallurgy in solid state or stir casting process in liquid state [4]. Stir casting is commercially used for particulate reinforced aluminium metal matrix composites due to ease, flexibile and economical process with an advantage of large quantity of production applicability [5] . Hardness, microstructure of the Aluminium metal matrix composites are influenced by stirring speed and stirring time. Lower stirring speeds and lower stirring time results in particle clustering and uniform , high hardness values are achieved by increasing the stirring speed and stirring time for A384 aluminium alloy reinforced with SiC [6]. Compo-casting, squeeze casting, friction stir processing, spray casting etc. are the other manufacturing processes used for the fabrication of metal matrix composites but up to a lesser extent [7] . Microstructure and mechanical properties of the composites depends on reinforcement particle size and volume fraction, hardness, tensile, and compressive strength of the composites increased with decreasing particle size and increasing reinforcement content . Al- Al_2o_3 composites are prepared with Alumina (Al_2o_3) particles of sizes 50 mm, 10 mm, and 20 nm & it is observed significant improvements in hardness and tensile strength are attained in the nano-composites [8]. The corrosion behavior of the Aluminium metal matrix composites can be analysed using weight loss approach by immersing the composites in respective acidic solution for a specific duration corrosion rate decreased with the increase in weight percentage of reinforcements in the metal matrix [9]. Dry sliding wear test of the composites fabricated by powder metallurgy or stir casting can be conducted on pin-on-disk testing setup by choosing a suitable track diameter, Load, sliding distance and sliding velocity . The wear rate increases with increase in normal load and decrease with wt % of reinforcement [10]. Stirring process parameters, such as the blade angle, rotating speed, diameter of the impeller, and the stirrer geometry, effects the flowing characteristics of the molten matrix in achieving the effective flow pattern and to uniformly disperse the ceramic particle reinforcements in the molten matrix [11]. Based on the stated potential benefits of metal matrix composites this current study is expected to give an in-depth understanding of various factors like (a) effect of various reinforcement (b) mechanical behaviour like strength, wear ,fatigue ,corrosion behaviour, etc. (c) processing methodology and its effects of single and hybrid Aluminium metal matrix composites were discussed.

2.Reported works on Aluminium alloy metal matrix composites with Single reinforcement.

Bhaskar Chandra kandpal [12] investigated aluminum alloy 6061 reinforced with different amounts of Al_2O_3 particles (5%, 10%, 15%, and 20% by weight) using stir casting process. The research focused on creating and analyzing these composites for applications requiring high wear resistance. Scanning electron microscopy found that the Al_2O_3 particles improved the grain structure and were evenly distributed in the aluminum matrix, though some clusters were observed. The Al_2O_3 reinforcement particles bonded well with the matrix, leading to increased micro hardness and tensile strength of the composites. The mechanical testing was done to evaluate the mechanical properties of composite material. It was found that both tensile strength, UTS and hardness was improved by 106.66 % and hardness by 47.03 % as the percentage of reinforcement increased from 5 % to 20 %. But the percentage of elongation was decreased and the increase in Al_2O_3 content shifted the fracture mode from ductile to brittle.

S.A. Sajjadi [13] fabricated A356/Al_2O_3 composites with different particle sizes of micro and nano reinforcements using stir-casting and compo-casting techniques. In this research the investigation is carried out on different factors such as micro and nano hard particles reinforcement, weigth % of particles, type of fabrication process and its effect on microstructural & mechanical properties of composites. The magnitude of alumina powder injected into the composites were chosen 1, 3, 5 and 7.5 wt.% micro-alumina and 1, 2, 3 and 4 wt.% nano-alumina. Compo-casting resulted in lower porosity and finer grain size compared to stir-casting, & Scanning electron microscopy (SEM) revealed that the compo-casting method achieved a good distribution of particles with minimal alumina agglomeration. The yield, ultimate tensile, and compression strengths of the composites improved with increased Al_2O_3 content, and yield , tensile strength increased with higher nano-particle content, while fracture strain decreased. The strength and hardness of the composites showed significant improvement with the addition of 3 wt.% nano-Al_2O_3 and 5 wt.% micro-Al_2O_3 for compo-casting, and 2 wt.% nano-Al_2O_3 and 5 wt.% micro-Al_2O_3 for stir-casting and further increases in Al_2O_3 content led to a reduction in strength values.

Mohanavel [14] studied hybrid AA6351 aluminum matrix composites incorporating both Al_2O_3 and graphite (Gr) as reinforcing materials fabricated using the stir casting method. Optical microscopy showed that the uniform & homogeneous distribution of reinforcements within the AA6351 matrix and addition of Al_2O_3 and Gr improved the macrohardness, tensile strength, and flexural strength of the AA6351 alloy.

Ravi, B [15] identified improvement of wear resistance and strength of Aluminum Matrix Composites reinforced with hard ceramic particles like SiC, Al_2O_3, and B_4C. B4C reinforcement of 25μm size (for 5 and 10 wt. %) are uniformly distributed in the aluminium matrix . B4C particles prevented the grains from growing as large as the pure AA6061 alloy as reinforcement particles in the melt increased the number of nucleation sites. The hardness value is increased by increasing the wt % of B4C

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reinforcement particles , as the presence of hard reinforcement particles resists the plastic deformation. The strength of the grain boundaries increases to maximum level and dislocation movement of atoms is decreased by increasing the wt% of reinforcement, which gives strength to the matrix and thereby hardness of the composite gets increased. The B4C reinforcement enhanced the tensile strength of Aluminium Matrix Composites (AMCs) from 117 MPa to 145 MPa due to better interfacial bonding between the matrix and the reinforcement.
Pankaj P Awate [16] evaluated the effects of graphene nanoplates at varying weight percentages (2%, 4%, 6%, 8%, and 10%) on the microstructure and mechanical properties of AA6061 aluminum alloy for demanding applications like aircraft fuselages, wings, internal panels, and luxury vehicle chassis. Field emission scanning electron microscopy confirmed a uniform distribution of graphene in the aluminum matrix, the tensile strength increased by 127%, hardness by 158%, and yield strength by 402% compared to the unreinforced AA6061 alloy.
Pazhouhanfar, Y [17] varied TiB_2 reinforcement levels 3%, 6%, and 9% by weight of Al6061 aluminum matrix composites fabricated using the stir casting method optimizing the process parameters, preheating temperature, stirring speed, and duration, enhancing the quality of the composites. Reinforcement / matrix interfaces are approximately free of porosity due to the improvement of wettability by adding K2TiF6 and preheating of TiB2 particles just before adding to the melt. TiB2 ceramic particles are located at grains interiors and mostly at grain boundaries and are distributed in both transgranular and intergranular regions as observed in microstructure. Mg2Si and Al5FeSi peaks are observable in diffraction pattern of Al6061 matrix alloy as investigated by XRD analysis. The tensile strength and hardness of the composites increased with higher TiB_2 content and the improved mechanical properties of Al6061-TiB_2 composites, are attributed to the interaction of dislocations with reinforcement particles via the Orowan mechanism.
Singh, J [7] analysed Mechanical Properties of AMC Fabricated by adding silicon carbide in Aluminum alloy 6063 by 5%, 7.5%, 10%, 12.5% and 15% (of mass ratio) respectively by Vacuum Stir Casting Process and enhanced the mechanical properties such as density (upto 3.70%), hardness (upto 95.72%) ultimate tensile strength (upto 33.65%) . Semi-ductile behavior in the form of small dimples and facets were observed in the fractography analysis of MMCs. The Archimedean principle was made used while computing the density for different percentage weight fractions of SiC particles. The tensile strength of cast Al alloy was observed as 205 MPa, which was minimum of all the tested samples; whereas, it was the maximum value for MMC having reinforcement of 12.5% wt. The SEM images of fractured specimen with 12.5 wt% of SiCp shows the presence of SiCp . Both the ductile & brittle types of fracture mechanisms revealed in the SEM results found that the reinforced SiCp facets show brittle fractures while the matrix shows ductile fractures.
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Wu, C [19] studied the size of B4C particles prepared for 56.9 µm, 4.2 µm, and 2.0 µm affecting the properties of Al 7075 metal matrix composites. Composite with the smallest B4C particles had the best strength and showed clumping i.e smaller particles enhance strain gradient strengthening and mismatch strengthening, leading to more dislocations in the material. High density of dislocations was observed in the Al 7075 matrix in the vicinity of the B4C particles which exhibited various geometries,

such as dislocation networks, dislocation walls, straight dislocations, dislocation semi-circles and dislocation tangles. All the specimens fractured along 45^o relative to the compression direction, indicating a relatively high ductility. Coarse reinforcement particles in the composite were prone to crack during compression testing mainly due to the pre-existing voids and cracks and the composite with smallest reinforcement particles (~ 2.0 μm) was more prone to fracture along prior particle boundaries.

Arekh Sharma [20] added micro and nano-sized Boron Carbide (B4C) powders to aluminum alloy AA 7075-T6 using Friction Stir Processing (to enhance mechanical and damping properties. optical microscopy and Electron Backscatter Diffraction of the nano-reinforced composites showed a significant reduction in grain size, down to 2.9 μm from the original 37 μm and obtained 66% increase in hardness reaching 141 HV compared to the base material and these composites exhibited excellent damping performance in thermal and mechanical cyclic tests between -60°C and 60°C.

Pradeep Kumar Krishnan [21] successfully explored the use of car scrap aluminum alloy wheels (SAAWs) and spent alumina catalyst (SAC) from oil refineries as materials and created aluminium metal matrix composites using a new stir-squeeze casting method. Four types of composites were produced they are AlSi7Mg with alumina, Scrap aluminum alloy with alumina, AlSi7Mg with spent alumina catalyst, Scrap aluminum alloy with spent alumina catalyst. It is identified that reinforcement particles mixed with the eutectic silicon phase in the matrix alloy and microstructures exhibited an almost non-dendrite shape at the grain boundaries. Composite made from scrap aluminum alloy and alumina had the lowest porosity (7.3%), the least abrasive wear (0.11 mg), the highest hardness (58.5 BHN), and strong ultimate tensile strength (125 MPa) and ultimate compressive strength (312 MPa).

Fakhir Aziz Rasul Rozhbiany[22] investigated four types of reinforcements , two types of ceramics and one type of synthetic and also one type of waste vegetable which is wheat straw materials are used as reinforced metals—MA, NFC, MCA, and SA each added at a constant rate of 5 wt.% to Al 6063 alloy created using a modified mechanical stirrer with three blades and processed with a coated carbide tool insert. This study examined chip formation during turning at cutting speeds of 10 and 90 m/min observed chips varied in length and shape at higher speeds (90 m/min), keeping the chip volume ratio remained within standard limits. NFC increased chip length at 10 m/min, while MA shifted chip formation from discontinuous to continuous at 90 m/min. Surface roughness reduced with NFC at all speeds, followed by MCA.

ZAFARUDDIN KHAN [23] produced composites through liquid casting using industrial waste materials fly ash and bagasse ash by mixing them into an Eutectic AlSi alloy (LM6, which has 10.58% Si) . It is found that combination of 10 wt.% fly ash and 10 wt.% bagasse ash provides the best reinforcement for aluminum composites, making them suitable for use in lighter and stronger automotive components like engine blocks and pistons. It is also observed that as the percentage of both the ashes is increased obtained a relatively decreasing Tensile Strength.

Akbari M [24] worked on optimizing the mechanical and microstructural properties of aluminum composites (A 356) reinforced with SiC, TiC, ZrO2, and B4C particles using neural networks and a modified NSGA-II algorithm .Rotational speed, traverse speed, and types of reinforcing particles, are different friction stir processing (FSP) parameters were tested to fabricate the composites. TOPSIS method is used to select the optimal solution from the set of Pareto-optimal parameters.

Kumar [25] fabricated AA6061–TiC composites by reaction of alloy with potassium hexa fluorotitanate and graphite at 900°C and then hot forged at 500°C with a strain rate of 0.0115 mm/s and a 65% deformation degree. Both cast and forged composites were analyzed for grain size and TiC particle dispersion using microscopy. Forged composites had a uniform distribution of TiC particles, with no clumping and exhibited improved Brinell hardness and tensile strength with increase of TiC . Cast composites primarily failed due to interdendritic cracking, while forged composites showed a mixed fracture mode, with a dominant ductile behaviour and forged composites exhibited better mechanical properties than those of cast ones.

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Alipour, M [26] examined the microstructure and mechanical properties of Al–10Zn–3.5Mg–2.5Cu aluminum alloy composites reinforced with graphene nanoplates, produced through ball milling and stir casting. It is observed that Graphene nano platelets significantly enhance the composite's strength, tensile strength with the T6 heat treatment shows the best strength . optimal results obtained was 0.7 wt% graphene and T6 heat treatment for enhanced strength

Lakshmi Narayana, K. S [27] reviewed incorporation of graphite in the form of fibres or particulates into the aluminium matrix to improve wear resistance produced using stir casting method. In the review it is mentioned that weight percentage of graphite reinforcement in the AA7075 matrix from 5% to 20%, in increments of 5% the ultimate tensile strength of the composites decreased with increasing graphite content, decline in strength was attributed to the brittle nature of graphite, which tends to promote crack initiation and propagation at the metal-graphite interface. AA6351/Graphite (Gr) composites fabricated with varying graphite weight percentages from 0% to 12%, in increments of 4%, the ultimate tensile strength of the composites decreased as the graphite content increased. due to to poor interfacial bonding between the graphite particles and the aluminum matrix. Similarly LM25/Graphite composite by stir casting route varying wt. % of Graphite from 2.5 to 10 wt% noticed a decrease in the hardness of the fabricated composite with an increase in wt. % of Graphite, AA7075, Al 6061, AA6351, matrix phase observed decrease in the hardness of the fabricated composite with an increase in the wt. % of Graphite , and observed increase in wear loss beyond a certain wt % Graphite , decrease in coefficient of friction of fabricated composites, increase in wear rate for the composites fabricated at constant B4C reinforcement of 8 % wt in Al2219/B4C and increase in wear rate is due to increase in the applied load, sliding velocity and sliding distance.

Parikh, V. K et.al [28] fabricated aluminum alloy 2014-based metal matrix composites with silicon carbide particulates using friction stir processing involving involved two sets of processing parameters, 270 rpm rotational speed and 78 mm/min transverse speed & 190 rpm rotational speed and 50 mm/min transverse speed and noted composites processed at 270 rpm and 78 mm/min exhibited better grain refinement and enhanced micro hardness.

Soltani, S et.al [29] investigates the impact of stir casting parameters on the microstructure and mechanical properties of aluminum matrix composites reinforced with micron-sized SiC particles with stirring temperatures 680°C and 850°C and stirring time done for 2 or 6 minutes and found Shorter stirring period of 2 minutes were sufficient for proper ceramic incorporation and achieving good metal-ceramic bonding and higher casting temperatures (850°C) enhanced ceramic incorporation and concluded stirring parameters significantly affect the microstructure, porosity and Al_4C_3 formation impacting the overall quality and performance of the composites.

V. Mohanavel, K.S et.al [30] developed AA6351 matrix composites using silicon nitride (Si_3N_4) particles as reinforcement varying weight fractions (0%, 1%, 2%, and 3%) using the stir casting method. Hardness, Compression and Tensile Strength increased with higher Si_3N_4 content & wear rate decreases from 0 to 3% Si_3N_4 reinforcement, showing improved wear resistance making suitable for demanding applications.

Hashim Hanizam et.al [31] optimized mechanical properties like hardness and ultimate tensile strngth by Taguchi analysis of A356 aluminium alloy composite reinforced with multiwalled carbon nanotube identifying the optimal mechanical stir casting parameters. This method used two factorial levels considering the response variables as hardness and ultimate tensile strength. The best hardness and UTS were achieved with 0.5 wt.% MWCNT, 0.5 wt.% Mg, and 10 minutes of mechanical stirring & optimal hardness and UTS values were 106.4 HV and 277.0 MPa, respectively resulting in improvements of 76.3% in hardness and 108.4% in UTS compared to the as-cast A356 alloy.

Alizadeh, A et.al [32] investigated comparison of combined stir casting and squeeze casting in mechanical properties and wear behavior of Al5083 matrix composites reinforced with SiC particles at weight percentages of 20%, 25%, and 30%. Combined casting method reduced porosity from 2.32% to 1.29% in composites with 30 wt% SiC & brinells hardness number increased to 85 BHN, enhancement of compression strength to 350 MPa, and **i**mproved wear Resistance by the reduction in wear debris size.

3.Reported works on Aluminium alloy metal matrix composites with hybrid reinforcement.

N. Ramadoss et.al [33] synthesized hybrid composites of Al7075 reinforced with Boron Carbide (B4C) and Boron Nitride (BN) with different weight percentages of B4C (3%, 6%, and 9%), keeping BN constant at 3% (as BN acts like lubricant) for marine & automotive applications . The formation of interfacial compounds such as Al_3BC, AlB_{12}, and AlN was observed in XRD analysis thus improving the hardness and improvement in tensile & compression of the hybrid composites by 22% compared to the base alloys due to the reinforced particle exited in nucleation which inhibits the grain boundary movement . The suspend dislocations moving continuously throughout the matrix has resulted in decrease in grain size. This inhibits the dislocation motion to accumulate the strengthening effect of these synthesized hybrid composites.

Amrendra Pratap Singh et.al[34] examined the hybrid composite of AA2024 reinforced with Al_2O_3, ZrO_2, and Graphite (Gr) fabricated by stir casting method. Hybrid composite of AA2024 with Al_2O_3, ZrO_2, and Graphite exhibits significant improvements in hardness and tensile strength. Weight fraction of reinforcement and well bonded particulates in metal matrix increases the constraint to the plastic deformation increasing the dislocation density & hardness of hybrid metal matrix composites. Al2O3/ZrO2 reinforcement strongly bonded to AA2024 matrix is responsible for the increase in dislocation density near the matrix reinforcement interface and grain strengthening effect.

Shivalingaiah, K et.al [35] reinforced aluminum matrix composites with advanced materials such as multiwall carbon nanotubes and graphene. Graphene Reinforcement has the most significant effect on hardness and wear resistance. This work incorporates Taguchi L16 matrix, analyzing four variables percent reinforcement of graphene, die temperature, melt temperature, stir speed to enhance mechanical properties . The optimal condition determined viz. the Taguchi-CRITIC-MOORA method ensures a dense microstructure with minimal pores.

D. Joslin Vijaya et.al [36] focussed on understanding the enhancements in strength, hardness, and interfacial bonding through various reinforcements and fabrication methods. AA7075 finds suitable for their high strength and suitability for both low and high-temperature applications. Titanium reinforcement enhances mechanical strength, ductility, and tribological properties and can be used for high temperature applications because of high creep and fatigue resistance & better corrosion resistance, making it suitable for naval and military applications. Niobium improves formability, weldability, and overall mechanical behavior. Graphene and Carbon Nanotubes reinforcement results in a denser microstructure with minimal pores, enhancing mechanical properties. It is concluded that nano reinforcements have a more significant impact compared to micro-reinforcements due to mechanisms like the Hall-Petch effect and Orowan strengthening.

Abebe Emiru, A et.al [37] experimented characterization of Al6061 alloy reinforced with molybdenum disulfide (MoS2), silicon carbide (SiC), and boron carbide (B4C) with weight Percentages for each reinforcement varying 3%, 6%, 9%, and 12% . Highest density was observed in the hybrid composite Al6061/12% SiC/4% MoS2, maximum hardness recorded was 114.03 HV for the Al6061/12% B4C/4% MoS2 composite, highest UTS achieved in Al6061/12% B4C/4% MoS2 composite. Double- and triple-reinforced composites exhibited less wear loss compared to non-reinforced specimens. The improved wear resistance is attributed to the presence of MoS2 as a solid lubricant and the formation of a protective B2O3 layer at the contact zone.

Song-Jeng Huang et.al [38] investigates the fabrication and characterization of AZ61 magnesium alloys reinforced with low weight fractions of Al2O3 (2 wt%) and SiC nanoparticle (0.5, 1.0, and 1.5 wt%) hybrid composites using the gravitating mechanical stir casting (GMSC) method. Micro structural observation of AZ61 alloy consists of α-Mg grains with β-Mg17Al12 intermetallic phases distributed at the grain boundaries and addition of Al2O3 and SiC reinforcements leads to β-Mg17Al12 phases transition from a round to a needle-like shape and highest hardness, tensile & compression strength is observed in 1 wt% SiC in the AZ61+2 wt% Al2O3.

Jayaprakash, D et.al [39] investigated using double stir-casting approach by varying weight fractions of SiC (2%, 4%, and 6% wt %) & constant amount of Graphene (Gr) particulate (2 %) affecting the mechanical, physical, and micro structural properties of LM25 aluminium matrix composites . Highest hardness, tensile strength, and yield stress were obtained with the LM25/4% SiC/2% Gr hybrid composite and double stir-casting approach, combined with preheating of the reinforcements, effectively improves the distribution and bonding of SiC and Gr in the aluminum matrix.

K S Madhu et.al [40] fabricated Al-7029 aluminum alloy reinforced with boron carbide (at weight fractions: 2%, 4%, 6%, and 8%) and graphite (2% constant) using conventional stir casting. The tensile strength, hardness & compression strength are found to be increased with decrease of % elongation with respect to increase of B4C reinforcement percentage attributed to the strengthening effect of B4C particles.

T.G. Gangadhar et.al [41] fabricated Al7050 aluminum alloy hybrid composites reinforced with zirconium dioxide (4 wt% constant) and fly ash particles with varying weight fractions (3 wt%, 5 wt%, 7 wt%) using stir casting. In this study effects of varying fly ash content and stirring speeds on mechanical performance were assessed. Al7050-based hybrid composites with 7 wt% fly ash and 4 wt% ZrO_2, stirred at 250 rpm, exhibited significant improvements in tensile strength, hardness, and impact strength & Uniform distribution of reinforcement particles and their interaction with the matrix alloy contribute to the enhanced mechanical properties and improved fracture toughness.

Ali et.al [42] explored the mechanical properties of AA6061 aluminum composites reinforced with Titanium diboride (6,8,10,12) and Silicon carbide (wt % 3,5,7 ,9), then composites were joined using friction stir welding with a cylindrical pin tool which yields considerably strong and ductile joints for aluminum matrix composites. Microscopic Examination of different weld zones,heat affected zone, thermo-mechanically affected zone, and stir zone revealed the grain size and distribution of the ceramic particles & also reveal narrow HAZ. Also, the stir zone consists of onion ring pattern **&** the ultimate tensile strength of the welded samples increased with higher TiB2 content, the maximum hardness achieved was 135.56 HV for AA6061/ 3 wt.% SiC/ 12 wt.% TiB2, the percentage elongation improved by 2.5%, enhancing the ductility of the weld specimens. This investigation concludes friction stir welding as the most appropriate choice for joining aluminum metal matrix composites with TiB2 and other ceramic reinforcements.

Kianoosh Rashnoo et.al[43] researched the effects of nano-clay reinforcement and heat treatment on the microstructure, mechanical properties, and fracture behavior of cylinder-head aluminum alloys prepared using gravity and stir casting methods. Tensile tests were conducted on standard samples at different displacement rates of (0.1, 1, and 10 mm/min). Fracture surfaces showed brittle behavior with cleavage and quasi-cleavage marks. SEM images revealed that reinforcement reduced the number and length of micro-cracks. Higher displacement rates also decreased micro-crack length due to lower ductility.

J.J. Jayakanth et.al [44] used squeeze casting method & evaluates the wear properties and friction characteristics of aluminum hybrid composites strengthened with SiC (2, 4, 6 wt %) and WC particles (wt % 2 constant). Pin-on-disk tests assessed wear properties and coefficient of friction under dry sliding conditions, with constant sliding distance but varying load and speed. The friction coefficients of SiC and WC particulates are in ranges between 0.14 and 0.47 for the applied loads of 10, 20 and 30 N, respectively. The wear loss analysis of synthesised aluminium hybrid composites has been significantly reduced to a maximum of 23.26% compared with monolithic materials.

Jatinder Kumar et.al [45] improved the properties of cast aluminum-silicon alloys used in automotive components by reinforcing them with silicon carbide (constant 10 wt %) and chromium (0–3 wt%, in 1.5% increments) using vortex casting. EDS images showed Cr3C2 compounds formed in the composites which significantly affected the hardness . Reinforcing aluminum-silicon alloys with SiC and chromium enhances density, mechanical properties and wear resistance, making them more suitable for various demanding automotive applications. The inclusion of 10 wt.% of SiC shows an improvement of 33.07% in wear-resistance, with a small reduction in the frictional coefficient & increment of chromium particulates with 10% SiC further increases the wear resistance. The scratch test result shows that traction force follows a proportional trend with respect to the reinforcement contents along with modest improvement in the apparent coefficient of abrasive friction.

R.S. Harish et.al[46] explored the mechanical properties of hybrid composites made from Al7075 alloy reinforced with aluminum oxide (3–12%) particles and E-glass fibers (2–8%). The uniform distribution of reinforcements in the Al7075 matrix due to maintaining optimum stirring speed and time as 400 rpm and 10 min,it also resulted to a 100 % improvement in both tensile strength and hardness of the hybrid composite as the stirring speed is increased from 300 rpm to 400 rpm over a 10-minute. Tensile strength, yield strength, and hardness improved with up to 9% Al_2O_3 and 6% E-glass. Beyond these percentages, the properties slightly decreased. The density of the composites increased with higher reinforcement content.

4. Conclusions.

This review article is mainly focused on the mechanical characterization of the different ceramic particulates (SiC, B4C and Al2O3) reinforced AMMCs. Mechanical properties of Aluminium matrix composites are dependent on the type of reinforcement and casting technique adopted for fabrication. Hybrid aluminium metal matrix composites consists of an aluminium metal matrix and two or more ceramic or non-conventional reinforcements like silicon carbide, boron carbide, fly ash , alumina etc. Stir casting, process parameters like stirring rate, stirring temperature, pouring temperature etc., are to be maintained for achieving better properties of Aluminium metal matrix composites. Addition of reinforcements like graphite, zirconia ,Silicon carbide, Boron carbide fly ash etc has shown an increase in the properties of the material.

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