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REVIEW ON HYBRID ALUMINIUM METAL MATRIX COMPOSITES

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Abstract*— *Now a day's single reinforced composites are replaced by hybrid composite due to tailorable properties. Aluminium alloys are generally used in aerospace and automobile industries due to their better properties such as high stiffness and specific strength, good corrosion and wear resistance, low coefficient of thermal expansion etc. The purpose of present study is to provide detail review on mechanical and tribological performance of hybrid aluminium matrix composites fabricated with different combination of reinforcement filler. The different methods of fabrication for these composites are also reviewed. It is concluded form most of the research papers that mechanical and tribological properties of composites are enhanced with different combination of reinforcement and increase in percentage addition of reinforcement.

Keywords—Hybrid aluminium matrix composites; Microstructural studies; Mechanical properties; SEM; Stir casting ; dry sliding wear

I. INTRODUCTION

Hybrid composites are those materials in which two or more different kinds of reinforcements are used in a single matrix. The hybrid composites have better properties than composite materials containing only a single kind of reinforcement. The reinforcement materials used in composites may be in the form of particles, whiskers, continuous and discontinuous fibres. [1-3]

Many studies have been done on development of hybrid metal matrix composite with commercially available aluminium alloys. Commercial aluminium alloys were generally used for metal matrix composites because aluminium is light weight, high strength and ductile material.

Manufacturing methodology used for hybrid aluminium matrix composites is classified as liquid phase processing and solid phase processing. Powder metallurgy is the mostly used solid phase method to fabricate composites. It gives uniform distribution of reinforcements among the matrix material. In liquid phase processing stir casting method is widely used for manufacturing composites. Stir casting is an economical method as compare to other process. Spray casting, squeeze casting, Compo-casting and friction stir processing etc. are the other liquid phase processing fabrication method but these methods are not commonly used.

II. REVIEW LITERATURE

The aim of this paper is to review the reinforcements effect on mechanical and tribological properties and the effect of the fabrication method on distribution particle on hybrid Al matrix composites, as experienced by various researchers.

A. Reinforcements Effect on Mechanical Characteristics Of Hybrid Aluminium Alloy Metal Matrix Composites

Poovazhagan et al. [4] investigated mechanical properties of Hybrid Aluminium Alloy (Al 6061) Composites Reinforced with SiC and B_4C Nano-particles, fabricated by high intensity ultrasonic cavitation. Experiment like Field emission SEM, Energy Dispersive Spectroscopy (EDS) analysis, Birnell's hardness test, Charpy impact test and tension test are performed to find out Brinell hardness values, stress strain diagram, impact energy process. It is observed that properties such as tensile strength, hardness, ductility and impact strength significantly improve by addition of small amount of Nano-particles in composites.

Pawar and Utpat [5] developed Aluminium alloy (Al6061) based metal matrix composite for Spur Gear. Silicon carbide was used as reinforcement particles. Microstructure Test, Hardness Test (Brinell hardness test) and Spur Gear Design Calculation were done on fabricated composites. The researcher suggested that these composites can be used as gears material.

Keshavamurthy et al. [6] investigated Mechanical and Microstructural characteristics of Al7075 alloy composite reinforced with TiB_2. The Microstructure analysis, tensile test, grain size studies and micro hardness test were performed. Experimental results showed that Al7075-TiB_2 composite have higher yield and tensile strength and lower ductility as compared to the unreinforced alloy.

Alanemea and Ajayi [7] investigated the mechanical and microstructural characteristics of Zn–27Al based hybrid composites. The hybrid composites are prepared by stir casting method with different percentage of silicon carbide (SiC), rice husk ash (RHA) and graphite particles. The fabricated hybrid composites were characterized by microstructure analysis and mechanical testing such as fracture toughness, tensile and Hardness test. The microstructure analysis of composites indicated fine distribution of the reinforcements particles on Zn–27Al alloy matrix. The results also showed that fracture toughness increased with increase in weight percent of RHA while hardness and tensile strength decreased of the composites.

Mohanavela et al. [8] studied the mechanical and microstructure behaviour of hybrid Aluminium Alloy 6351 aluminium alloy composites. The composites were reinforced with Graphite and Al_2O_3 particles and prepared by stir casting method. In this study tensile strength, flexural strength microhardness and macro hardness were measured. The optical microscope was used to observe particle distribution of the fabricated composites; it showed almost homogeneous dispersal of the reinforcements in the base alloy. The result indicated hardness, tensile strength and flexural strength were increased in the AA6351 base metal alloy with the increase in reinforcements. The dispersion of Al_2O_3/Gr particles were considerably improve mechanical properties of the A6351 composite.

Shalaby et al. [9] fabricated A359 composites with varying weight percentage of Silicon carbide and silicon nitride particles through stir casting and squeeze casting methods. Combined stir casting and squeeze casting methods reduce residual porosity and agglomerations of particles in composite. Microstructure analysis, X-ray diffraction analysis, compression test were performed to study the physical and mechanical behaviour of fabricated hybrid composite. Microstructure analysis showed uniform distribution of reinforcements within alloy matrix. Results also showed that higher values of Compressive strength in produced hybrid composites as compare to A359 matrix Alloy.

Gladston et al.[10] studied AA6061 aluminium alloy reinforced with various amounts of RHA particles, produced by compo casting technique. The produced composites were described by using SEM and X-ray diffraction test. The SEM analysis showed a uniform distribution of RHA particles on base metal matrix alloy. Micro hardness and ultimate tensile strength were also performed. The results showed that reinforcement of RHA particles in aluminium metal matrix increased the ultimate tensile strength and micro hardness of the composites.

Kumar and Kiran[11] investigated mechanical and Microstructural characteristics of aluminium 6063 matrix composites. The composites was prepared by stir casting and reinforced with titanium carbide. Density, tensile, impact and hardness, tests were performed for mechanical characterization of composites. X-ray diffraction techniques and Scanning electron microscopy were used to study the phase identification and fracture mechanism. Result showed that with the addition of titanium carbide increased in density, tensile strength and hardness of composites to 7.8%, 19.55 and 20% respectively while decrease in the elongation and impact strength of composites to 35% and 31% respectively.

Ghasali etal. [12] Studied mechanical properties of hybrid composites made of pure and 1056aluminum powders as matrix material and reinforced with 15 wt% SiC- 7 wt% TiC. The composites were produced through powder metallurgy method. Relative density, bending strength and micro hardness were investigated. Scanning electron micrograph showed homogenous distribution of reinforcements particle with in composites The results showed that microstructure and mechanical properties of composites fabricated by 1056 aluminium better compared to pure aluminium matrix composites.

B. Effect of Filler Content on Tribological Characteristics of Hybrid Aluminium Metal Matrix Composites

Kumar and Xavior[13] fabricated Al 2024 based hybrid composites reinforced with SiC and Graphene particles to study the effect of Graphene on wear and coefficient of friction on hybrid composites. The composites were fabricated by powder metallurgy route. Density flexural strength Hardness, and X-ray diffraction tests were performed on the hybrid composites. It was observed that reduction in the wear resistance and friction coefficient values in hybrid composite as compared to pure alloys. Also, results showed that there is a decrease in wear losses, surface roughness and coefficient of friction in hybrid composite.

Prasad and Shoba[14] studied the tribological behavior of A356 matrix hybrid composites with reinforcement of rice husk ash (RHA) and SiC particle. The composites were fabricated by vortex method containing 2, 4, 6, and 8 weight percentage RHA and SiC (in equal proportions).Pin-on disk wear test were performed and SEM was done to analyse the wear behaviour of the hybrid composites. The results showed that wear resistance increased in hybrid composites.

Ambigai and Prabhu[15] investigated tribological behavior of LM6 alloy composite reinforced with graphite (Gr) and Si_3N_4 nanoparticles. The gravity die acting method was used to fabricate Al−Gr nano composite, Al−Si_3N_4 nano composite and Al−Gr−Si_3N_4 hybrid composite. The wear characteristics such as coefficient of friction and wear rate were found under dry sliding conditions. The results indicated that the coefficient of friction wear rate and decreased in hybrid composite as compare to Al−Si_3N_4 nano composite. Also F-test and Analysis of variance (ANOVA) were applied to determine the significant parameters affecting the wear rates.

Anitha and Balraj[16] investigated the dry sliding wear behaviour of Al7075 hybrid composites. The Composites were prepared by stir casting method with different weight fraction of Al_2O_3 and graphite particles. Wear test was done on a pin-on-disc tribometer. SEM was done to ensure Uniform distribution of reinforcing particles. Coefficient of friction and wear rate were evaluated with various parameters such as applied load and sliding distance. The wear test data was analysed by analysis of variance. The wear test results showed that wear rate main influenced by Al_2O_3% and applied load While, applied load and percentage of graphite particles influenced the friction coefficient.

Carvalho et al. [17] investigated the tribological properties of AlSi aluminium alloy hybrid composite reinforced with 2wt% CNTs–5wt% SiC particles. Also compared wear behaviour of the unreinforced AlSi alloy, AlSi–2%wtCNTs andAlSi–5wt%SiC particles composite. Powder metallurgy method was used for fabrication of the AlSi alloy

composites. Wear tests were done on Dry reciprocating pin-on-plate machine. The results indicated enhance wear behaviour of all fabricated composites and AlSi hybrid composite had the best wear characteristics because combine effects of both reinforcements. SEM and EDS analysis was done to characterize the wear properties of hybrid composite. Which indicate that wear of hybrid composite is characterised by adhesive wear and abrasive wear.

Umanath et al. [18] studied wear properties of Al6061-T6 reinforced with discontinuous Al_2O_3 and SiC and hybrid composite. The wear test was performed by using a pin on disc wear tester. The effect of reinforcement volume fraction, counter-face hardness rotational speed and applied load on wear is analysed in detail. Analysis of variance (ANOVA) and statistical regression analysis were done to study the effect of various parameters on wear rate. The results showed that 15% hybrid composite has wear resistance better than that of the 5% composite.

Naplocha and Granat[19] studied wear properties of Aluminium alloy composites reinforced with different weight percentage of Al_2O_3 (Saffil) fibres and graphite (flakes and fibres), prepared by the squeeze casting method. The effects of the reinforcement volume fraction, form of graphite and applied load on dry sliding wear were observed using reciprocating movement. The results showed wear losses decreased with addition of alumina fibre while graphite addition increased wear loss. The results also indicated that Graphite fibres prevented the hybrid composite from wear better than graphite flakes.

Monikandan et al. [20] investigated mechanical and tribological properties of Al6061-10 wt. % B_4C–MoS_2 hybrid composites prepared by stir casting technique with self-lubricating characteristics. Microstructural analysis, hardness test, facture toughness test and wear rest were performed. The result showed uniform distribution of particles. Hardness and fracture toughness of the hybrid composites are decreased increase with reinforcement of MoS_2 particles. The Coefficient of friction and wear rate of the composites decreased with reinforcement of MoS_2 particles.

Elango et al. [21] studied wear properties of aluminium alloy LM25 filled with SiC and TiO_2 particles and manufactured by stir casting method. Dry sliding wear test was done on a pin on disk wear tester. The experiments were performed at a constant sliding distance and sliding velocity over a various loads for SiC 7.5% and 2.5% & 5% TiO_2. The results indicated that the wear rate reduced in hybrid composites. It was also indicated that increase in sliding distance and load the wear of the test specimen increased while decreased in coefficient of friction. Wear mechanism of worn surfaces were studied by Scanning Electron Microscope.

Hariprasad et al.[22] investigated wear behaviour of Al 5083 hybrid composites fabricated by stir casting process dispersed with four varying weight percentages of B_4C (0%, 3%, 5%,and 7%) and fix weight percentage of Al_2O_3. Dry wear test done on pin-on-disc testing machine to evaluate wear rate and wear loss with the different load. The Scanning Electron Microscope (SEM) was done to analyse worn surface. The SEM analysis showed light adhesive wear of worn surface. The result also showed that the increasing weight percentage of Al_2O_3 and B_4C improve wear resistance.

Kumar et al. [23] studied mechanical properties and wear characteristics of Al 6061 composites reinforced with Fly ash Magnesium 4%, and Graphite 4%, Magnesium 4%. Tensile Test, Hardness test (Vickers Hardness Tester), wear Test are performed to find out tensile strength, hardness, Specific Wear Rate. The results showed that graphite addition cause decrease in tensile strength, hardness and Specific wear rate. While addition of fly ash increased tensile strength and decreased Specific wear rate. Maximum tensile strength was observed in composite filled with 15% Fly ash, 4% Magnesium and maximum hardness were observed in composite of 20% Fly ash, 4% Magnesium.

Zhua and Hong Yan [24] investigated wear properties of an A356/fly-ash-mullite interpenetrating composites (IPC) fabricated by a three-stage schedule squeeze casting method. Wear test done by pin-on-disc tribometer. The composite have higher wear resistance and friction coefficient as compared to the base A356 alloy. The IPC has been suggested for brake material.

Kumar et al. [25] investigated physical, mechanical properties and wear behaviour of Al-7075 composites filled with nickel powder. The composites were prepared by stir casting method with four different percentage of nickel powder. Experiments are performed to assess void content, impact strength, compressive strength, Vickers hardness and sliding wear resistance of fabricated composites. The results showed that void content, impact strength, compressive strength and Vickers hardness of composites were increased with the increase in percentage nickel reinforcement, while flexural strength of the composites decreased with addition reinforcement. Also SEM was used to understand the wear mechanism of the composites. The author suggested application of these composites in gear material.

Uthayakumar et al.[26] investigated dry sliding wear behaviour of 1100 aluminium alloy hybrid composite reinforced with 5% SiC and 5% B_4C fabricated by stir casting method. Friction and wear performance of the hybrid composites were measured by using pin on disc tribometer at different load and sliding velocities. Scanning Electron Microscopy (SEM) with Energy Dispersive X-ray, studies were performed to find microstructure and deformation of composites. Results showed that the hybrid composites hold the wear resistance properties up to 60 N and wear rate and coefficient of friction were decreased with increase in sliding speed.

Shirazi et al. [27] fabricated Al 6061based hybrid nano-composites reinforced with graphite and SiC nano-particles to investigate the solid-particle erosion wear and dry sliding wear behaviour. The composites were fabricated by powder metallurgy method containing 0, 2, 5 and 7 % of volume of micro Graphite particles and fixed 2vol% of SiC nano-particles. The results showed that reduce hardness of nano composite with increase in percentage of graphite particle. The hybrid composite as Compared with Al/2SiC showed lower friction coefficient and higher wear resistance. SEM was done to study worn surfaces (dry wear).the SEM result indicated that adhesive wear accrued in Al/2SiC nano-composite while the Al/2SiC/Gr hybrid nano-composites showed abrasive wear.

III. CONCLUSIONS AND FUTURE SCOPE

Based on the literature survey of the published work on aluminium metal matrix hybrid composite the following interferences are drawn.

- Al is one of the most excellent choices available for matrix, because of its better mechanical property, with high corrosion resistance, high toughness and also low density. Al is also not expensive compared to other light elements. Thus, the use of aluminum based MMCs increased in the area where, advanced structural applications, good wear resistance at elevated temperature, and enhanced mechanical properties are significant.
- Various reinforcements like silicon carbide, Alumina, graphite, boron carbide, RHA, fly ash, silicon nitride, titanium carbide, titanium oxide etc. used in MMCs.
- SiC particle is easily available, low density reinforcement. In recent year, AMMCs with SiC reinforcements used in aerospace, civil, military and manufacturing industries because of its high strength, modulus, fatigue resistance and wear resistance.
- Stir casting method is the mostly used and economical fabrication method for metal matrix composites.
- Various mechanical properties such as, impact strength, hardness and tensile strength, density, microstructure, were evaluated at various reinforcement with varying percentage and combination.
- Tribological properties such as wear resistance, friction coefficient and surface roughness were evaluated at varying load, sliding speed and sliding distance condition.

Some researcher applied Taguchi method to optimize friction coefficient and wear rate.

REFRENCES

[1] Wang DZ, Peng HX, Liu J, Wear behaviour and micro structural changes of SiCp-Al composite under unlubricated sliding friction, *Wear, vol. 184(2),*1995,pp187–192.

[2]W. D. Callister, Jr., *Materials Science and Engineering,* (2008), John Wiley & Sons, page 400-736.

[3]Karl Ulrich Kainer, *Basics of Metal Matrix Composites,* (2006), WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.

[4]Poovazhagan.L, Kalaichelvan.K, Rajadurai.A and Senthilvelan.V, Characterization of Hybrid Silicon Carbide and Boron Carbide Nanoparticles-Reinforced Aluminum Alloy Composites, *Procedia Engineering vol.64* (2013),pp. 681 – 689.

[5]P.B.Pawar and Abhay A. Utpat, Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite for Spur Gear, *Procedia Materials Science, vol. 6* (2014),pp. 1150 – 1156.

[6]R.Keshavamurthy, Sadananda Mageri, Ganesh Raj, B.Naveenkumar, Prashant M Kadakol and K.Vasu, Microstructure and Mechanical Properties of Al7075-TiB_2 in-situ composite, *Research Journal of Material Sciences Vol. 1(10),* November (2013),pp 6-10.

[7]Kenneth Kanayo Alanemea and Olusola Joseph Ajayi, Microstructure and mechanical behavior of stir-cast Zn–27Al based composites reinforced with rice husk ash, silicon carbide, and graphite, *Journal of King Saud University – Engineering Sciences,vol.29,* (2017),pp.172–177.

[8]Mohanavela, K.Rajanb, P.V.Senthilc, S.Aruld, Mechanical behaviour of hybrid composite (AA6351+Al_2O_3+Gr) fabricated by stir casting method, *Materials Today, Vol. 4,* Issue 2, Part A, (2017), pp. 3093-3101.

[9]Essam A.M.Shalaby, Alexander Yu. Churyumov N, Alexey N. Solonin, A.Lotfy, "Preparation and characterization of hybrid A359/ (SiC and Si_3N_4) composites synthesized by stir /squeeze casting techniques", *Materials Science & Engineering, vol.A674,*(2016),pp.18–24.

[10]J. AllwynKingslyGladston, N. Mohamed Sheriff, I. Dinaharan, J. David Raja Selvam, Production and characterization of rich husk ash particulate reinforced AA6061 aluminum alloy composites by compocasting, *Trans. Nonferrous Met. Soc. China, vol. 25,* (2015),pp. 683−691.

[11]K.Ravi Kumar, K. Kiran, V.S. Sreebalaji, Micro structural characteristics and mechanical behaviour of aluminium matrix composites reinforced with titanium carbide, *Journal of Alloys and Compounds, vol. 723,* (2017),pp. 795-801.

[12] Ehsan Ghasali, Rahim Yazdani-rad, Keivan Asadian, Touradj Ebadzadeh, Production of Al-SiC-TiC hybrid composites using pure and 1056 aluminum powders prepared through microwave and conventional heating methods, *Journal of Alloys and Compounds, vol. 690,* (2017),pp.512-518.

[13]Prashanthakumar and Anthony Xavior, Assessment of mechanical and tribological properties of Al 2024- SiC - graphene hybrid composites, *Procedia Engineering ,vol.174,* (2017), pp.992 – 999.

[14]Dora Siva Prasada and Chintada Shoba, Hybrid composites – A better choice for high wear resistant materials, *Journal of Material Research and Technology, vol.3(2),* (2014),pp.172–178.

[15]R. Ambigai and S. Prabhu, Optimization of friction and wear behaviour of Al−Si_3N_4nano composite and Al−Gr−Si_3N_4 hybrid composite under dry sliding conditions, *Trans. Nonferrous Met. Soc. China, vol.27,*(2017), pp. 986−997.

[16]P. Anitha and U. Shrinivas Balraj, Dry Sliding Wear Performance of Al/7075/Al_2O_3/Grp Hybrid Metal Matrix Composites, *Materials Today Proceedings, vol.4,* (2017), pp. 3033–3042.

[17]O.Carvalho, M.Buciumeanub, S.Madeira, D.Soares, F.S.Silva, G.Miranda, Dry sliding wear behavior of AlSi–CNTs SiC particle hybrid composites, *Tribology International, vol. 90,*(2015), pp.148–156.

[18]K. Umanath, K. Palanikumar, S.T. Selvama , Analysis of dry sliding wear behaviour of Al6061/SiC/Al_2O_3 hybrid metal matrix composites, *Composites: Part B 53,* (2013),pp.159–168.

[19]K. Naplocha ,and K. Granat, Dry sliding wear of Al/Saffil /C hybrid metal matrix composites, *Wear, vol.265,* (2008),pp.1734–1740.

[20]V.V. Monikandan, M.A. Joseph, P.K. Rajendrakumar, Dry sliding wear studies of aluminum matrix hybrid composites, *Resource-Efficient Technologies, vol. 2,* (2016) ,pp.S12–S24.

[21]G. Elangoa and B.K.Raghunath, Tribological Behavior of Hybrid (LM25Al + SiC+ TiO_2) Metal Matrix Composites, *Procedia Engineering,vol.64,* (2013),pp. 671 – 680.

[22]T.Hariprasad, K.Varatharajan, S.Ravi, Wear Characteristics of B_4C and Al_2O_3 Reinforced with Al 5083 Metal Matrix based Hybrid Composite, *Procedia Engineering,vol.97,* (2014),925 – 929.

[23]Vinay Kumar, Rahul Dev Gupta, N K Batra, Comparison of Mechanical Properties and effect of sliding velocity on wear properties of Al 6061, Mg 4%, Fly ash and Al 6061, Mg 4%, Graphite 4%, Fly ash Hybrid Metal matrix composite, *Procedia Materials Science, vol.6,* (2014),pp.1365 – 1375.

[24]Jianbin Zhua and Hong Yan, Fabrication of an A356/fly-ash-mullite interpenetrating composite and its wear properties, *Ceramics International, vol.43,*(2017), pp.12996-13003.

[25]Ashiwani Kumar, Amar Patnaik, I. K. Bhat, Investigation of nickel metal powder on tribological and mechanical properties of Al-7075 alloy composites for gear materials, *Powder Metallurgy, vol.60(5),* (2017), pp.1-13.

[26]M. Uthayakumar, S. Aravindan, K. Rajkumar, Wear performance of Al–SiC–B_4C hybrid composites under dry sliding conditions, *Materials and Design,vol.47,* (2013), pp. 456–464.

[27] S. Mosleh-Shirazi, F.Akhlaghi ,D.Y.Li, Effect of graphite content on the wear behavior of Al/SiC/Gr hybrid nano-composites respectively in the ambient environment and an acidic solution, *Tribology International, vol.103,* (2016), pp.620–628.