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Mechanical Properties of Aluminum Based Metal Matrix Composites – A Review

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Abstract—Metal matrix composites (MMC's) are a range of advanced materials got significant growth in various advanced industries like aerospace, automotive, nuclear, bioengineering. Aluminum metal matrix composites (AMMC's)are very important among other MMC's, because of its excellent material properties such as light weight, low cost, high strength to weight ratio, high wear resistance, etc. Different types of AMMC's can be produced and possess range of mechanical qualities based on the chemical structure of the aluminum-matrix. The fortification in AMMC's is in the arrangement of continuous /or discontinuous fibers, whisker, and particulate matter as alternative phase reliant on its usage. Mechanical properties in AMMC's are highly dependent on the adding several reinforcements namely fly ash, TiC, SiC, Al_2O_3, TiO_2, B_4C, etc. In the present paper, a review has been conducted to examine the mechanical quality of various AMMC's. effects of different reinforcements and its percentage has also been studied. The concluding remarks has been drawn from the study.

Keywords—Metal matrix composites, Aluminum metal matrix parts, Mechanical properties, Reinforcement material

I. INTRODUCTION

From the few times, material scientists and engineers have highlighted on manufacture of light weight and robust products for advanced applications[1]. Advanced industrial needs forced industrialists and investigators to change their attention from monolithic to composite parts[2]. A composite job is a grouping of more than chemically discrete constituents to form a tougher job by taking advantages of all the materials being formed to make the composite material [3]. The term composite generally states that the material structure is created of a discrete constituent distributed in a incessant phase matrix. Composite material has contained distinguishing characteristics which drawn from the properties of constituents used[4]. Composite materials are categorized into polymer matrix[5], metal-matrix and ceramics, based on its physical and /or chemical form of matrix phase used to manufacture [6].

Metal matrix composites (MMC's) are alloys which reinforced along with supplementary metal, ceramic from a one material. MMC's are produced by dissolving the reinforcements in the metal matrix. Reinforcements are very often used to enhance the mechanical qualities namely strength, stiffness, conductivity, wear, and corrosive resistance of the base metals being used. The materials like aluminum, silicon, copper, titanium, magnesium, nickel, etc., are used for production of MMC's. In MMC's, aluminum and related parts have paying consideration as base metal, due to its excellent properties. From the last decade, Al based alloys have attained significance progress in modern appliances[7] because of its enhanced mechanical characteristics, virtuous stability in higher temperature environments, [8][9].

Aluminum (AL) is one of the major constituents used for fabricating aluminum metal matrix composites (AMMC's)[10]. Aluminum helpful to forms percolating network between materials in matrix phase. Different categories of AMMC are displayed in Fig. 1 [11]. The quality of AMMC's in respect of mechanical properties (wear resistance, hardness, thermal conductivity, etc.) is highly depends on reinforced materials used during fabrication process [12]. The significant parameters related to reinforced materials which influence AMMC's are reinforcement type, mass, profile, volume portion, modulus of elasticity, inflexibility, and production method [13]. The reinforcement can be conducted by continuous / discontinuous process. AMMC's are developed by either discontinuous method is formed as isotropic form and by continuous course are anisotropic shape. The different reinforcing ingredients which used in the fabrication of AMCs may categorized into a). synthetic ceramic particulates, b). industrial wastes and c) agro-waste byproducts.

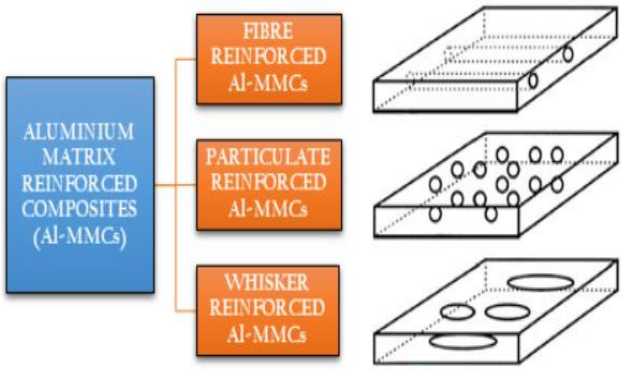

Fig.1 Various types of AMMC's

Silicon carbide (SiC), alumina (Al_2O_3), boron carbide (B_4C), tungsten carbide (WC), graphite (Gr), carbon nanotubes (CNT) and silica (SiO_2) are important synthetic ceramic particulates used to made AMMC's. Among the others SiC and Al_2O_3 are widely used particulates for manufacturing of AMMC's [14]. Industrial wastes like reinforcement fly ash (FA) and red mud, which generally produced from power plants, aluminum-based industries, are used as reinforcing materials for production of AMMC's. Agro waste derivatives like bamboo leaf ash, rice husk ash, bagasse ash, palm kernel shell ash, maize stalk ash, corn cob ash, etc. are also used as reinforcing materials for manufacturing of AMMC's.

Four types of processes (Fig. 2) [15] namely liquid state (LS), solid-state (SS) method, deposition method and in situ are widely used for manufacturing of AMMC materials. Among the other methods, LS and SS methods are very often used to create AMMC's. The liquid state procedures are stir casting, compo casting, squeeze casting, ultrasonic assisted casting, etc., and high energy consuming ball mill, friction stir method, diffusion bonding, etc., comes under solid state processes. The final quality of the AMMC materials produced by using liquid and solid-state processes highly depend on many interactive parameters. Different Applications of AMMC's are displayed in Fig. 3. The mechanical properties of the AMMC's plays important role in its usage for different industrial applications.

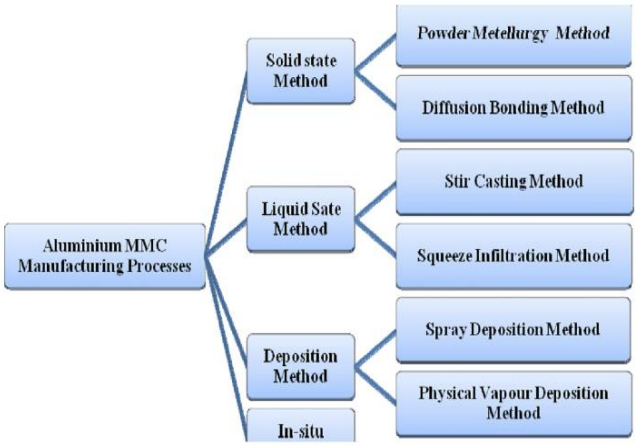

Fig. 2 AMMC's fabrication processes

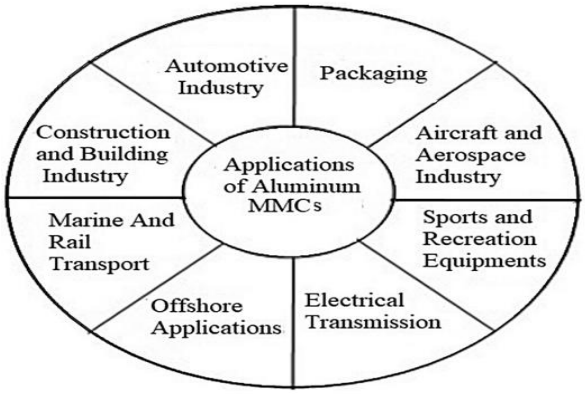

Fig. 3 Various Applications of AMMC's[16]

II. LITERATURE SURVEY

The literature survey is conducted to study the mechanical properties of AMMC's made by different manufacturing processes by varying processing parameters. The details of survey are given as follows:

In reference [8], researcherhad been fabricated the aluminum metal matrix composite materials using powder metallurgy process. He investigated the effects of volume of reinforcement quantifiable, SiC, on mechanical qualities of composite material. Researcher stated from his work that response parameters density, hardness and strength are increases and force ability was decreasing with increase of percentage of SiC. Reference [17], authors had been studied the influences of fabrication control parameters on spreading of particles in cast MMC's. Researchers were tried different operating settings (i. e. conditions) by varying the three levels of stirring speed (i. e. 500, 600 and 700 rpm) and stirring time (i. e. 5, 10 and 15 min). They found better distribution of SiC particles while increasing (i. e. higher) levels of operating parameters. They stated from their work that processing variables were highly affects the quality of the material produced. Researchers [13]had produced AA7075/TiC MMC materials by stir casting manufacturing methodology. Researchers were observed better hardness and UTS values when enhancing weight fraction of TiC particulates in both cast as well as heat treated situation. As in [18] researcher was also studied the effects of processing variables on quality characteristics of AMMC materials. They found desired responses like hardness, impact strength and normalized displacement with increase of composition of SiC particles. As in [19]f aluminum composite was abricatedby varying different fractions of SiC reinforcements. He studied the significance of percentage of SiC on mechanical properties of composite.

Again, researchers [20]had been studied mechanical qualities of AL alloy 2024 reinforced with SiC and fly ash hybrid MMC's. They identified from the study that tensile strength (TS), yield strength (YS) and hardness of the hybrid composites were boosted with expansion in area portion of reinforcement. In reference [21], investigatorhad produced the three sets of Al (Al6061) MMC's with reinforcement material were fly ash of particle sizes. They noticed from the study that quality parameters had been increased with increase of additives. In reference [22], authorshad been scrutinized the significance of percentage of silicon carbide on mechanical qualities of silicon carbide (SiC) reinforced AL composite. He mentioned that micro hardness of part was improved with enhancement in volume percentage of SiC. In reference [23], researchersinvestigated on mechanical qualities of AL hybrid composites which formed by double stir casting process. they considered different volume fractions of rice hush ash (RHA) and equal proportions of SiC particulates in reinforcement of aluminum hybrid composites. They found better mechanical properties: yield strength and UTS with increasing RHA volume faction and SiC content for aluminum hybrid composites.

In reference [24]authors had been examined the solidification characteristics of titanium carbide particulate reinforced AL alloy composites. Researchers made the composite material by considering the 11.8% silicon alloy (LM6) as matrix and the 5% and 15% weight fractions of TiCp in gravity casting process. They found from the study that solidification time decreased and observed finer grain size and better mechanical properties by adding TiCp as reinforcement to LM6 alloy. Reference [25]presented the fabrication process of SiC reinforced aluminum alloy using squeeze casting method. He studied the variations of mechanical properties with varying volume fractions of SiC reinforced particulates. Reference [26] focused to study the effects of percentage of silicon dioxide content in LM6 alloys. They found from their study that TS and Young's modulus values were declined with expansion of silicon dioxide percentage from 5% to 30%. Reference [27]was also focused tostudy and analyze the fabrication process of Al-4.5%Cu/10TiC composites by using in-situ method. They analyzed the mechanical qualities such as YS, UTS and hardness of the job. They were used TiC particles as reinforcement. Investigators had been found desired mechanical properties with addition of TiC particles in Al-4.5%Cu/10TiC part. Reference [28] was also focused to analyze the fabrication of aluminum alloy-boron carbide (AABC) composites using liquid metallurgy technique by varying different particulate weight fractions. they studied mechanical properties obtained on AABC's and identified that similar dispersal of the boron carbide (BC)

particles in the matrix phase were improved strength of material. Mechanical properties like hardiness and density were increased and decreased with increasing of BC amount especially in matrix phase.

III. CONCLUSIONS

In the present study, the importance of MMC's is discussed. The status of AMMC's is also briefed. The main applications of AMMC's for different applications are also given in the study. Obtaining the desired mechanical properties on AMMC's are important area of research. The literature survey made and discussed mechanical properties of different AMMC's are discussed with control parameters. The followings are the conclusions drawn from the study:

- AMMC's the advanced materials have got immense importance of various advanced applications.
- The quality characteristics of the AMMC's are highly depends on processing methodology, percentage of reinforcement, matrix material, properties of additives, etc.
- SiC is widely used reinforcement which increases the mechanical properties of tensile strength, hardness, density. wear resistance, etc., of aluminum and its alloys.
- Fly ash reinforcements are highly encouraged use for producing AMMC's because of its low cost and can ability to produce desired mechanical properties.
- Fly ash reinforcements can increase the wear resistance property, but it also decreases the corrosion resistance of AMMC
- SiC reinforced Al-MMC's have possess higher wear resistance than Al_2O3 reinforced MMC's
- Al_2O_3 reinforcements can produce good compressive strength and wear resistance for AMMC's
- B_4C presence in aluminum matrix can increase the hardness of AMMC's
- The addition of zircon can increase wear resistance.

REFERENCES

[1] R. Rudrapati, N. Kumar, and P. K. Pal, "Application of Taguchi method for parametric optimization of through transmission laser welding of acrylic plastics," in *AIP Conference Proceedings*, Jan. 2019, vol. 2057, no. January, p. 020013, doi: 10.1063/1.5085584.

[2] K. Soorya Prakash, P. M. Gopal, and S. Karthik, "Multi-objective optimization using Taguchi based grey relational analysis in turning of Rock dust reinforced Aluminum MMC," *Meas. J. Int. Meas. Confed.*, vol. 157, p. 107664, 2020, doi: 10.1016/j.measurement.2020.107664.

[3] S. Wakeel and A. A. Khan, "REVIEW ARTICLE A REVIEW ON THE MECHANICAL PROPERTIES OF ALUMINIUM BASED METAL MATRIX," *Int. J. Innov. Sci. Res.*, vol. 6, no. 11, pp. 1096–1100, 2017.

[4] S. Madhan Kumar, E. Govindaraj, S. S. Sai Girish, C. Yaswanth, and G. Sai Bharath, "Fabrication and characterization of aluminum metal matrix composite reinforced with graphite," *Mater. Today Proc.*, no. xxxx, 2021, doi: 10.1016/j.matpr.2020.12.237.

[5] J. O. Rudrapati, Ramesh, pradip kumar pal, "On the Relationship Between Laser Welding Process Variables in Through-transmission Laser Welding (TTLW) of Polycarbonate Plastics," *Lasers Eng.*, vol. 44, no. 1–3, pp. 51–65, 2019, [Online]. Available: https://web.a.ebscohost.com/abstract?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=08981507&AN=138079105&h=F%2FiGu1zMSC9zDDW5nemTJ2sQao4qkQ9ChQui5XKnmYcNlJ8zWfxBBpiL22TkBCKxVObMH%2FeyNwjC3ozwyu%2Fbbw%3D%3D&crl=c&resultNs=AdminWebAuth&resultLo.

[6] G. B. V. Kumar, C. S. P. Rao, and N. Selvaraj, "Mechanical and Tribological Behavior of Particulate Reinforced Aluminum Metal Matrix Composites – a review," *J. Miner. Mater. Charact. Eng.*, vol. 10, no. 01, pp. 59–91, 2011, doi: 10.4236/jmmce.2011.101005.

[7] R. Rudrapati, P. Sahoo, and A. Bandyopadhyay, "Optimization of process parameters in CNC turning of aluminium alloy using hybrid RSM cum TLBO approach," in *IOP Conference Series: Materials Science and Engineering*, Sep. 2016, vol. 149, no. 1, p. 012039, doi: 10.1088/1757-899X/149/1/012039.

[8] S. Das, R. Behera, A. Datta, G. Majumdar, B. Oraon, and G. Sutradhar, "Experimental Investigation on the Effect of Reinforcement Particles on the Forgeability and the Mechanical Properties of Aluminum Metal Matrix Composites," *Mater. Sci. Appl.*, vol. 01, no. 05, pp. 310–316, 2010, doi: 10.4236/msa.2010.15045.

[9] A. Macke, B. F. Schultz, and P. Rohatgi, "Metal matrix: Composites offer the automotive industry an opportunity to reduce vehicle weight, improve performance," *Adv. Mater. Process.*, vol. 170, no. 3, pp. 19–23, 2012.

[10] P. P. Rao, "Enhancement in mechanical properties of ceramic reinforced aluminum MMC via stir casting methodology : A review Enhancement L n Mechanical Properties R f Ceramic Reinforced Aluminum M 0 & Y ia Stir Casting Methodology : A Review," *AIP Conf. Proc.*, vol. 050022, no. February, 2021.

[11] C. Bulei, M. P. Todor, I. Kiss, and V. Alexa, "Aluminium matrix composites: Processing of matrix from re-melted

aluminium wastes in micro-melting station," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 477, no. 1, 2019, doi: 10.1088/1757-899X/477/1/012049.

[12] G. B. V. Kumar, C. S. P. Rao, N. Selvaraj, and M. S. Bhagyashekar, "Studies on Al6061-SiC and Al7075-Al₂O₃ Metal Matrix Composites," *J. Miner. Mater. Charact. Eng.*, vol. 09, no. 01, pp. 43–55, 2010, doi: 10.4236/jmmce.2010.91004.

[13] V. R. Rao, N. Ramanaiah, and M. M. M. Sarcar, "Fabrication and investigation on properties of TiC reinforced Al7075 metal matrix composites," *Appl. Mech. Mater.*, vol. 592–594, pp. 349–353, 2014, doi: 10.4028/www.scientific.net/AMM.592-594.349.

[14] K. Manigandan, T. S. Srivatsan, Z. Ren, and J. Zhao, "Influence of reinforcement content on tensile response and fracture behavior of an aluminum alloy metal matrix composite," *Adv. Compos. Aerospace, Mar. L. Appl. II*, vol. 2013, no. July, pp. 103–119, 2016, doi: 10.1007/978-3-319-48141-8_8.

[15] S. Senthil, M. Raguraman, and D. Thamarai Manalan, "Manufacturing processes & recent applications of aluminium metal matrix composite materials: A review," *Mater. Today Proc.*, no. xxxx, 2020, doi: 10.1016/j.matpr.2020.08.792.

[16] A. K. Sharma, R. Bhandari, A. Aherwar, and R. Rimašauskiene, "Matrix materials used in composites: A comprehensive study," *Mater. Today Proc.*, vol. 21, pp. 1559–1562, 2020, doi: 10.1016/j.matpr.2019.11.086.

[17] S. B. Prabu, L. Karunamoorthy, S. Kathiresan, and B. Mohan, "Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite," *J. Mater. Process. Technol.*, vol. 171, no. 2, pp. 268–273, 2006, doi: 10.1016/j.jmatprotec.2005.06.071.

[18] R. S. Fono-Tamo and J. Tien-Chien, "Effect of reinforcememt particles preheating on mechanical and microstructural properties of AMC," *Acta Metall. Slovaca*, vol. 24, no. 4, pp. 337–346, 2018, doi: 10.12776/ams.v24i4.1136.

[19] R. Purohit, R. S. Rana, and C. S. Verma, "FABRICATION OF Al-SiC p COMPOSITES THROUGH POWDER Metallurgy Process and Testing Of Properties," vol. 2, no. 3, pp. 420–437, 2012.

[20] M. Mahendra Boopathi, K. P. Arulshri, and N. Iyandurai, "Evaluation of mechanical properties of Aluminium alloy 2024 reinforced with silicon carbide and fly ash hybrid metal matrix composites," *Am. J. Appl. Sci.*, vol. 10, no. 3, pp. 219–229, 2013, doi: 10.3844/ajassp.2013.219.229.

[21] H. C. Anilkumar, H. Hebbar, and K. S. Ravishankar, "Mechanical properties of fly ash reinforced aluminium alloy (Al6061) composites," *Int. J. Mech. Mater. Eng.*, vol. 6, 2011.

[22] A. V. Muley, S. Aravindan, and I. P. Singh, "Nano and hybrid aluminum based metal matrix composites: An overview," *Manuf. Rev.*, vol. 2, 2015, doi: 10.1051/mfreview/2015018.

[23] D. S. Prasad, C. Shoba, and N. Ramanaiah, "Investigations on mechanical properties of aluminum hybrid composites," *J. Mater. Res. Technol.*, vol. 3, no. 1, pp. 79–85, 2014, doi: 10.1016/j.jmrt.2013.11.002.

[24] N. Fatchurrohman, S. Sulaiman, M. K. A. Ariffin, B. T. H. T. Baharuddin, and A. A. Faieza, "Solidification characteristic of titanium carbide particulate reinforced aluminium alloy matrix composites," *J. Eng. Sci. Technol.*, vol. 7, no. 2, pp. 248–256, 2012.

[25] Y. Sahin, "Preparation and some properties of SiC particle reinforced aluminium alloy composites," *Mater. Des.*, vol. 24, no. 8, pp. 671–679, 2003, doi: 10.1016/S0261-3069(03)00156-0.

[26] S. Sulaiman, M. Sayuti, and R. Samin, "Mechanical properties of the as-cast quartz particulate reinforced LM6 alloy matrix composites," *J. Mater. Process. Technol.*, vol. 201, no. 1–3, pp. 731–735, 2008, doi: 10.1016/j.jmatprotec.2007.11.221.

[27] A. Kumar, M. M. Mahapatra, and P. K. Jha, "Fabrication and Characterizations of Mechanical Properties of Al-4 . 5 % Cu / 10TiC Composite by In-Situ Method," *J. Miner. Mater. Charact. Eng.*, vol. 11, no. November, pp. 1075–1080, 2012.

[28] S. R. Rao and G. Padmanabhan, "International Journal of Materials and Biomaterials Applications," *Int. J. Mater. Biomater. Appl.*, vol. 2, no. 3, pp. 15–18, 2012.