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A REVIEW ON FABRICATION ROUTES AND MECHANICAL PROPERTIES OF AL BASED METAL MATRIX COMPOSITES

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Abstract

MMCs has an advantage over other composites because of their ability to resist high temperatures, moisture, radiation and zero outgassing at vacuum, thermal and electrical conductivities, enhanced mechanical properties. Among the several available matrix materials, aluminium and its alloys are widely used to produce MMCs. Some of the attractive properties of aluminium are less weight, economically feasible, easy to process with good mechanical characteristics. This paper reviews various combination of matrix and reinforcement materials available for metal matrix composites, different fabrication methods used and recent studies on mechanical properties of aluminium based metal matrix composites.

Introduction:The composite materials is a mixture of two or more materials insoluble in one another and possess properties which are superior to any of the component materials.[1].In today's era with a need for advanced materials, combination of materials offer the advantage of superior characteristic of the resultant material compared to their parent metal.[2].Classification: the composites are classified into two categories[3]

1.**according to base matrix**: Metal Matrix Composites(MMCs), Ceramic Matrix Composites(CMCs),Polymer Matrix Composites(PMCs),Carbon Matrix Composites.

2.**According to reinforcement materials utilized**: Fiber reinforced Composite, Particulate reinforced Composites,Laminar Composites and Flake Composites.

Among the above listed diferrent types(according to base matrix) of composites MMCs are most widely in engineering applications due to their advantages over other composites.Because of their ability to resist high temperatures, moisture and radiation, also thermal and electrical conductivities and enhanced mechanical properties[1,4].

Metal Matrix Composites(MMCs): is a combination of ductile metal or alloy matrix reinforced with other metal, nonmetallic or organic compounds.[5].The following figure shows various combinations of matrix and reinforcement materials that can be used for the production of MMCs.[1]

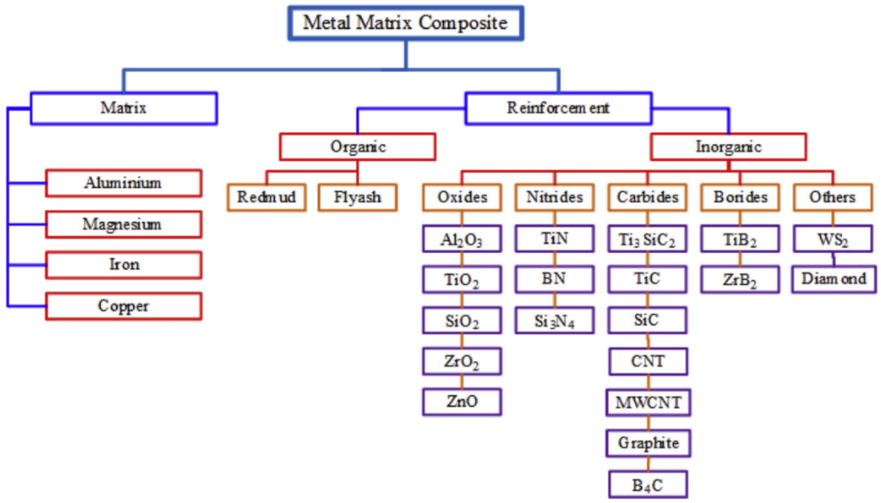
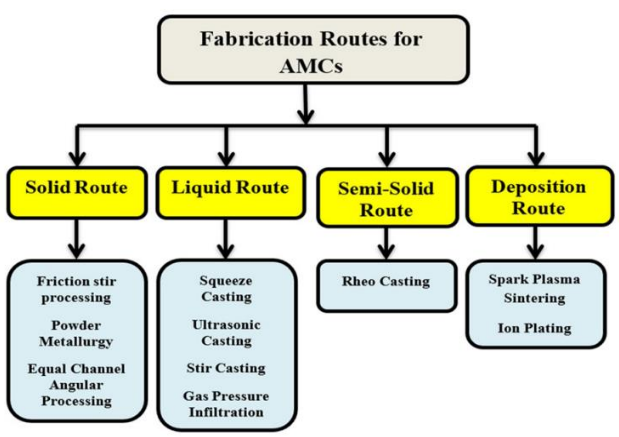


Fig1:Different combination of matrix and reinforcement materials of MMMCs[1]

Selection of matrix and reinforcement material depends on application of the composite.Among various choices available, aluminium is the most commonly used as matrix material. The most important feature offered by aluminum is low density, high strength and wear resistance along with improved mechanical properties. With a need for high strength and lower weight materials for automobile and aerospace applications.hence Aluminium metal matrix composites(AMMCs) has received higher attraction by engineers.[1-3].

The reinforcement material is generally used to enhance the desired characteristics of the matrix material. The mechanical characteristics of the composite material are determined by different factors, which includes the properties of the matrix and reinforcement materials, the characteristics of the bonds between the matrix and reinforcement materials, the volume ratio of the matrix and reinforcement materials, the orientation, structure and shape of the reinforcement material within the structure of composite. In case of reinforcing and optimizing lightweight metallic materials, the use of Metal Matrix Composite is a highly attractive option for both engineering and many other industrial applications. Types of reinforcement materials having a significant role in the selection of fabrication techniques of AlMMCs. The reinforcement particles which generally used are, Al2O3[7,8,9], SiC[10,11,12,13] TiC[15,16,17], B4C[13,14,18-21], graphite[22] and metal particles.[23]



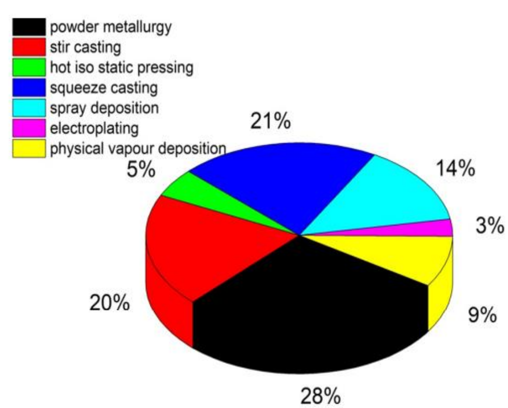


Figure2: fabrication methods of Aluminium metal matrix Composites[2]

Figure3: Pie diagram with usage percentage of various fabrication methods during the past 15 years (Source Scopus data

Solid state processing/powder metallurgy Solid state fabrication of MMCs is the process of bonding matrix material and reinforcements due to mutual diffusion arising between them in solid states at a higher temperature and under pressure.

Powder metallurgy is known as near net shape manufacturing process as it eliminates the requirements of further processing of resultant product. It employs raw material in powder form and therefore referred as costly process as the powder form of any material is costlier than its solid form. As can be seen in Fig. 18, it employs four different steps for completion of the process. The raw material is converted in the powder form through different techniques like atomization etc. This powdered base matrix is mixed or blended with reinforcement materials with the help of milling (ball, planetary, high enemy mill etc.). [86] The mixture of powders is than compacted at high pressure, by using high capacity hydraulic presses. The compacted powder takes the shape of the dies, employed during compaction. This compact is then sintered in sintering furnace to provide the desired strength to the green compact [2,86,87].

stir casting : Stir casting is a liquid state primary manufacturing process for the production of MMCs. Stir casting is a process of mixing dispersed phase ceramic particles or short fibres in a molten matrix metal using mechanical stirring. Its advantages lie in its simplicity, flexibility, and applicability to large quantity with low-cost production [1]. Stir casting is a process of mixing dispersed phase ceramic particles or short fibres with a molten matrix metal using mechanical stirring The economy, simplicity and ability to produce large and intricate parts are the key parameters that makes stir casting the most preferred method for producing AMCs [2,25,26,27]. Stirring of molten mixture before pouring in mold cavity promotes uniform distribution of reinforcement in aluminium matrix. Stirring induces vortex formation and the reinforced particles get mixed at the side of the vortex [7,28–31].

The basic principle and components of stir casting process is shown in figure 5.

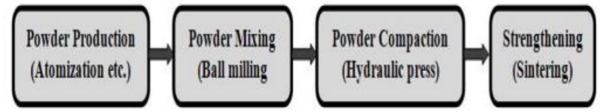


Figure3:processing route of powder metallurgy.[2]

Squeeze casting. Squeeze casting is a combination of casting and hydraulic forging as schematically shown in Fig. In this process, the liquid metal is poured into the die and immediately forged using the hydraulic press at high pressure. The runway is connected between bottom pouring and the mould to transfer molten metal from the furnace to the die.[2]

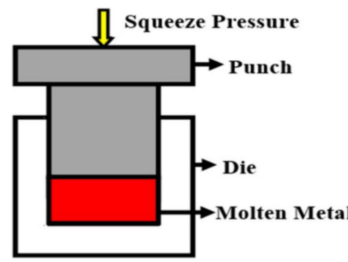


Figure 4:schematic view of squeeze casting process[2]

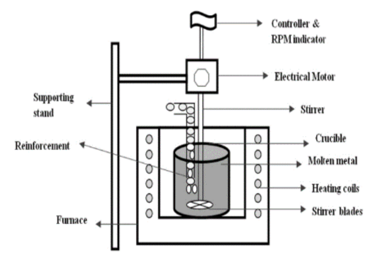


Figure 5: schematic view of stir casting process[2].

There are some critical factors to be considered while choosing stir casting methods and are listed below[1]:

1. Achieving a uniform distribution of particles in the cast MMCs.

2. Achieving perfect bonding between matrix and reinforcement materials.

3. Minimizing the percentage of porosity in the cast MMCs.

4. Avoiding chemical reactions between the reinforcement material and matrix alloy.

5. Avoiding the reaction of the melt with the atmospheric elements.

Mechanical properties of AMMCs:

Sl.no	Composite	Weight fraction	Casting method	Particle size	Hardness	Ultimate strength	References
1	AA2024 (AlCu4Mg1)/Al_2O_3	10,20 and 30	Stir	16, 32 and 66 (µm)	135 BHN	112 (T)	[4]
2	A356(Al-Si7Mg)/Al_2O_3	1, 3, 5 and 7.5	Stir	20 µm	75 BHN	450 (C)	[32]
3	AA2024 (AlCu4Mg1)/Al_2O_3	5	Stir	50 µm	82 HV	224 (T)	[33]
4	Al2011/graphite	2,4	stir	50–60 µm	62 BHN	239.79(T)	[34]
5	A356 alloy/B_4C	3,6	stir	40 µm	65.43BHN	183.2(T)	[35]
6	Al 6061/TiC	0,2.5,5%	stir	-----	80HV	170(T)	[36,37]
7	SiC/ LM6 alloy	7%	stir	-----	68.3HRB	----	[38]
8	Al4032/sic	0.4,6,8	stir	54 µm	189.2 HV	138(T)	[39]
9	Al7025/B_4C	3,9	stir	80	---	250(T)	[40]
10	AA7075 (Al-Zn6MgCu)/Al2O3	1.2	Stir	50 nm	160 HV	400 (T)	[41]
11	AA6061 (AlMg1SiCu)/SiC	6	Stir	20 µm	90 HV	160 (T)	[42]
12	AA7075(AlZn6MgCu)/SiC	6	Stir	150 µm	118 HB	269 (T)	[43]
13	AA6061(AlMg1SiCu)/B4C	15	Stir	60 µm	80 VHN	260 (T)	[44]
14	AA6061(AlMg1SiCu)/B4C	15	Stir	30 µm	97 VHN	270 (T)	[45]
15	A356(Al-Si7Mg)/B4C	10	Stir	20 µm	74 BHN	265 (T)	[46]

(T)-Ultimate tensile strength & ©-Compressive strength

Table 1: mechanical properties of various combination of aluminium and reinforcements

Conclusion: from the above study we can conclude that after addition of reinforcement, the hardness and ultimate strength are greatly enhanced compared to base alloy.Thus proving their applicability to the suitable components in engineering applications.

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References:

1.Ramanathan Arunachalam, Pradeep Kumar Krishnan, Rajaraman Murali raja. A review on the production of metal matrix composites through stir casting – Furnace design, properties, challenges, and research opportunities Journal of Manufacturing Process 42(2019)213-245

2.*vineet chak,Himadri Chattopadhyay,T L Dora.A review on fabrication methods,reinforcements and mechanical properties of aluminium matrix composites. Journal of Manufacturing Process 56(2020)1059-1074.*

3.ManishShukla,S.K.Dhakad,PankajAgarwal,M.K.Pradhan,characteristic behavior of aluminium metal marrix composites: a review. Mater.Today proceedings 5(2018)5830-5836

4. Kok M. Production and mechanical properties of Al2O3 particle-reinforced 2024 aluminium alloy composites. J Mater Process Technol 2005;161:381–7. https:// doi.org/10.1016/j.jmatprotec.2004.07.068.

5.Ekka KK, Chauhan SR, Varun. Dry sliding wear characteristics of SiC and Al2O3 nanoparticulate aluminium matrix composite using Taguchi technique. Arab J Sci Eng 2014;40:571–81. https://doi.org/10.1007/s13369-014-1528-2.

7.Bharath V, Nagaral M, Auradi V, Kori SA. Preparation of 6061Al-Al2O3 MMC's by stir casting and evaluation of mechanical and wear properties. Procedia Mater Sci 2014;6(January 1):1658–67.

8. Maj J, Basista M, Węglewski W, Bochenek K, Strojny-Nędza A, Naplocha K, et al. Effect of microstructure on mechanical properties and residual stresses in interpenetrating aluminum-alumina composites fabricated by squeeze casting. Mater Sci Eng A 2018;715(February 7):154–62

9. Casati R, Fabrizi A, Tuissi A, Xia K, Vedani M. ECAP consolidation of Al matrix composites reinforced with in-situ γ-Al2O3 nanoparticles. Mater Sci Eng A 2015;648(November 11):113–22.

10. Hamdollahzadeh A, Bahrami M, Nikoo MF, Yusefi A, Givi MB, Parvin N. Microstructure evolutions and mechanical properties of nano-SiC-fortified AA7075 friction stir weldment: the role of second pass processing. J Manufacturing Process 2015;20(October 1):367–73.

11. Khodabakhshi F, Gerlich AP, Švec P. Fabrication of a high strength ultra-fine grained Al-Mg-SiC nanocomposite by multi-step friction-stir processing. Mater Sci Eng A 2017;698(June 20):313–25.

12. Sert A, Celik ON. Wear behavior of SiC-reinforced surface composite Al7075-T651 aluminum alloy produced using friction stir processing. Indian J Eng Mater Sci 2014;21:35–43.

13.Dinaharan I, Murugan N, Thangarasu A. Development of empirical relationships for prediction of mechanical and wear properties of AA6082 aluminum matrix composites produced using friction stir processing. Engineering science and technology. Int J 2016;19(September 1 (3)):1132–44.

14. Bodukuri AK, Eswaraiah K, Rajendar K, Sampath V. Fabrication of Al–SiC–B4C metal matrix composite by powder metallurgy technique and evaluating mechanical properties. Perspectives Sci 2016;8(September 1):428-31

15. García-Vázquez F, Vargas-Arista B, Muñiz R, Ortiz JC, García HH, Acevedo J. The role of friction stir processing (FSP) parameters on TiC reinforced surface Al7075- T651 aluminum alloy. Soldagem&Inspeção 2016;21(December (4)):508–16

16. Thangarasu A, Murugan N, Dinaharan I. Production and wear characterization of AA6082-TiC surface composites by friction stir processing. Procedia Eng 2014;97(January 1):590–7.

17. Dinaharan I. Influence of ceramic particulate type on microstructure and tensile strength of aluminum matrix

composites produced using friction stir processing. J Asian Ceramic Societies 2016;4(June 1 (2)):209–18.

18. Rana H, Badheka V. Influence of friction stir processing conditions on the manufacturing of Al-Mg-Zn-Cu alloy/boron carbide surface composite. J Mater Process Technol 2018;255(May 1):795–807.

[19]. Khan M, Rehman A, Aziz T, Shahzad M, Naveed K, Subhani T. Effect of inter-cavity spacing in friction stir processed Al 5083 composites containing carbon nanotubes and boron carbide particles. J Mater Process Technol 2018;253(March 1):72–85.

[20]. Yuvaraj N, Aravindan S. Fabrication of Al5083/B4C surface composite by friction stir processing and its tribological characterization. J Mater Res Technol 2015;4(October 1 (4)):398–410.

[21] Rana HG, Badheka VJ, Kumar A. Fabrication of Al7075/B4C surface composite by novel friction stir processing (FSP) and investigation on wear properties. Procedia Technol 2016;23(January 1):519–28

22. Maurya R, Kumar B, Ariharan S, Ramkumar J, Balani K. Effect of carbonaceous reinforcements on the mechanical and tribological properties of friction stir processed Al6061 alloy. Mater Design 2016;98(May 15):155-66

23.Arun kumar sharma,Rakesh bhandari,amit Ahewar,Ruta Rimasauskiene,camelia pinca -Bretotean.Materials Today:proceedings 26(2020)2419-2424

24. Mechanical and Wear Performances of Aluminium-Based Metal Matrix Composites: A Review. P. Venkateshwar Reddy ,G. Suresh Kumar, D. Mohana Krishnudu, H. Raghavendra Rao. Journal of Bio- and Tribo-Corrosion (2020) 6:83 https://doi.org/10.1007/s40735-020-00379-2

25. Hashim J, Looney L, Hashmi MS. Metal matrix composites: production by the stir casting method. J Mater Process Technol 1999;92(August 30):1–7.

26.] Moses JJ, Dinaharan I, Sekhar SJ. Characterization of silicon carbide particulate reinforced AA6061 aluminum alloy composites produced via stir casting. Procedia Mater Sci 2014;5(January 1):106–12.

27.] Vishnu Prasad K, Jayadevan KR. Simulation of stirring in stir casting. Procedia Technol 2016;24:356–63. https://doi.org/10.1016/j.protcy.2016.05.048.

28. Kala H, Mer KK, Kumar S. A review on mechanical and tribological behaviors of stir cast aluminum matrix composites. Procedia Mater Sci 2014;6(January 1):1951–60.

[29] Rahman MH, Al Rashed HM. Characterization of silicon carbide reinforced aluminum matrix composites. Procedia Eng 2014;90(January 1):103–9.

[30] Pazhouhanfar Y, Eghbali B. Microstructural characterization and mechanical properties of TiB2 reinforced Al6061 matrix composites produced using stir casting process. Mater Sci Eng A 2018;710(January 5):172–80.

[31] Sijo MT, Jayadevan KR. Analysis of stir cast aluminium silicon carbide metal matrix composite: a comprehensive review. Procedia Technol 2016;24(January 1 (2016)):379–85.

[32] Sajjadi SA, Ezatpour HR, Torabi Parizi M. Comparison of microstructure and mechanical properties of A356 aluminum alloy/Al2O3 composites fabricated by stir and compo-casting processes. Mater Des 2012;34:106–11. https://doi.org/10. 1016/j.matdes.2011.07.037

[33] Yigezu BS, Mahapatra MM, Jha PK. Influence of reinforcement type on microstructure, hardness, and tensile properties of an aluminum alloy metal matrix composite. J Miner Mater Charact Eng 2013;1:124–30. https://doi.org/10.4236/ jmmce.2013.14022.

[34] Impact of micro graphite particles addition on the mechanical behavior of Al2011 alloy metal composites. M. S. Raksha, Adaveesh Basavalingappa, Madeva Nagaral, Chandrashekar Anjinappa, B. Omprakash,Abdul RazakNasim Hasan.Engineering reports.WILEY.9.07.2023. DOI: 10.1002/eng2.12746.

[35] Ali Z, Muthuraman V, Rathnakumar P, Gurusamy P, Nagaral M. Influence of B4C particle size on the

mechanical behavior of A356 aluminium composites. Res. Eng. Struct. Mater., 2023; 9(2): 527-540.

[36] K. J. Lijay, J. D. R. Selvam, I. Dinaharan, and S. J. Vijay, "Microstructure and mechanical properties characterization of AA6061/TiC aluminum matrix composites synthesized by in situ reaction of silicon carbide and potassium fluotitanate," Transactions of Nonferrous Metals Society of China, vol. 26, no. 7, pp. 1791–1800, 2016

[37] Gebre Fenta Aynalem, Review Article Processing Methods and Mechanical Properties of Aluminium Matrix Composites, Hindawi Advances in Materials Science and Engineering Volume 2020, Article ID 3765791, 19 pages https://doi.org/10.1155/2020/3765791.

[38]Aripata Chatterjee,et al. Fabrication and Characterization of SiC-reinforced Aluminium Matrix Composite for Brake Pad Applications. *Metals* **2023**, *13*(3), 584; **https://doi.org/10.3390/met13030584**

[39] Pardeep Saini and Pradeep K Singh. Fabrication and characterization of SiC-reinforced Al-4032 metal matrix composites. Eng. Res. Express 4 (2022) 015004, https://doi.org/10.1088/2631-8695/ac4831

[40] Madeva Nagaral, V Auradi , S A Kori, Reddappa H N , Jayachandran , Veena Shivaprasad. Studies on 3 and 9 wt. % of B4C Particulates Reinforced Al7025 Alloy Composites. AIP Conference Proceedings 1859, 020019 (2017); doi: 10.1063/1.4990172

[41]Ezatpour HR, Torabi Parizi M, Sajjadi SA, Ebrahimi GR, Chaichi A. Microstructure, mechanical analysis and optimal selection of 7075 aluminum alloy based composite reinforced with alumina nanoparticles. Mater Chem Phys 2016;178:119–27. https://doi.org/10.1016/j.matchemphys.2016.04.078.

[42] Balaji V, Sateesh N, Hussain MM. Manufacture of aluminium metal matrix composite (Al7075-SiC) by stir casting technique. Mater Today Proc 2015;2:3403–8. https://doi.org/10.1016/j.matpr.2015.07.315

[43] Kumar GBV, Rao CSP, Selvaraj N. Mechanical and dry sliding wear behavior of Al7075 alloy-reinforced with SiC particles. J Compos Mater 2012;46:1201–9. https://doi.org/10.1177/0021998311414948.

[44] Shabani MO, Mazahery A. Good bonding between coated B4C particles and aluminum matrix fabricated by semisolid techniques. Russ J Non-Ferrous Met 2013;54:154–60. https://doi.org/10.3103/S1067821213020120.

[45] Taylor P, Mazahery A, Shabani MO. Existence of good bonding between coated B4C reinforcement and Al matrix via semisolid techniques: enhancement of wear resistance and mechanical properties. Tribol Trans 2013;3:37–41. https://doi.org/ 10.1080/10402004.2012.752552

[46] Mazahery A, Shabani MO, Rahimipour MR, Tofigh AA, Razavi M. Effect of coated B4C reinforcement on mechanical properties of squeeze cast A356 composites. Mater2012;50:107–13. https://doi.org/10.4149/km_2012_2_107