DOI: https://doi.org/10.46632/mc/1/2/6
Materials and its Characterization
Vol: 1(2), 2022
REST Publisher; ISBN: 978-81-948459-0-4
Website: http://restpublisher.com/book-series/materials-and-its-characterization/

Mechanical Properties of Metal Matrix Composites: Short Review

[1]Rohan S, *, [2]Ankit Kumar Mishra
[1]ASTROEX RESEARCH ASSOCIATION, Deoria, Uttar Pradesh, India.
[2]REST Labs, Krishnagiri, Tamil Nadu, India.
*Corresponding author Email: ankitkumarm1998@gmail.com

Abstract. This paper provides an overview of the increasing R&D activity in metal matrix composites worldwide, with a particular focus on cast particulate metal matrix composites. Large-scale applications of cast aluminum alloy MMCs in everyday use in the transportation and consumer durables industries are expected to advance rapidly over the next decade. India has great potential for widespread application of cast composites, especially in the fields of transportation, energy and electrical machinery. Widespread use of composites can result in significant material and energy savings and, in some cases, reduced pollution. It is important to organize engineering education and short courses to make students and engineering professionals aware of his MMC. India already has an excellent infrastructure for composites development and a long track record of world-class cast metal matrix composites research. Today there is a need to catalyze prototypes and series production of selected composite components and use them in various sectors, especially in railways, cars, trucks, buses, scooters and other electrical machines. This requires a well-funded strategy to bring together the world-class foundry composites talent already present in India to form a viable development group. We will then establish a manufacturing facility that incorporates the process engineering capabilities that already exist in the country. Cast composites must be developed for use in power generation equipment, aerospace electronic packaging systems, and smart structures.
Keywords: Composites, Mechanical, Metal, Properties.

1. Introduction

A metal matrix composite, or MMC for short, is a composite material made of fibres or particles spread in a metallic matrix like copper, aluminium, or steel. The secondary phase is often a metal or ceramic, such as alumina or silicon carbide .Typically, they are categorised according on the kind of reinforcement: short continuous fibres, long continuous fibres, or particles. There are some similarities between cermets and MMCs, with the latter often containing less metal by volume than 20%. A hybrid composite is one in which at least three components are incorporated. MMCs are frequently employed in demanding applications because they can have strength-to-weight ratios, stiffness, and ductility that are significantly greater than those of standard materials. Pradeep K. Rohatgi et.al (1993) study examines the global increase in research and development efforts related to metal-matrix composites, with a focus on cast metal-matrix particulate composites. In the following 10 years, it is anticipated that cast aluminium alloy MMCs will find widespread daily use in the transportation and durable goods sectors. Andreas Mortensen et.al (2010) the authors provided information such as metal matrix composites, a metal is combined with another, often non- metallic, phase to produce a novel material. A subject of much research in the 1980s and 1990s, this class of materials has increased significantly in variety. Research on composites such as particle-reinforced aluminium has served as potent vehicle for elucidation of mechanics of high-contrast two-phase elastoplastic materials. L. C. Davisa et.al (1995) studied thermal conductivity of metal-matrix composites, which are potential electronic packaging materials, is calculated. Thermal boundary resistance, which occurs at the interface between the metal and the included phase (typically ceramic particles), has a large effect for small particle sizes. It is found that Sic particles in Al must have radii-in excess of 10 pm to obtain the full benefit of the ceramic phase on the thermal conductivity. L. H. Hihara et.al (1994) sates about thermal conductivity of metal-matrix composites, which are potential electronic packaging materials, is calculated. Thermal boundary resistance, which occurs at the interface between the metal and the included phase (typically ceramic particles), has a large effect for small particle sizes. It is found that Sic particles in Al must have radii-in excess of 10 pm to obtain the full benefit of the ceramic phase on the thermal conductivity. M.Vamsi Krishna et.al (2014) have suggested Aluminium alloy Metal Matrix Composites (MMCs) are gaining wide spread acceptance for automobile, industrial, and aerospace applications. MMCs are characterized by microstructural studies and density, and mechanical properties were evaluated as per the standards. The dispersed Graphite and SiC in Al6061 alloy contributed in enhancing the tensile strength of the composites. Ashish Kumar et.al (2019) says about Stir casting method is prominent technique for developing metal matrix composites (MMCs) due to its easiness and production at reasonable price with bulk manufacturing competency. AMMCs composite materials are used in marine, defence, automotive, aerospace, and heat prone areas. This review article contains substantial aspects of stir casting route like; mechanical properties, effect of various reinforcement, various challenges and future research potential in the development of composites. Brian Ralph et.al (1997) gives an overview of the different processes available for processing metallic matrix composites, as well as a discussion of their respective properties.

These are divided into those where the main steps are performed in the solid state and those where they are processed in the molten state.

2. Processing of Metal Matrix Composites

Processing of metal matrix composites (MMC) can be classified into three main categories and are as mentioned below Solid State Processing, Liquid State Processing, In-Situ Processing. Solid State Processing: Powder blending and consolidation, as well as physical vapour deposition, are the two basic manufacturing techniques for solid state processing of metal matrix composites. Powder Blending and Consolidation: Metal alloy powder is mixed with ceramic whiskers, short fibres, or particles either dry or wet. The combination is then put through additional processing after blending, including cold compaction, canning, degassing, and high temperature consolidation. Depending on the powder and processing circumstances, there are some oxides particles in the volume fraction of 0.05–0.5. Metal matrix composites made of aluminium and magnesium are often processed using this technique. Diffusion Bonding: Bonding between the metal matrix and fibres is produced by the interdiffusion of atoms at the metallic surfaces under pressure. For MMCs made of aluminium or magnesium and reinforced with continuous or discontinuous fibres, this production technique is often utilised. Physical Vapor Deposition: Fibres are continuously passed through a region of high partial pressure of metal to be deposited. The vapor is produced and inserted in the process, and then the condensation occurs at this region to produce a coating on the fibre. The rate of deposition is about 5-10 micro meters per minute. The coated fibres are then consolidated by hot pressing or hot isostatic pressing. Liquid State Processing: Stir Casting: It a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. Stir Casting is the simplest and the most cost effective method of liquid state fabrication. Spray Deposition: A deposition layer with porosity of 5–10% is formed on the metal surface as a result of the injection of reinforcements in the form of particles, whiskers, and short fibres. The depositions are then processed further to achieve their maximum density. Metal matrix composites with continuous (long) fibre reinforcement are made by spraying metals onto the fibres. In this processing procedure, the fibre volume fraction and distribution are impacted by the fibre spacing and fibre layer. In-Situ Processing: Chemical processes known as in-situ processing lead to the formation of a reinforcing phase inside a metal matrix. The precipitation of a liquid or a solid can produce reinforcements. This technique offers compatibility between thermodynamics at the matrix-reinforcement interface. A stronger matrix-dispersion bond can be achieved because the reinforcement surfaces are also likely to be clean.

3. Mechanical Properties of Metal Matrix Composites

MMCs offer a number of advantages over their base metals, including higher modulus of elasticity and strength, lower coefficient of thermal expansion, and superior properties at high temperatures such as resistance to creep and improved breaking strength. Lower density is an attractive property of MMCs fabricated using a metal matrix with a higher density than ceramic reinforcement. Fig 1 shows the percentage change in density of several aerospace alloys with increasing volumetric content of silicon carbide reinforcement. The improvement of these properties is controlled by the stiffness, strength, volumetric mass and shape of the reinforcement. Fig 2 shows the effect of increasing the volume content of continuous alumina fibres on the elastic modulus and yield strength of aluminium-lithium alloys in the parallel and transverse (anti-fibre) directions. The longitudinal and transverse properties increase linearly with the fiber content, and stiffness and strength can be increased by 50-100% compared to the base metal.For example, figure 3 shows a large increase in fatigue life of aluminum alloys when reinforced with silicon carbide particles. Fatigue improvement is often the result of the composite's higher modulus and hardening rate compared to the base material.

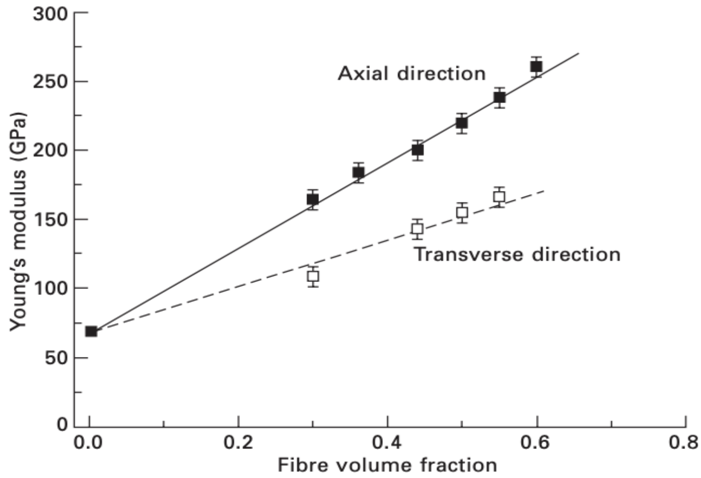

FIGURE 1. Young's modulus vs fibre volume fraction [16]

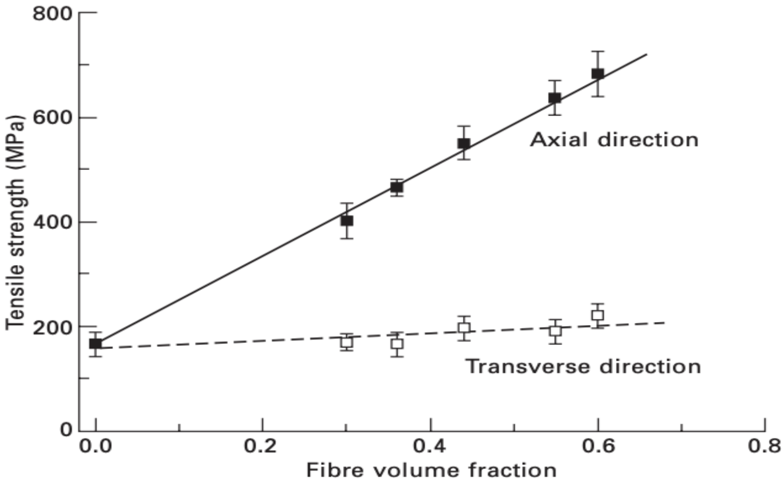

FIGURE 2. Tensile strength vs fibre volume fraction for MMCs [16]

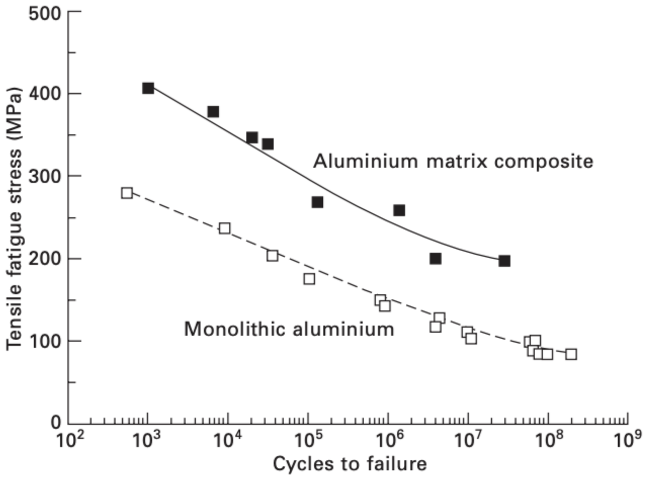

FIGURE 3. Tensile fatigue stress vs Cycles to failure [16]

4. Thermal Properties of Metal Matrix Composites

Metal matrix composites with high thermal conductivity (TC) and thermal expansion (CTE) are of vital importance to enhance the performance, life cycle and reliability of electronic devices. Al and Cu were usually used as metal matrix due to their high TCs, and the reinforcements involved SiC, carbon and diamond metal is attractive because of its ease of.machinability, while diamond/metal becomes a hotspot. Non-wetting and undesirable interfacial reaction make.difficulty on the fabrication process and greatly limit the improvement of thermal properties.

5. Corrosion Resistance in Metal Matrix Composites

Graphene has attracted much attention in the field of corrosion protection due to its excellent barrier function. Unlike toxic chromium-based coatings that have been used to protect steel, graphene could be a green alternative with equal or better impermeability. Electrochemical reactions showed that graphene's superior ability to block the influx of corrosive media reduced the corrosion rate of graphene-coated Ni and Cu. Therefore, using graphene with more uniform and larger grain size, higher structural integrity and fewer defects, and thicker graphene layers can further improve its anti-corrosion performance. Proposed to encapsulate graphene with (3-aminopropyl) triethoxysilane (APTES) to block the passage of electrons and inhibit the corrosive activity of graphene. Incorporating graphene into polymers can also repair some defects in graphene and further improve corrosion resistance performance.In such Gr/Cu composites, the Cu matrix is divided into micro/nanodomains surrounded and protected by graphene, where the anticorrosive and reinforcing effects of uniformly dispersed graphene are combined. Figure 1 shows how material design based on a building block strategy for getting graphene's anti-corrosion role.

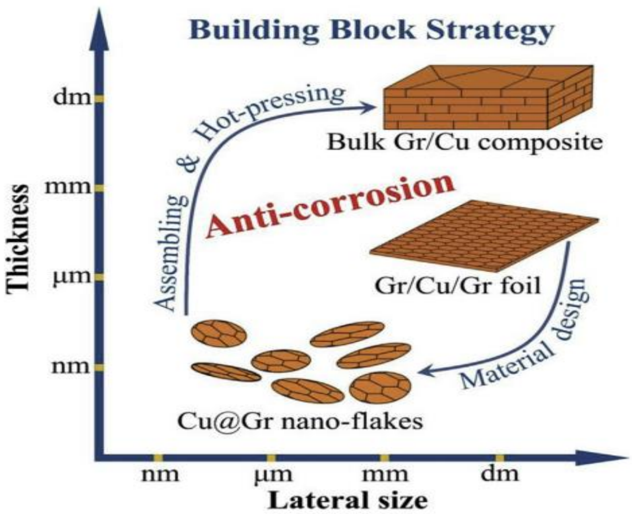

FIGURE 4. Enhanced corrosion resistance in metal matrix composites assembled from graphene encapsulated copper nanoflakes [1].

6. Conclusion

Metal matrix composites with tailored properties could become one of the fastest growing new material families that could have a major impact on India. Today, the highest performing and most expensive MMCs are being considered for high value-added, relatively low volume military and aerospace applications. However, power applications in automobiles and other motors and electrical machines are now commercialized and require large quantities of parts at low cost and these should be of greatest concern to India. High performance and low cost converge as composite manufacturing processes continue to evolve and alloy designs improve, including the potential use of particle composites. Near-term developments include the use of casting and powder processes to create customized interfaces, new matrix alloys that result in higher ductility and toughness, and higher strength for discontinuously reinforced composites. The science of predicting the properties and performance of metal matrix-particle composites will gain considerable ground. Currently, low cost fine grain composites such as cast aluminium-alumina, aluminium-silicon carbide and aluminum-graphite composites appear to be the most promising in India. These composites can be made using readily available materials and simple techniques and can be used in energy and material saving applications. It's best to start with simple applications such as bearings, pistons and cylinder liners and move on to other high performance components. India should pay particular attention to his MMC's deployment potential in priority energy, housing and transport sectors, including the solar, semiconductor and superconducting industries. India has an excellent research and industrial base for manufacturing MMC for domestic consumption and export.

References

1. Baoyin Jin, Ding-Bang Xiong, Zhanqiu Tan, Genlian Fan, Qiang Guo, Yishi Su, Zhiqiang Li, Di Zhang , Enhanced corrosion resistance in metal matrix composites assembled from graphene encapsulated copper nanoflakes Journal of Carbon 2019 Vol 142, Pp 482-490.
2. Pradeep K. Rohatgi, Metal-matrix Composites Defence Science Journal, Vol 43, No 4, October 1993, pp 323-349 .
3. Andreas Mortensen, Javier Llorca, Metal Matrix Composites, Annual Review of Materials Research 2010 Vol. 40: pp. 243-270.
4. L. C. Davis, B. E. Artz ,Thermal conductivity of metal matrix composites , American Institute of Physics. 1995 Vol 77 pp. 4954 - 4960.
5. L. H. Hihara and R. M. Latanision, Corrosion of metal matrix composites 1994 Vol.39 No.6 pp. 245 - 264.
6. M.Vamsi Krishna, Anthony.M.Xavior,An Investigation on the Mechanical Properties of Hybrid Metal , Procedia Engineering Vol 97, 2014 pp. 918 – 924.
7. Ashish Kumar, R.C. Singh, Rajiv Chaudhary Recent progress in production of metal matrix composites by stir casting process: An overview, Materials Today: Proceedings, 2019.
8. Avinash Lakshmikanthan, Santosh Angadi , Vinayak Malik , Kuldeep K. Saxena , Chandar Prakash, Saurav Dixit and Kahtan A. Mohammed , Mechanical and Tribological Properties of Aluminum-Based Metal-Matrix Composites , *Materials*, Vol 15 ,Issue 17, 2022.
9. Xuan-hui QU, Lin ZHANG, Mao WU, Shu-bin REN, Review of metal matrix composites with high thermal conductivity for thermal management applications, Progress in Natural Science: Materials International 21 (2011) Pp 189-197.
10. Brian Ralph·, H.C. Yuen· and W.B. Lee, The processing of metal matrix composites - an overview , Journal of Materials Processing Technology ,Vol 63, 1997, pp. 339-353 .

11. Rajendra U. Vaidya & K. K. Chawla, THERMAL EXPANSION OF METAL-MATRIX COMPOSITES, Composites Science and Technology, Vol 50, 1994, pp. 13-22.
12. B. Vijaya Ramnath, C. Elanchezhian, RM. Annamalai, S.Aravind, T. Sri Ananda Atreya, V. Vignesh and C.Subramanian, ALUMINIUM METAL MATRIX COMPOSITES - A REVIEW, Rev.Adv.Mater.Sci, 2014, Vol 38 pp. 55 - 60.
13. M K SURAPPA Aluminium matrix composites: Challenges and opportunities, Sadhana, 2003, Vol 28, pp. 319–334.
14. Y. BRECHET, J. D. EMBURY, S. TA0 , L. LUO DAMAGE INITIATION IN METAL MATRIX COMPOSITES, Acta metall. Mate, 1991 Vol. 39, No.8, pp. 1781-1786.
15. Riccardo Casati and Maurizio Vedani, Metal Matrix Composites Reinforced by Nano-Particles—A Review, Metals, 2014, Vol 4, pp. 65-83.
16. William C. Harrigan Jr, Commercial processing of metal matrix composites Materials Science and Engineering A244, 1998, pp. 75–79.
17. J.W. Kaczmar, K. Pietrzak, W. Woosinski, The production and application of metal matrix composite materials Journal of Materials Processing Technology ,2000,Vol-106 pp. 58-67
18. John V. Foltz, Charles M. Blackmon Metal-Matrix Composites, ASM Handbook, Vol 2 pp. 903-912.
19. Mortensen & I. Jin Solidification processing of metal matrix composites International Materials Reviews, Vol 37, pp. 101-128.
20. Tomac, K, Tannessen, Machinability of Particulate Aluminium Matrix Composites, Annals of the ClRP 1992, Vol. 4, pp. 55-58.

