Fabrication and Characterization of Aluminium Based Metal Matrix Composites: A Review

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ABSTRACT

Metal matrix composites (MMCs) are most promising material of recent interest because of its ability to meet engineering applications. Now a days ,a wide range of aluminium based MMCs are commercially used in aerospace industries and automobile sectors . Aluminium metal matrix composite exhibits favourable mechanical and micro structural properties. An effort has been made in this research work to highlight the major improvements in mechanical behaviour of Al based MMCs by varying the proportions of reinforced particulates. Meanwhile, it is found that the favourable change in properties is restricted up to an optimum limit of reinforcement addition in aluminium matrix. A comparative analysis is made over Al alloys and its MMCs synthesized by different reinforcement material including non-metallic and ceramic particles like molybednum disulfide (MoS_2), titanium diboride(TiB_2), zirconium dioxide(ZrO_2), silicon carbide (SiC), alumina (Al_2O_3), boron carbide (B_4C), graphite, fly ash etc.This research work summarizes the most optimised ratio of reinforcements to be done in order to achieve the best versions of Aluminium based MMCs.

Keywords: *MMCs, Aluminium alloys, Matrix, SEM, XRD.*

1.INTRODUCTION

Composites are basically a combination of two types of material, called ‘matrix’ and ‘reinforcement’. The matrix holds the reinforcement to provide a structural shape while the reinforcement improves the mechanical strength and other properties. Composites consist of atleast single discontinuous phases embedded in a continuous phase in which discontinuous phase termed as the 'reinforcement' or 'reinforcing material', is generally harder and stronger than the continuous phase called 'matrix'. Depending upon the nature of material used ,composites are categorized into different forms eg. Polymer matrix, metal matrix, ceramics, organic based etc.

While dealing with metal matrix composites, aluminium alloy based composites are widely used due to its light weight and improved mechanical properties. Basically aluminium metal matrix composites (AMCs) are made by reinforcing the aluminium or its alloy with another material. There are various methods adopted for manufacturing of AMCs in which stir casting, infiltration, squeeze casting and powder metallurgy are common. limit of reinforcement addition in aluminium matrix . Usually non-metallic and ceramic particles like molybednum disulfide (MoS_2), titanium diboride(TiB_2), zirconium dioxide(ZrO_2), silicon carbide (SiC), alumina (Al_2O_3), boron carbide (B_4C), graphite and fly ash are used . AMCs are fabricated by varying weight percentage of reinforcement material. Non-homogenization of SiC particles and porosities in Al matrix were observed in the microstructure of 10 wt. % SiC reinforced AMC because of entrapped air molecules between SiC particles while casting [1].The hardness test result shows addition of reinforcement SiC and TiB_2 improves hardness . But at the same time it was observed that an increase above 15 wt.% of reinforcement addition reveals reduction in hardness value [2] .Likewise, improvement in tensile strength and wear resistance were also marked by governing the rate of reinforcement used. Morphological studies carried out under scanning electron microscopy (SEM) and X-ray diffraction (XRD) characterizes the micro structures of fabricated aluminium alloy based metal matrix composite.

2.LITERATURE REVIEW

2.1 Microstructures

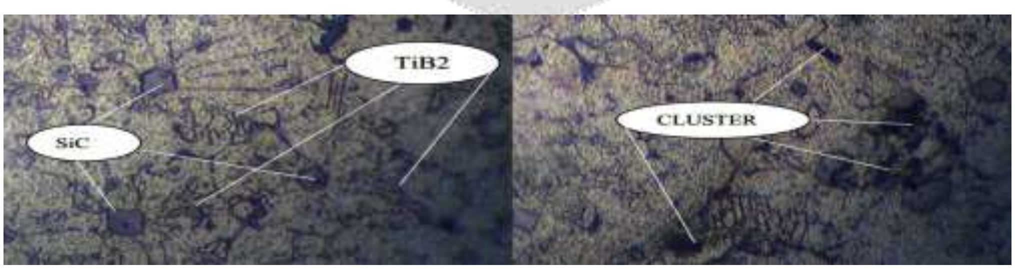
According to Md. Habibur Rahman et al. [1] the properties of composites depends on the microstructures and interface characteristics between reinforcements and matrix. Fig.1 (a),(b) & (c) shows the optical microstructures of 5, 10 and 20 wt. % SiC reinforced AMCs respectively. From microstructural analysis, clustering and non-homogeneous distribution of SiC particles in Al matrix were observed. This was due to the variation of contact time between SiC particles and molten Al during composites processing, high surface tension and poor wetting behavior of SiC particles in the liquid Al [6]. Non homogenization of SiC particles in Al matrix can be observed in the microstructure of 10 wt. % SiC reinforced AMC as shown in Fig.1(b). Some places in Al matrix can be identified without SiC reinforcing particles. Porosities were observed in all microstructures. This was because when SiC particles were added in the melt during casting, it introduced air in the melt entrapped between the particles. Therefore increasing wt. % of SiC particles increased entrapped air resulted in higher amount of porosity [4]. Johny James.S et al. [2] micro structural analysis proved the presence of SiC and TiB_2 reinforcements and its uniform distribution in the metal matrix. From Fig.3(b) it has been observed that clusters are formed around the Sic particle reinforcement. These clusters are mainly due to the increased weight percentage of TiB_2 reinforcement. It is also noted that porosity is mainly located around the cluster formed regions. As the increase in weight percentage of TiB_2 leads to porosity and cluster formation the weight percentage of TiB_2 with the matrix is limited to 2.5%.

(a) (b) (c)

Fig.1-Microstructures of (a) 5 wt. % (b) 10 wt% (c) 20 wt. % SiC reinforced AMCs [1]

(a) (b)

Fig.2-Optical micrograph of (a) 10 wt.%SiC-0wt.%TiB2 (b) 10 wt.%SiC-2.5wt%TiB2 [2]



(a) (b)

Fig.3-Optical micrograph of (a) 10 wt.%SiC-5wt.%TiB2 (b) Cluster formation (10 wt.%SiC-5wt%TiB2) [2]

2.2 Hardness

Johny James.S et al. [2] proved that the addition of TiB_2 with aluminium matrix increases the hardness value.When % of TiB_2 increases up to 5% there is a sudden decrease in hardness value. This decrease in hardness value is due to cluster formation which leads to porosity. Experimentally it has been concluded that the high amount of reinforcements reduces hardness value in metal matrix composites, resulting the optimal % of reinforcement of TiB_2 is fixed to 2.5.

Fig.4-Micro hardness plot of AMC specimens [2]

2.3 Tensile strength

Pankaj Sharma et al. [3] proposed a work on aluminium based metal matrix composite containing up to 5%, 10% and 15% weight percentage of Silicon carbide (SiC) particles along with 5% fly ash synthesized using stir-cast method. The tensile strength of aluminium increases with increasing weight percentage of SiC and fly ash. The maximum tensile strength obtained was of the order of 145MPa for a composition of 10% SiC and 5% fly ash reinforcement in aluminium .However the amount of SiC beyond 10 wt.% cause weakening of composites, it may be because of clustering of carbide- carbide particle which may cause uneven distribution of reinforcement into matrix.

Table 1- Tensile strength [3]

Sr. No.	*%age of matrix and reinforcement (by weight)*			*Tensile strength (MPa)*
	%age of aluminium	*%age of SiC*	*%age of Fly ash*	
1	100	00	00	20.82
2	95	5	0	67.65
3	90	5	5	107.23
4	85	10	5	145.33
5	80	15	5	140.02

2.4 Wear test

Siddesh Kumar N G et al. [9] developed and characterized Al2219 reinforced with B_4C+ MoS_2 hybrid composites using stir cating technique recorded the variation of wear rate with addition of wt% reinforcement to Al alloy for different sliding velocity viz-1.256m/s, 2.513m/s, 3.77m/s, 5.027m/s & 6.294m/s identified that the addition of wt% of reinforcement reduces wear rate in all different sliding speeds (fig.5).With increase in sliding velocity from 1.256m/s to 6.294m/s wear rate tend to decrease since B4C particle & solid lubricant MoS_2 spreads on the surface of pin leading to the development of thin protecting layer.

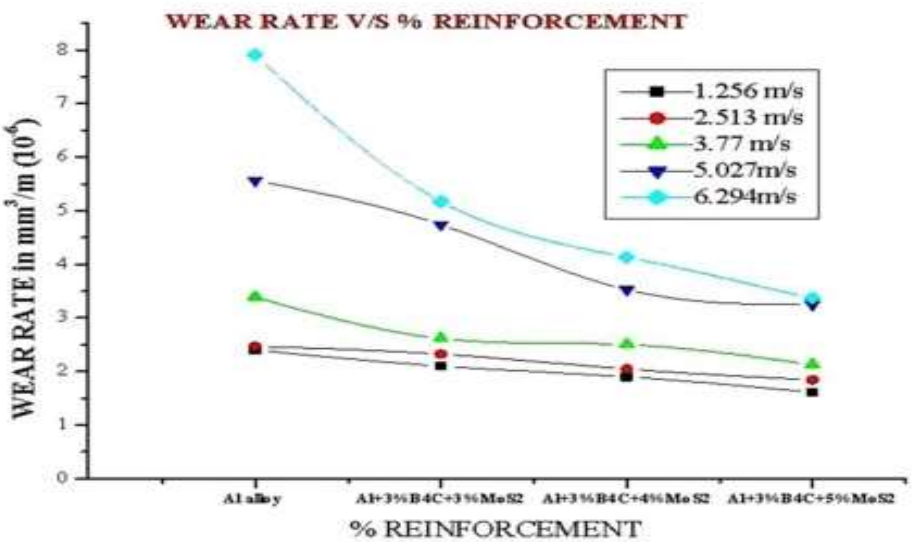
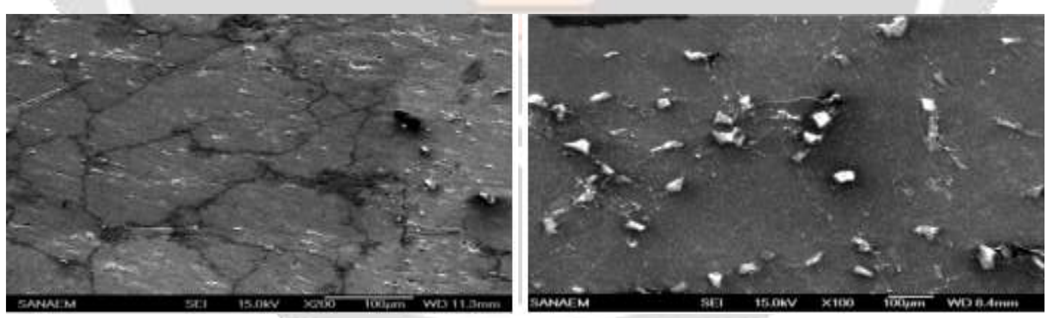


Fig.5- Variation of wear rate with wt% of reinforcement for different sliding velocities at constant load 30N and at a sliding distance of 1500m [9].

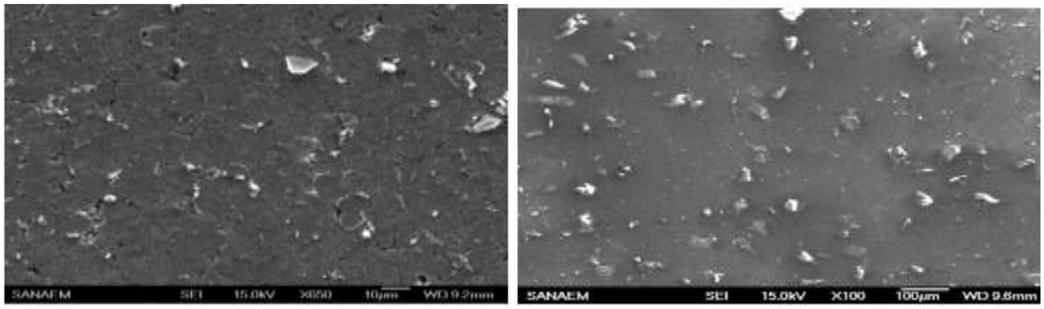
2.5 Scanning Electron Microscopy (SEM) Analysis

Y. Sahin et al. [7] investigated the microstructures and hardness of aluminium alloys (Al-2014 and Al-2124 alloy) and their composites containing 10wt.% Al_2O_3 with 3 μm and 43 μm sizes of particles produced by powder metallurgy (PM) method . Scanning electron microscopy (SEM) investigation showed a nearly uniform distribution of the Al_2O_3 particles within the Al-2124 alloy matrix although some porosities were found in the Al-2014 alloy matrix. It seems that no reaction forms between the particle and matrix. It may be an indication of enough bonding between the particles and matrix. A clear interfacial reaction product/layer at Al-SiC interface for composites held for a relatively long processing time (>30 min), but no reaction product was observed at Al-B_4C and Al-Al_2O_3 interfaces [4].



(a) (b)

(a) SEM micrograph of a pre-alloyed Al-2014 alloy sintered at 610 degree celcius for 2 hours, at increased magnification.
(b) SEM micrograph of an Al-2014 alloy /10wt.% Al2O3 reinforced aluminium alloy composites with 43 μm sizes of particles at low magnification.



(c) (d)

(c) SEM micrograph of an alloyed Al-2124 matrix alloy, sintered at 610 degree celcius for 2 hours, at low magnification.

(d) SEM micrograph of Al-2124 alloy and its MMC, showing distributions of 10wt. %Al_2O_3 particles in 2124 Aluminium alloy.

Fig.6 (a),(b),(c)& (d) –SEM micrographs of Al-alloys and its MMCs [7].

2.6 X-ray diffraction (XRD) analysis

Munmun Bhaumik and Kalipada Maity [5] fabricated Al-MMC by mixing the 5wt% ZrO_2 and Al2O3reinforcement into the Al6063aluminium alloy matrix by stir casting method.The prepared Al-MMC characterized by , X-ray diffraction(XRD) analysis clearly identifies Al, Al_2O_3, ZrO_2 as the main phase of the composite. Al_3Zr_4, Al_3Zr and Ti_9Al_{23} are also observed as a secondary phase as shown below in fig.-7.

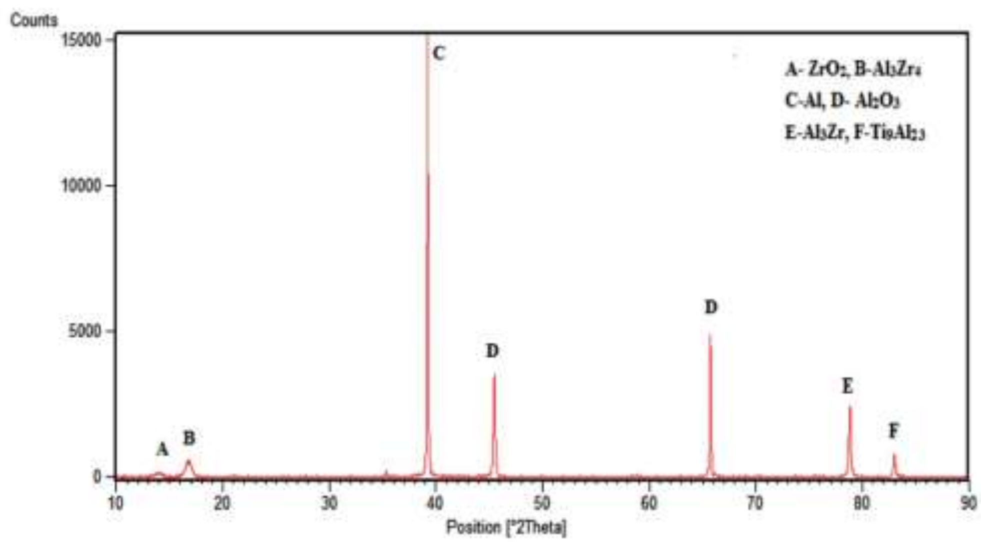


Fig.7- X-ray diffraction pattern of fabricated Al-MMC [5]

3. CONCLUSION

In this experimental study, various AMCs of varying wt.% reinforcement contents were prepared mainly using stir casting and powder metallurgy route techniques. Micro-structural behaviour, and mechanical properties including hardness, tensile strength and wear characteristics of the prepared composites were studied. Based on the several researches, the outcomes shows that the quality improvement in AMCs are made by proportionate use of particulates or reinforcements in metal matrix composites.

4. REFERENCES

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