Investigation of Mechanical properties of Non-asbestos composite material and its Optimisation

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Abstract— **Metal matrix composites (MMCs) shows their excellent mechanical properties from the combination of a hard reinforcement phase such as silicon carbide (SiC) and a ductile matrix material such as aluminum or magnesium. They are formed by governing the morphologies of the constituents to achieve optimum combination of properties. Properties of the composites depend on the properties of the constituent phases, their relative amount, and spread phase geometry including particle size, shape and orientation in the matrix. In this paper, mechanical properties, performance and micro structural evolution of aluminium metal matrix metallic composites fabricated under various process conditions were examined to understand their process structure– property relations by optimization process. Addition of silicon carbide to aluminum has shown an increase in its mechanical properties.**

Keywords— **MMC, Al composites Silicon Carbide SiC**

I. Introduction

A composite material is a material system composed of a suitably prepared mixture or combination of two or more nano, micro, or macro constituents with an interface separating them that vary in form and chemical composition and are essentially insoluble in each other. The discrete constituent is called the reinforcement and the continuous phase is called the matrix. According to the chemical nature of the matrix phase, composite are classified as metal matrix (MMC), polymer matrix (PMC) and ceramic matrix composites (CMC). MMC's recently are drawing interests of the researchers because of the ability to change their physical properties like density, thermal expansion, thermal diffusivity and mechanical properties like tensile and compressive behavior , creep, tribological behavior etc. by varying the filler phase.

MMCare thecomposite material consisting of silicon carbide particles dispersed in a matrix of aluminium alloy. It combines the benefits of high thermal conductivity of metal and low CTE (coefficient of thermal expansion) of ceramic.

AMCs can be manufactured by liquid state processing (stir casting, infiltration, squeeze casting etc.), semisolid processing and powder metallurgical route. Usually nonmetallic and ceramic particles like silicon carbide (SiC), alumina (Al2O3), boron carbide (B4C), graphite etc. are used as reinforcements in AMCs. When loads are applied outwardly to the composites, metal matrix transmits loads to reinforcements and then loads are carried by dispersed reinforcements bonded with the matrix.

Al-SiC can be used in the food, chemical, marine, electrical and many other industries and, above all, in road transport vehicles where it is used for wheels, cylinder blocks and heads, and other engine and body castings.

Tamer Ozben, ErolKilickap, OrhanCakır (2008) It was observed that increase of reinforcement elements addition produced better mechanical properties such as impact toughness and hardness, but tensile strength showed different trend; increased upto 10 wt.% of SiC reinforced.[2]. Md. HabiburRahmana, H. M. Mamun Al Rashed (2014) studied and result shows that introducing SiC reinforcements in aluminum (Al) matrix increased hardness and tensile strength and 20 wt. % SiC reinforced AMC exhibited maximum hardness and tensile strength *[3]*. P.B.Pawar, Abhay A. Utpat (2014) in this work a composite is advanced by adding silicon carbide in Aluminum metal by mass ratio 2.5%, 5%, 7.5%and 10%. The composite is prepared by stir casting technique. Mechanical test result states that MMC can be used for power transmitting elements such as gears which are subjected to continuous loading.*[4]*. AkhileshJayakumar and Mahesh Rangaraj (2014) worked on processing of SiC particles reinforced functionally graded Aluminium matrix composite cylinders and non-reinforced Aluminium cylinders by centrifugal casting to obtain the microstructure and mechanical properties for evaluation.*[5]*.

According to the literature review, precise control of the Al–SiC interface is the first key parameter to achieve improved mechanical properties which depends on manufacturing processes. Properties of Al-SiC are much better than the aluminum metal.This all discussion shows that mechanical properties and tribological properties of the non asbestos material is affected by manufacturing processes. So it is essential to find optimized constituents and best suitable manufacturing process for metal matrix composite and also there effects on properties.

This problem arises a need of development of composite material by different manufacturing processes & evaluation of its mechanical properties. [1]

Objectives

Work Objectives are to check feasibility of the Aluminium based silicon carbide metal matrix composite by different manufacturing processes, Evaluate the mechanical properties of the MMC, To determine the best alternative manufacturing process to give required properties, To perform SEM analysis.

II. MATERIALS AND METHODS

The Specimens are prepared from LM 25 Al cast alloy, (LM 25 Al alloy reinforced with 15%, 20%, 25 % by mass of Silicon carbide particles) composite. LM25 - Aluminium Casting Alloy (A1-Si7.5) EN 1706 AC-42000 conforms to BS 1490:1988 LM25. Castings are standardized in the as cast (M) condition, the precipitation treated (TE) condition, the solution treated and stabilized (TB7) condition and the fully heat treated (TF) condition [6], [9]. The specimens are prepared by Stir casting and Powder metallurgy process.

For the preparation of composite, stir casting technique also selected becausein this technique due to stirring action in molten metal vortex is created & there iswell distribution of SiC particles in matrix phase and also desired shape can be givento the composite by varying mould dimensions.

Powder metallurgy is the process of blending fine powdered materials, pressing them into a desired shape (compacted), and then heating the compressed material in a controlled atmosphere to bond the material (sintering). The powder metallurgy process generally consists of following basic steps:

(1) Powder manufacture,
(2) Powder mixing and blending
(3) Compacting
(4) Sintering
(5) Extrusion

Fig.1 samples

Optimisation

Grey Relational Analysis

a. Data Preprocessing

Grey data processing must be performed before Grey correlation coefficients canbe calculated. A series of various units must be transformed to be dimensionless.Usually, each series is normalized by dividing the data in the original series by theiraverage.

Let the original reference sequence and sequence for comparison berepresented as,

*x*o(*k*) and *xi*(*k*), *i*=1, 2, . . .,*m*; *k*=1,2, . . ., *n*, respectively,

where*m* is thetotal number of experiment to be considered, and *n* is the total number of observationdata. Data preprocessing converts the original sequence to a comparable sequence.Several methodologies of preprocessing data can be used in Grey relation analysis,depending on the characteristics of the original sequence

For larger-the-better

$$x_i^*(k) = \frac{x_i^{(O)}(k) - \min .\ x_i^{(O)}(k)}{\max .\ x_i^{(O)}(k) - \min .\ x_i^{(O)}(k)}$$

For smaller-the-better

$$x_i^*(k) = \frac{\max .\ x_i^{(O)}(k) - x_i^{(O)}(k)}{\max .\ x_i^{(O)}(k) - \min .\ x_i^{(O)}(k)}$$

b. Grey Relational Coefficients and Grey Relational Grades

$$\gamma\left(x_0^*(k), x_i^*(k)\right) = \frac{\Delta_{\min .} + \zeta\, \Delta_{\max .}}{\Delta_{0i}(k) + \zeta\, \Delta_{\max .}} \qquad 0 < \gamma\left(x_0^*(k), x_i^*(k)\right) \leq 1$$

Here, the Grey relational grade represents the level of correlation between thereference and comparability sequences. If the two sequences are identical, then thevalue of the Grey relational grade equals to one. The Grey relational grade alsoindicates the degree of influence exerted by the comparability sequence on thereference sequence. Consequently, if a particular comparability sequence is moreimportant to the reference sequence than other comparability sequences, the Greyrelational grade for that comparability sequence and the reference sequence willexceed that for other Grey relational grades.

Grey Relational Analysis for Stir Casting

1. Performance characteristics

SiC percentage	Density	Hardness	Compressive strength	Double shear strength	Tensile strength
15 %	2.2705	111.36	110.75	27.4	242
20 %	2.3265	114.33	160.1	28.2	265.4
25 %	2.3820	127.38	187.3	28.8	257.2

2. The sequences of each performance characteristic after data processing

SiC percentage	Density	Hardness	Compressive strength	Double shear strength	Tensile strength
Reference sequence	1.0000	1.0000	1.0000	1.0000	1.0000
15 %	1	0	0	0	0
20 %	0.498	0.185	0.645	0.5714	1
25 %	0	1	1	1	0.6496

3. Calculated Grey Relational Coefficient and the Grey Relational Grade

SiC percentage	Grey relational coefficient					Grey relational grade, ξ	Rank
	D	H	C	S	T		
15 %	1	0.3333	0.3333	0.3333	0.3333	0.4666	3
20 %	0.50	0.3802	0.5848	0.5384	1	0.60	2
25 %	**0.333**	**1**	**1**	**1**	**0.588**	**0.7842**	**1**

Grey Relational Analysis for Powder metallurgy

4. Performance characteristics

SiC percentage	Density	Hardness	Compressive strength	Double shear strength	Tensile strength
15 %	2.625	98.5	159.15	26.35	222.4
20 %	2.5814	105.7	212	26.44	238.93
25 %	2.8159	131	194.5	27.093	208.7

5. The sequences of each performance characteristic after data processing

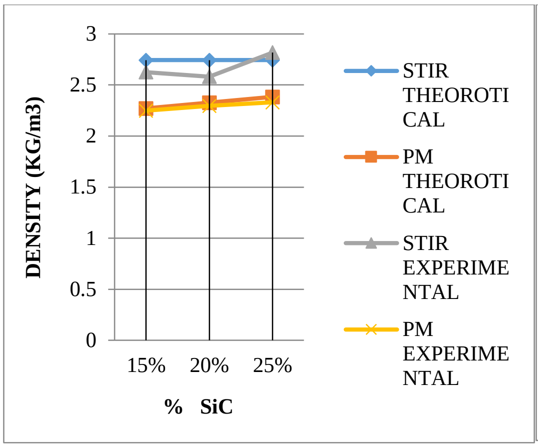
SiC percentage	Density	Hardness	Compressive strength	Double shear strength	Tensile strength
Reference sequence	1.0000	1.0000	1.0000	1.0000	1.0000
15 %	0.8141	0	0	0	0.471
20 %	1	0.2215	1	0.1211	1
25 %	0	1	0.6689	1	0

6. Calculated Grey Relational Coefficient and the Grey Relational Grade

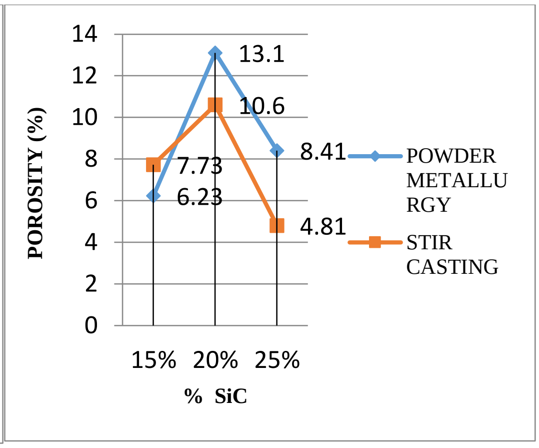
SiC percentage	Grey relational coefficient					Grey relational grade, ξ	Rank
	D	H	C	S	T		
15 %	0.729	0.333	0.333	0.333	0.486	0.443	3
20 %	**1**	**0.3910**	**1**	**0.3626**	**1**	**0.7507**	**1**
25 %	0.333	1	0.6016	1	0.333	0.6533	2

III. EXPERIMENTAL RESULTS AND DISCUSSION

It has been observed that, there is no major changes in the density byincreasing amount of SiCGr 1 shows that the increment in the density. Theoreticaldensity is slightly greater than the experimental density. Also the componentsmanufactured by powder metallurgy shows less values of density as compared withstir casting which is desirable property.



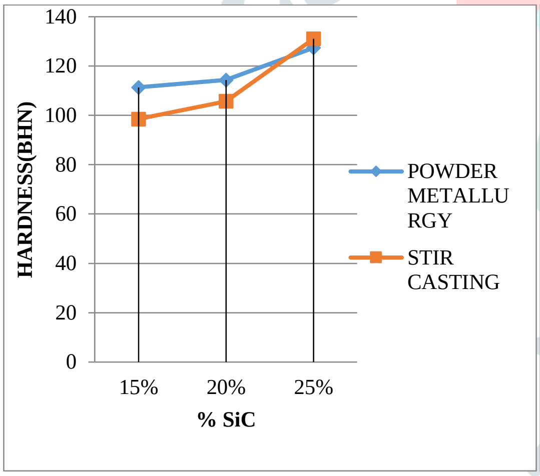
Gr.1 Density variation with Sic



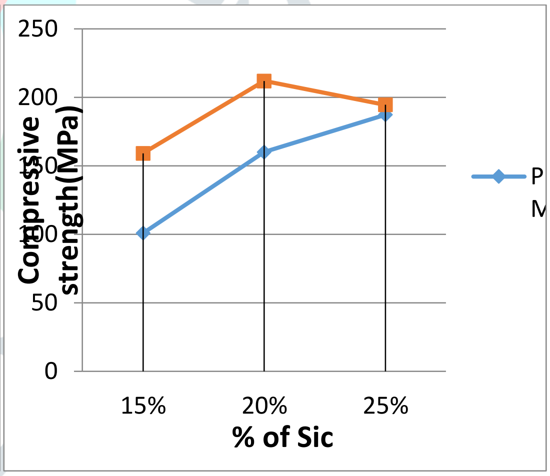
Gr.2 Porosity variation with Sic

From Gr.3 it has been observed that, Hardness of the pure Aluminium increaseswith the increase in percentage of Sic, without an increase in density of aluminiumwhich is desirable for light weight material. If we compare the hardness of pure Alwith the MMC's there is a significant increment in the hardness. Also in comparisonbetween PM and stir casting, PM shows greater value of hardness due to uniform distribution of SiC particles as compare to stir casting process.

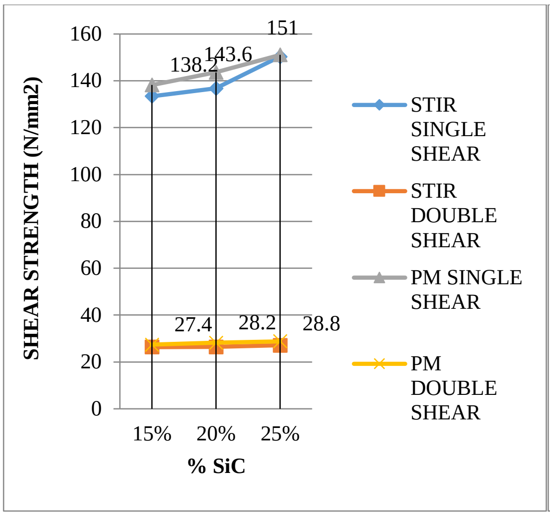
Gr.4 shows that there is an appreciable increment in the compressive load onadding the SiC. Pure Al has compressive strength up to 74 MPa, There issignificant rise in compressive strength without increment in density, which is adesirable property of light weight material. At low % of sic, there is perfect crackto the specimen, but at more percentage, i.e. 25 % of SiC s there is no cracks onspecimens. This is due to the proper and homogeneous dispersion of sic particlesin Al matrix developed by PM route. In stir casting, Sic does not distributeuniformly. So due to the improper dispersion of sic particles in Al matrix, mmcdoes not show appreciable increase in compressive strength as compare to PMTechnology.



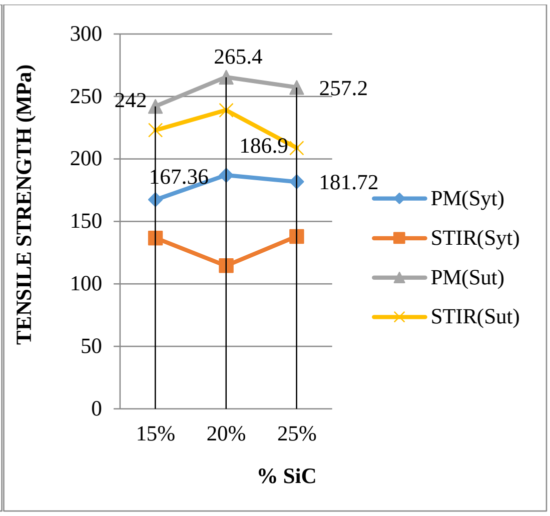
Gr 3 Hardness variation with Sic



Gr.4 Compressive Strength variation with Sic



Gr.5 Shear Strength variation with Sic



Gr.6 Tensile Strength variation with Sic

From Gr.5 it has been observed that, with addition of Sic, tensile strengthincreases up to 20-22% without changing density of material which is desirable forlight weight material but after exceeding certain value, it decreases in both thefabrication routes. As SiC material increases, Yield strength increase. This is due to the properdispersion of SiC in Al matrix and strong bonding between sic particles and Almatrix. Also the specimen developed by powder metallurgy shows more strength ascompare to stir casting.

Optimisation

The overall evaluation of the multiple performance characteristics is based on thegrey relational grade. The experimental results can be Analyze using the greyrelational grade. Here Rank 1 i.e. 25 % indicates the optimized percentage of SiCwhich shows best desirable properties for given application prepared by powdermetallurgy route. Also Rank 1 i.e. 20 % indicates the optimized percentage of SiCwhich shows best desirable properties for given application manufactured by stircasting route.

IV. CONCLUSION

Al powder as base matrix mixed with SiC as a reinforcement material in weight percentages of 15, 20 and 25, are produced through powder metallurgy route. The specimens are Sintered and extruded successfully. All the Specimens were subjected to evaluate the behavior of mechanical properties of MMC‘s.

From the investigation, we conclude that,Hardness increases without increase in Density of composites, Observable rise in hardness and compressive strength without increase in brittleness, Shear strength increases with increase in Sic percentage, Tensile strength also increases with addition of Sic up to 20-22% and then again decreases, Mechanical test results shows better properties of specimen prepared by PM technique than stir casting, 25 % optimized percentage of Sic prepared by powder metallurgy route and 20 % optimized percentage of Sic manufactured by stir casting route, SEM analysis shows that the mechanical properties of composite increases with Sic , but due to uniform distribution of Sic, Powder metallurgy may become a best route for MMC manufacturing compared with stir casting.

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