iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** IV **Month of publication:** April 2019

DOI: https://doi.org/10.22214/ijraset.2019.4440

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue IV, Apr 2019- Available at www.ijraset.com

Fabrication and Characterisation of Metal Matrix Composites

Sakshi Singh[1], Prateek Gangwar[2]
[1]M.Tech. Scholar, [2]Assistant Professor, ME Department Faculty of Engineering and Technology, Rama University

Abstract: Currently, it has been observed that combining the prodigious properties like high specific strength, fracture strength, Young's Modulus, good thermal and electrical property, metal matrix composite (MMCs) has held the desirability for the replacement with the existing materials in the field of aerospace, electronics and automobiles. In connection to this, type and appropriate amount of reinforcement in a metal matrix play a significant role to prove this system as a potential candidate to be used in light weight metal matrix composite application. In the present study metal is melted in furnace as per melting point of material and reinforcement material are also melted with a molten matrix metals by means of mechanical stirring. The melted liquid is casted by conventional casting methods. The properties are then characterized to study various properties such as vibrations and damping capacity.

Keywords: Matrix, Reinforcement, Stir Casting, Damping, melting Point

I. INTRODUCTION

Metal matrix composites (MMCs) are made of a continuous metallic matrix and one or more discontinuous reinforcing phases. The reinforcing phase may be in the form of fibers, whiskers or particles. MMCs are made by dispersing a reinforcing material into a metal matrix**.**

Types of metal matrix composites on the basis of reinforcement in MMC

1) Particle reinforcement
2) Short fiber reinforcement
3) Continuous fiber reinforcement
4) Laminate reinforcement

A. *Advantages of Metal Matrix Composites*

1) High strength & Toughness
2) Low sensitivity to changes in temperature.
3) Low sensitivity of surface flaws
4) High Electrical conductivity.
5) Higher temperature capability.
6) Better radiation resistance

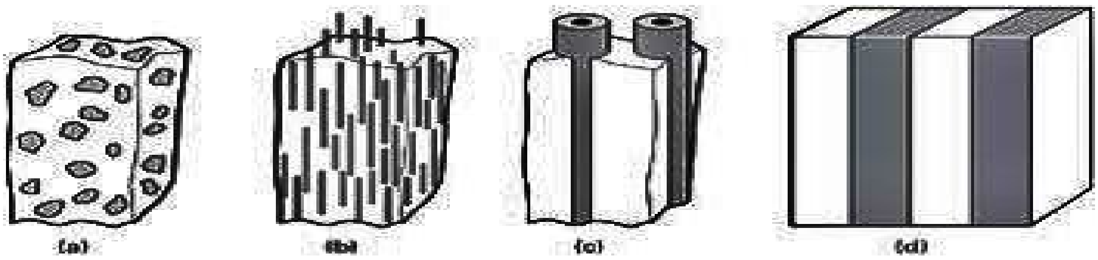


Fig 1: Metal matrix composites on the basis of reinforcement in MMC **[1]**

B. *Reinforcement*

The reinforcement material is embedded into the matrix. It is used to modify the properties. Reinforcements for metal matrix composites have a manifold demand profile, which is determined by production and processing and by the matrix system of the composite material. The material used as a reinforcement must have Low density, High Young's Modulus, High compression and tensile strength[2].

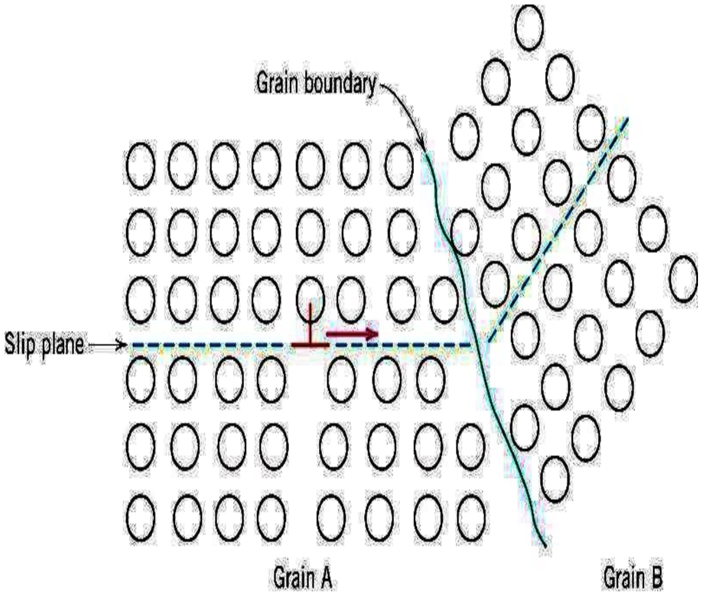
Table 1
Metal Matrices and their Reinforcement [5]

Matrix	Reinforcements
Aluminium and alloys	C, Be, SiO_2, B, SiC, Al_2O_3, Steel, B_4C, Al_3Ni, Mo, W, Z_rO_2
Titanium and alloys	B, SiC, Mo, $SiO_{2,}$ B_e,ZrO_2
Nickel and alloys	C, B_e, $Al_2O_{3,}$SiC, Si_3N_4, steel, W, Mo, B
Magnesium alloys	C, B, glass, Al_2O_3
Molybdenum and alloys	B, ZrO_2
Iron and Steel	Fe, Steel, B, Al_2O_3, W, SiO_2,ZrO_2
Copper and alloys	C,B, Al_2O_3, E-glass

II. MECHANISM OF PROPERTY MODIFICATIONS

A. Strengthening Mechanisms

1) Grain Size Reduction



2) *Solid Solutions:* Due to presence of impurity atoms distortion in lattice takes place which generate the stress. The stress produce a barrier to dislocation motion.
3) *Strain Hardening (Cold Work):* Room temperature deformation.

Common forming techniques used to change the cross sectional area

a) Forging
b) Rolling
c) Drawing
d) Extrusion

4) *Annealing:* Process where material is heated to above the recrystallization temperature of the sample and then cooled down. Main purpose is to improve Cold work properties by increasing ductility and retaining most of the hardness.

B. Mechanisms of Elastic Modulus

A change in shape caused by the applied stress is completely reversible and the specimen will return to its original shape on release of the applied stress. The elastic properties of materials can be understood by considering the attractive and repulsive forces between atoms and molecules. Elastic strain results from a change in the intermolecular spacing and, at least for small deformations, is reversible [3].

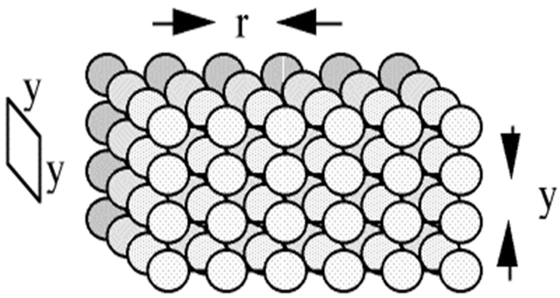


Fig. 2 Attractive and Repulsive forces between atoms

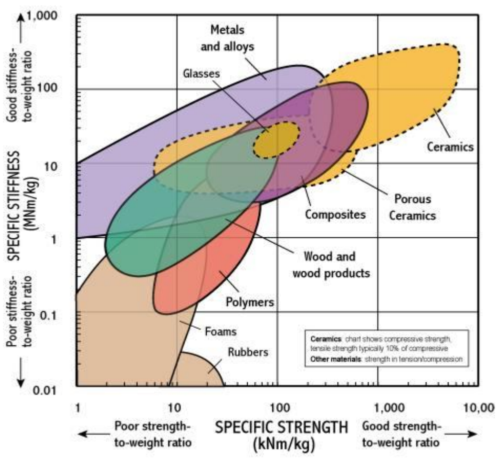


Fig. 3 Specific Strength v/s Specific Stiffness[8]

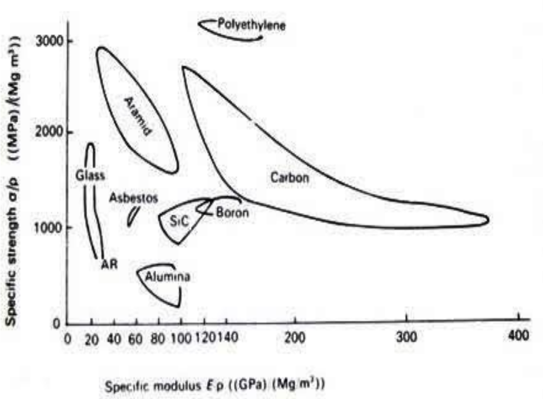


Fig.4 Specific Modulus v/s Specific Strength[7]

C. Damping Mechanism

Damping is primarily associated with the irreversible transition of mechanical energy into thermal energy. In metals, Defects such as dislocations, phase boundaries, grain boundaries, and various interfaces also contribute to damping, since defects may move slightly and surface may slip slightly with respect to one another during vibration, thereby dissipating energy. Microstructure greatly affects the damping capacity of material.

The effect of SiC and graphite particulates on the damping behaviour of metal matrix composites has been investigated by Zhang et al. They demonstrated that the damping capacity of aluminium alloy was significantly improved by the addition of either SiC or graphite particulates.

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III. METHODOLOGY

A. Fabrication Methods
1) Liquid-phase processes
a) Stir Casting
b) Infiltration
2) Solid–liquid processes
a) Diffusion Bonding
b) Powder Processing or Powder Metallurgy
3) Deposition techniques
a) Spray Forming
b) Electroplating
c) Spray Deposition
d) Chemical Vapour Deposition (CVD)
4) In situ processes
5) Two- phase (Solid–liquid) processes

B. Steps of fabrication in Stir casting Method
1) Metal is carried out in molten form in furnace according to melting point of material.
2) Reinforcing materials (ceramic particles, fibers) are melted with a molten matrix metal by means of mechanical stirring.
3) The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies

Fig.5: Stir Casting

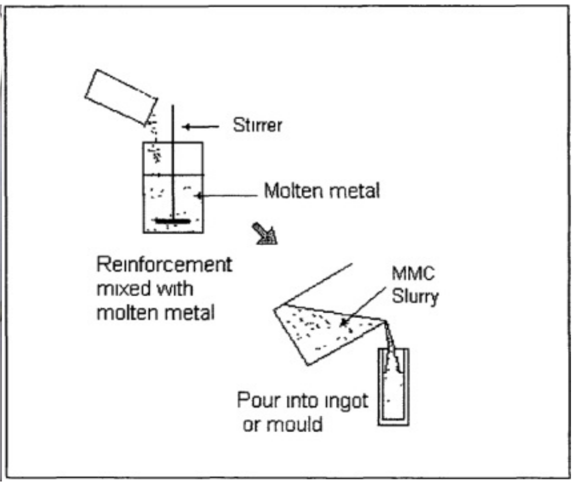

Fig 6: Schematic Diagram of Stir Casting **[10]**

C. The Attention is Paid
1) To achieve uniform distribution of the reinforcement material.
2) To obtain sufficient wettability between the two main substances.
3) To reduce porosity in the cast metal matrix composite.

Various process parameters to obtain good metallurgical properties of MMCs:
a) Stirrer design
b) Stirrer spee
c) Stirring temperature
d) Stirring time (Holding time)
e) Preheat temperature of reinforcement
f) Preheated Temperature of mould
g) Reinforcement Feed Rate
h) Wettability-promoting agent
i) Pouring of melt

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D. Precautions/Safety Measures

1) Always wear an apron as it will protect your clothes and hold loose clothing such as ties in place.
2) Wear good strong shoes. Training shoes are not suitable.
3) When learning how to use a machine, listen very carefully to all the instructions given by the teacher. Ask questions, especially if you do not fully understand.
4) Keep hands away from moving/rotating machinery.
5) Always wear safety glasses, or face shields designed for the type of the work operating any machine.
6) Even after the power is off, don't leave the machine until it has stopped running. Someone else may notice that it is still in motion and be injured.
7) Work in an airy room for further safety.

E. Measurement of Damping

There are two ways to measure the damping:

1) *Under Free Vibration Condition:* Logarithmic decrement method is used to measure damping in time domain. In this method the free vibration displacement amplitude history of a system to an impulse is measured and recorded. Logarithmic decrement is the natural logarithmic value of the ratio of two adjacent peak values of displacement in free decay vibration
2) *Under Forced Vibration Condition:* The half-power band method is based on the points related to the half-power to define the damping of the system under forced vibration. This method gives estimation of the damping rate for system with damping lower than 0.05. The procedure is based on determining the frequencies in the points Z_1 and Z_2 located in the answer curve, 3dB below the maximum amplitude. The bandwidth between these points is the frequency known as 'half-power band. Damping of material can be characterized by vibration under free and forced condition. Damping ratio is calculated with the help of logarithmic decrement in free vibration condition. Half power band width (HPBW) method is used to find damping in terms of loss factor under forced vibration. The loss factor. $\boldsymbol{\eta = (\omega_2 - \omega_1)/\omega_n}$ and, where ω_n is natural frequency and ω_1 and ω_2 are frequencies corresponding to $An/\sqrt{2}$ where An is maximum amplitude at ω_n.

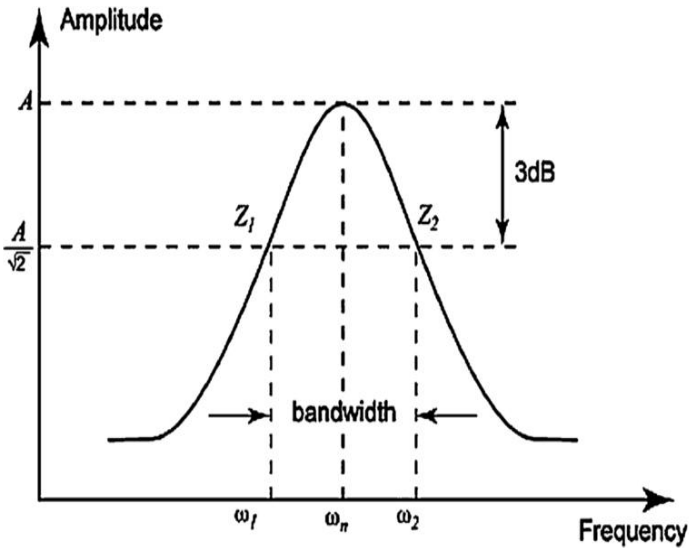

Fig. 7 Half power width method

F. Experimental Procedure

Fabrication of Al-MMC

Composition: Aluminium Alloy 1100 = 90%, Silicon Carbide = 5%, Graphite = 5%

First of all, the metal was melted in a graphite crucible in an open hearth furnace. Adjust the temperature according to the melting point of the material. Add the Silicon Carbide and Graphite to the already melted Aluminium and melt them together. Then stirring is done at 400 rpm for 5 minutes.

Fig. 8 Melting in Stir casting process

The mixture is taken out in molten form and poured it into a mould. After solidification it is revert back from the mould.

Fig. 9 Solidification of composite into the mould

G. *Vibration Characterization*

1) *Vibration Testing Setup:* The experimental setup consists of a cantilever beam, transducers (accelerometer, laser sensor), a data-acquisition system and a computer with signal display and processing software. The values of damping ratio, damping frequency for vibration test are obtained as follows and the values of logarithmic decrement and loss factor are also calculated

Length- 12.0 cm, Width- 2.0 cm, Height- 0.5 cm

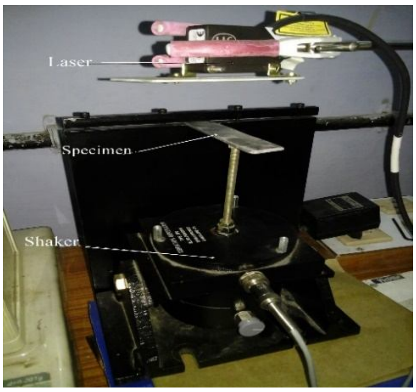

Fig.10: Shaker (Vibration testing system)

IV. RESULTS & DISCUSSIONS

Damping Properties	Aluminium	Composites(90%Al, 5%Si, 5%Gr)
Damping Ratio (ξ)	0.00194	0.002035
Loss Factor (η)	0.0066	0.002310

V. CONCLUSIONS

1) *Fabrication:* In this work, the Silicon carbide-graphite reinforced Aluminium composite was fabricated using stir casting method.
2) *Damping:* To enhance the damping property to add the Silicon Carbide and Graphite to the already melted Aluminium and melt them together.

The significant conclusions of the studies carried out on composites are as follows:

A. The composite with 90% aluminium 1100, 5% silicon carbide, 5% Graphite has improved damping properties such as damping ratio and loss factor as compared to its base alloy aluminium 1100.
B. The Aluminium silicon carbide graphite composites possess good dynamic properties as well as high damping.
C. Silicon carbide-graphite reinforced composites are better materials to be used for damping vibrations.

VI. ACKNOWLEDGMENT

The authors would like to acknowledge the facilities of Rama University to carry out the research work.

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