Vibration Characteristics of Aluminium Reinforced with SiC - A Review

Srinidhi Acharya S R [1], Dr. Suresh P M [2], Dr. Suresh R [3]
Assistant Professor, Department of Mechanical Engineering, ACS College of Engineering, Bangalore, VTU Research Centre, Bellagio, India [1],
Professor, Department of Mechanical Engineering, ACS College of Engineering, Bangalore, India. [2]
Professor and Program Coordinator, Department of Mechanical Engineering, VTU, Mysore [3]

Abstract:- **Over a past few decades Aluminium and its Alloys is an important topic in the research field as it plays a vital role in aircrafts and automobiles sectors. Aluminium when mixed with reinforcements such as Silicon Carbide, Titanium carbide, etc is more advantageous over other materials due to its mechanical properties. It is inexpensive and having high strength to mass ratio. It is important to do vibration analysis because it gives the information about dynamic characteristics like natural frequency and mode shapes. Hence, the evaluation of mode shape and frequency response is important. Designers should consider resonant frequencies and modal shapes in designing the component. The structural members are generally subjected to vibrations in the form of external excitation. The modal analysis helps designers to design the structures which withstand the vibration effect resulting in better life span of the structure.**

The processing of Aluminum composites is changing continuously over a period of time. Considering the quality of the product and the ease of fabrication the commonly employed processing techniques are stir casting, squeeze casting, powder metallurgy, infiltration and reactive in situ techniques are employed.

This review work emphasizes on the vibration characterization of aluminum composites with various reinforcements fabricated using stir casting technique. Also to consider the dynamic characteristics like natural frequencies and modal shapes.

***Key Words**: Aluminium, Reinforcements, Modal Analysis, Vibration Analysis, FFT Analyser*.

1. INTRODUCTION

Composite material is a mixing up of two or more materials with different chemical and physical properties. These materials are mixed at large scale to obtain a newer material which possesses improved strength and stiffness. Also the other properties such as strength, surface hardness, corrosion resistance protection, surface characteristics, and weight and fatigue life are enhanced.

Aluminum based metallic lattice composites show an increasingly erosion obstruction, wear and other mechanical properties. Aluminum Metal Composites (AMCs) are of light weight and superior material frameworks. Their high quality, strength, low weight and different attributes of MMC's make them as the widely accepted materials for various applications in aircrafts, automobiles and transportations applications.

An extensive range of research oriented towards the mechanical properties and characterizing the connection between those properties, microstructure, and processing methodology has been done.

2. STUDIES RELATED TO FABRICATION PROCESS.

M. Vijaya et.al., [1] developed and obtained the Mechanical Properties of Aluminium reinforced with SiC. They worked on the Al 6351 reinforced with SiC properties which is manufactured by liquid metallurgy process (Stir casting). The reinforcement ranged from 2% - 10% of SiC powder. Mechanical properties such as Hardness, Tensile Strength and Yield Strength of the MMC's was done. The results indicated that Aluminium alloy increases with increase weight percentages of SiC and % of elongation decreases. Also, the microstructures are observed through Scanning Electron Microscope (SEM) analysis and confirmed that a homogeneous dispersion of SiC particles. The addition of SiC into the Al 6351 material causes the composite exhibit better mechanical properties with increased hardness, strength and density.

Cao Fenghong et.al., [2] studied the effect of Silicon Carbide and Tungsten Carbide in Aluminium Metal Matrix Composites (MMC's). They adopted a stir casting method to synthesis the Al6061/SiC/WC hybrid aluminum composites with a different mass percentage of reinforcement. Mechanical properties such as tensile Strength, Compressive strength, resistance to wear, Hardness were investigated. Micro structural analysis like SEM analysis was done. From the analysis it was observed that reinforcement particles have been uniformly distributed without clustering of particles in matrix alloy. Hardness of hybrid composites has been enhanced due to incorporation of stronger reinforcement in the matrix material. The addition of SiC and WC reinforcement in the matrix improved the mechanical properties like compressive, tensile strength and wear resistance of aluminum hybrid composite.

Vedrtnam et.al., [3] fabricated and characterized wear properties Aluminium with Silicon Carbide and Copper. Aluminium matrix with SiC of 3, 6, and 9 weight Percentage and Cu with 0.5, 0.75 and 1 weight percentage were used as the reinforcement to obtain the composite using stir casting principle as shown in the figure 1. SiC reinforcements particles were preheated at a temperature of 750°C for more than 30 minutes. During this process, the composite melts and was continuously stirred using a mechanical stirrer for about 30 Minutes in order to obtain a proper dispersion of the reinforcement in the matrix. Finally, their test result depicts that the higher weight percentage of reinforcements, less load, sliding distance, and speed results in a minimal wear loss of the composite.

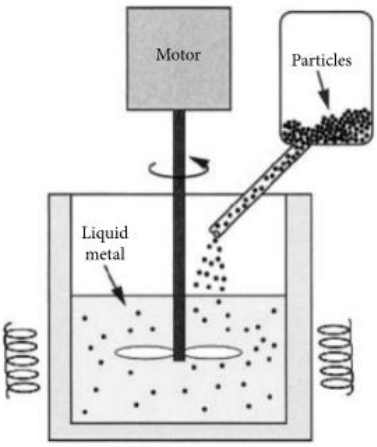

Figure .1: Stir Casting Process

Srinidhi Acharya S R et.al., [4] selected Al7075 and the base material and powdered Silicon Carbide (SiC) as the reinforcement. A various percentage of SiC (2% to 10%) was mixed with Al 7075 using a stir casting technique. For the dispersion of reinforcement in the matrix the Power X ray diffractions (XRD) and Scanning Electron Microscopy (SEM) tests was conducted. Microstructures clearly revealed that the proper and homogenous distribution of SiC in Al 7075 indicting the stir casting operation was successful.

3. STUDIES RELATED TO VIBRATION ANALYSIS.

Baij Nath Singh et.al., [5] analyzed vibration mode localization of rectangular plate. Modal analyses were conducted to obtain the natural frequencies and natural modes of the system. Rectangular aluminum plate model was simulated in this paper using ABAQUS® 13.1 and Pulse 18.1. Vibration Mode localization analysis using point mass variation has been carried out. Mode shapes and frequencies obtained showed that vibration along major portion of the plate is found to be curbed.

Amreen Taj et.al., [6] conducted experiment on vibration analysis of Aluminium Graphite MMC's using FFT analyzer as shown in the figure 2. The experimental and FE modal analysis of the Aluminium-Graphite composite was conducted successfully with FFT Analyzer and ANSYS. The analytical and experimental results agreed with each other with s slight deviation of 1 to 10%. The damping factor varied from 0.098 to 0.033 which concluded that the density of the alloy decreases when graphite as the reinforcement is increased. Further, it was concluded that Aluminum Graphite alloy is an under damped system.

Robert R. Claryn et.al., [7] obtained the vibration characteristics of Aluminum Plates Reinforced with Boron-Epoxy Composite Material. The vibrations of these MMC's were investigated experimentally and analytically. Variations in the natural frequencies, mode shapes, and damping were studied and were compared with base aluminum plates. The obtained results demonstrate the advantage of using directional composite materials in design for controlling vibrations of plates. The experimental results showed that the reinforced plates have more damping value when compared to aluminum plates.

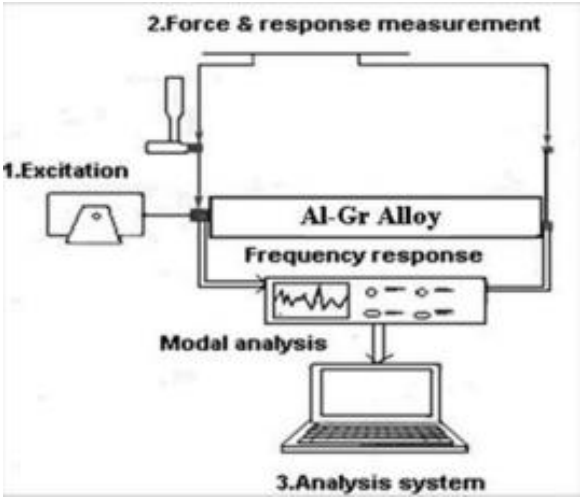

Figure 2: FFT Analyzer Experimental Setup

Ersoy Fatih Erdurcan et.al.,[8] conducted Free Vibration Analysis of a Functionally Graded Material Coated Aluminum Beam. The work focused on a theoretical investigation on the free vibration of a symmetric beam consisting of an aluminum core coated with functionally graded material. The Young's Modulus and density are varied throughout the thickness of the coating material using a polynomial and an exponential function. To model the gradually changing mechanical properties in a truthful way, the coating is represented by 25 layers of material, whereas each layer itself is homogeneous and isotropic. To obtain a numerical solution, the Timoshenko finite element model beam theory is used. For this purpose, a finite element code was written using MATLAB and the natural frequencies of the beam were found. It was clearly observed that the studied parameters had a significant effect on the natural frequencies.

Santhosh N et.al., [9] performed vibration tests of Aluminium 5083 reinforced with Silicon Carbide (SiC) and Fly ash with varying weight percentage. The casting was done using stir casting and MMC's were obtained. The resulting samples were subjected to vibration test using FFT Analyzer. The dynamic characteristics alloy was done and concluded that 9% SiC and 2% fly ash leads to better damping characteristics. The initial four natural frequencies were analysed using experimental and simulation methods for the cast samples. Theses frequencies varied between 35 Hz to 350 Hz while the FRF Magnitude varies from 0.02 mm to 1.12 mm for different compositions of the specimens. The results indicated in experimental and simulation values wherein close relation.

A. P. Kumbhar et.at., [10] investigated vibration response and mechanical characterization of Aluminium alloy 6061/Sic composite. These MMC's (AAMMC) are mainly used in sliding wear application, automobile, Aircraft and aerospace components, Marine fittings, Transport and other industry are becoming highly advantageous due to their excellent wear resistance, lighter weight, higher strength and durability. The effect of reinforcement percentage on vibration response and mechanical properties of metal matrix composite has been investigated. Composite material was prepared by varying SiC (0, 3, 6, and 9 wt. %) by stir casting method. Natural frequency, tensile strength, Rockwell hardness and compressive strength were analyzed. The result shows that,

addition of SiC in Aluminium matrix increases natural frequency, hardness, tensile strength, compressive strength and 9 wt. % showed maximum natural frequency, hardness, tensile strength, compressive strength.

M Gunashekar Reddy et.al., [11] evaluated free vibration properties of Glass fiber-ISO resin bar. They fabricated the different combination of bars by changing the fiber glass thickness and ISO resin. The natural frequencies of all the specimens for different combination of bars were performed using experimentation and FEA. They concluded that increase in the percentage of glass fiber the frequency reaches a maximum value and decreases thereafter. The maximum natural frequency occurred for specimen with 60% ISO Resin and 40% Glass Fiber.

Yahya Bozkurt et.al., [12] determined the vibration behavior of Metal Matrix Composite (MMC's) used in aerospace industry by FEM. AA2124/SiC/25p material is metal matrix composites (MMCs) reinforced with particles and homogeneous distribution and used majorly in the aerospace industry. Vibrations of these MMC's were evaluated by the finite element analysis (FEM). Initially a rectangular plate of 130×50×3 mm was analysed for natural frequency and was found to be 0-5000 Hz range. Also frequency modes of the material were determined. In order to determine the reaction against the load material, the point has implemented and forced damped vibrations. Finally, the reaction spread by forced vibration damping materials was examined. The analysis of the MMC plates natural frequency and modal frequency of the material in this shape has been determined. The reaction among the materials was measured under node and distributed harmonic forces. natural frequency of the material was determinate as 4092 Hz. At this frequency point, materials can operate without resonance is observed. Also vibration modes of the material were determined. According to the analysis, the results are reliable secure frequency range from 0 to 500 Hz. Because the natural frequency of 4092 Hz material, the limit value is assessed as 5000 Hz. Up to this limit the modes frequencies was 220, 1380 and 3870 Hz, respectively. Material exhibits a fairly consistent behavior across vibrations and does not in different reference ranges.

P.S Samuel Ratna Kumar et.al., [13] conducted modal analysis of Multi-Wall Carbon Nano tube reinforced with AA5083 composite material. Al 5083 is widely accepted material used for structural applications due to its strength to weight ratio and resistant to corrosion environment. By adding, Multi-wall Carbon nanotube with Aluminium alloy 5083 in different compositions, the mechanical property of the composite material is enhanced. Mechanical properties of the material play a vital role for evaluating the frequency and deformation under different loading conditions. In this present work using Finite Element Method, free vibration study was carried out to find the natural frequency for the alloy and composite material. Modal analysis results show, the shifting of frequency than for the composite materials compared to the base alloy due to the addition of Multi-Wall Carbon nanotube (MWCNT) and the results were validated using analytical method.

A dynamic characteristic like natural frequencies and modal shapes of Aluminium 6061 plates were analyzed by Sanagondla Bugide Ramu et.al., [14]. Modal analysis was conducted by both simulation and experimental methods. Experimentation was conducted on Aluminium Plate with thin tire tube attached to it for different dimensions which acts as damper. The first five natural frequencies were derived. The test results yield that natural frequencies of flat aluminum plate and aluminum plate with covered tire tube sheets are significantly varied because of change in mass and properties of material.

The present study involves a review about the fabrication process and vibration characteristics of Aluminium with different various weight or volume percentage of Silicon Carbide (SiC) by stir casting method and the effect of Silicon carbide particulates on the vibration characteristics. The Aluminium plates or rods were manufacturing using per ASTM Standards. The prepared alloys are subjected to vibration test and following aspects were reviewed.

- Dynamic Characteristics of alloys.
- To study the effects reinforcements on the dynamic characteristics.

4. MATERIAL SELECTION AND ITS PROPERTIES

4.1 MATRIX MATERIAL: ALUMINIUM

Aluminium with zinc as the major constituting element is the widest range of Metal Matrix Composites (MMC's). Its excellent mechanical characteristics like high ductility, good strength, High toughness, and increased resistance to fatigue, greater Young's Modulus, less density, increased thermal conductivity.

It is the widely accepted Aluminium alloy used for many structural applications with high stressed condition. It is extensively used in many aircraft and automobile structural parts. Al 7075 alloy's composition approximately includes 5.62–6.18 % of zinc, 2.13–2.49 % of magnesium, 1.19–1.62 % of copper, and a minimum percentage of silicon, iron, manganese, titanium, chromium, and other metals.

4.2 REINFORCEMENT: SILICON CARBIDE (SIC)

The reinforcement is generally placed in matrix material to strengthen few mechanical properties like wear resistance, hardness, density, porosity, mechanical strength, thermal expansion, and electric conduciveness. Reinforcement can be either continuous, discontinuous, particle or whisker form. Silicon Carbide (SiC), also known as carborundum is a semiconductor majorly constituting silicon and carbon. It is naturally occurring and a rare mineral.

5. METHODOLOGY:

The process involves melting of heating of Aluminum at a temperature of 800ºC above the melting point temperature of Aluminum. Further, the molten metal is initially stirred with a rotating spindle of the impeller at a speed of 300 rpm. Then the reinforcement Silicon Carbide (SiC) is added in various volume and weight percentage. The mixture is then stirred at a higher temperature of 750º C for about 30 minutes as shown in figure 3.

Figure 3: Stir Casting Process.

5.1 Vibration Analysis using FFT (Fast Fourier Transform) Analyzer

Vibration is a Mechanical characteristic where in the dynamic movements of the alloy are analysed. Its analysis used to detect the flaws in any rotating parts such as Fans, Motors, Pumps, Gearboxes, other structural members and automobile parts. A Fast Fourier Transform (FFT) is an algorithm type that computes Discrete Fourier transform (DFT) for any sequence. The DFT is obtained by sending a series of sequence values into components at different frequencies. Fourier transforms are extensively used for applications in various fields like engineering, music, science, and mathematics. The FFT or Fast Fourier Transform range analyzer utilizes advanced flag handling procedures to break down a waveform. The FFT analyzer consists of:

- Data Acquisition (DAQ) system:8xACC (Dual Core), USB-based 8-channel IEPE/Voltage unit
- Sensors and transducers: Modal hammer Dewesoft IH-400N-1 (scaling: 22,7 mV/N), Acceleration sensor
- Dewesoft I1T-50g-1 (scaling: 99,3 mV/g)
- Used software: Dewesoft X2, DSA package (including Modal test FRF)

5.2 Experimental Procedure:

Initially, the lines are marked in the form of blocks. Each intersection point is treated as single node. A constant torque is applied to fasten the bolt using torque wrench. The Personal Computer (PC) is connected to the vibration analyzer equipment through cables. Impact Hammer is Connected. An Accelerometer is fixed to the last node. Hammer excitation is done. The resulting vibration response of the sample at any Now, open the software in PC which analyses the input signals that are received to vibration analyzer. The software in PC will give the respond and gives the resonant frequencies.

The vibration tests are carried out using an experimental setup established in concurrence with the ISO 230-8 standards, the setup comprises of a mild steel frame with rubber cushioning and grouting to damp the vibration, C clamps, accelerometer probes, amplifiers, modal hammers; The accelerometer probes are connected to the data acquisition system which in turn is interfaced with the system through a LAB VIEW software for interpretation of the results for better visualization.

Vibration analyzer will get the signals from impact hammer and accelerometer. This signal then enters the second channel of the FFT analyser, where its frequency response will be obtained. The response point was kept fixed at a particular point and the location of excitation was varied throughout the plate. Both input and output signals are investigated by means of FFT and resulting frequency response functions are transmitted to a computer for modal parameter extraction. The output from the analyser will be displayed on screen. The results thus obtained by experimental methods are further validated using ANSYS modal analysis.

6. CONCLUSION

From the literature review it is clear that,

- Stir casting method is the effective method for fabrication process. These methods of fabrication give the homogenous dispersion of reinforcement in the Aluminium Matrix.
- Microstructure investigations like Scanning Electron Microscopy (SEM) and Power X Ray Diffraction (XRD) clearly reveals the presence of reinforcements in the Aluminium matrix.
- Fast Fourier Transforms (FFT) Analyzer gives a clear view about the natural frequency and Damping values.
- From experimentation and simulation data obtained, it is clear that the Hybrid Metal Matrix Composites (HMMC's) with 8 to 10 weight percentage of reinforcements in the matrix yields better damping characteristics.
- From the review it is clear that the addition of reinforcements increases the mechanical properties like hardness toughness, Yield Strength, wear resistance and damping ratio leading to better dynamic characteristics, this is because of the reason that these reinforcements does not allow the waves to transmit from one atomic interstitial periphery to the other, thereby reducing the frequency and amplitude of vibrations resulting in damping of the vibrations.

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