Vibration Analysis of Aluminum Alloy Based Hybrid Composite Material

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Abstract - These focuses on the Vibration analysis of seven different Hybrid composite materials. The composites include varying compositions of LM6, Si_3N_4, and MoS_2. Static structural analysis was conducted to evaluate the deformation behaviour under applied loads, while modal analysis was performed to investigate the natural frequencies and mode shapes. The results provide insights into the mechanical properties and dynamic behaviour of the composites. Comparisons between different compositions reveal the effects of Si_3N_4 and MoS_2 on the stiffness, strength, and deformation characteristics of the LM6 matrix material. The analysis was conducted using ANSYS Workbench software, employing numerical simulations and theoretical models. The static structural analysis investigated the deformation behaviour of the composites under applied loads, providing insights into their mechanical properties such as stiffness, strength, and deformation characteristics. Modal analysis was performed to study the natural frequencies and mode shapes of the composites, enabling the understanding of their dynamic behaviour and vibration properties. By comparing the results of the different compositions, the influence of Si_3N_4 and MoS_2 on the composite's mechanical and dynamic properties was assessed. The outcomes of this project offer valuable insights into the design and optimization of composite materials, propelling advancements in various industries and fostering technological innovation.

***Key Words*:** Vibration, ANSYS Workbench, Static Structural analysis, Modal Analysis, Hybrid Composites, Mode shapes.

1.INTRODUCTION

Due to their remarkable mechanical qualities and adaptability, composite materials have attracted a lot of attention in a variety of industries. The blending of several materials enables the development of composites with improved properties, including increased strength, stiffness, and durability. These materials have uses in a variety of industries, including aerospace, automotive, electronics, and biomedical engineering. The investigation of Nano composite materials has been sparked by the rising demand for lightweight, high-performance materials. For their design and use to be optimized, it is essential to comprehend their mechanical behavior. In assessing the performance and dependability of these materials under various stress circumstances, static and dynamic assessments are crucial. It is possible to get important insights for the efficient design of hybrid composite materials by conducting a thorough study on the static structural and modal analyses of hybrid composite materials.

2. OBJECTIVES AND METHODOLOGY

2.1 Research Objectives

The main goal is to undertake static and dynamic assessments of composite materials, with a particular emphasis on the LM6 matrix material with various Si_3N_4, and MoS_2 compositions. The following are the precise research goals:

- To precisely mesh and model the composite materials in ANSYS Workbench.
- To do static structural analysis to look at the stress distribution and deformation behavior.
- To conduct modal analysis in order to identify the natural frequencies and mode shapes.
- To evaluate and contrast the outcomes for the various composite compositions.
- To draw conclusions about how Si_3N_4, and MoS_2 affect the mechanical performance of composites.

2.2 Scope and Methodology

The static structural analysis and modal analysis of composite materials are the main topics of this study. The study is restricted to the LM6 matrix material in combination with different concentrations of MoS_2 (1%), Si_3N_4 (2%, 4%, and 1%) and LM6. A popular finite element analysis program called ANSYS Workbench is utilized to do the analysis. The research comprises meshing, modeling, and analyzing composite materials step-by-step, then interpreting and contrasting the outcomes. The outcomes will help in the development and refinement of composite materials with specialized mechanical properties for particular applications.

3. LITERATURE REVIEW

2019. Ridwanet al. [1] Analytical and finite element analyses are used to examine the behavior of an aluminum matrix (LM6)/silicon nitride composite. Tests are conducted to determine the static (deformation) and dynamic (natural frequency) behavior of silicon nitride/LM6 composites at volume fractions of 0%, 6%, and 10%. The finite element analysis program ANSYS is used to simulate static analysis (deformation) and modal analysis (natural frequency).

2013 [2] P. Jeyaraj et al. This study uses the finite element method to examine the static behavior of functionally graded carbon nanotube reinforced polymer composite plates in non-uniform increased temperature fields. The expanded rule of mixture and carbon nanotube efficiency characteristics (which include size-dependent material properties) are used to determine the composite plate's effective material qualities.
2011.H.

Joardar et al. [3] In the current experiment, an effort is made to gauge how certain cutting factors, used in dry cutting conditions, affect surface roughness in plain turning of aluminum alloy (LM6) - SiCp metal matrix composites. The influencing parameters are chosen to be cutting velocity, cutting depth, and the weight percentage of SiC in the metal matrix. Three factors, two levels, and a central composite face centered design (CCD) with complete factorial are used in the trials, and the Response Surface Methodology is used to evaluate the data.

4. MATERIALS AND METHODS

4.1 Hybrid Composites

A hybrid composite material is one that combines two or more different types of elements with a matrix material, often two or more different types of fibers or particles. These components, which are picked based on their unique qualities, are merged to produce a material with better qualities than the sum of its parts.

In a hybrid composite, the matrix material acts as a support structure and a means of distributing loads among the reinforcing fibers or particles. It might be made of a polymer, a metal, a ceramic, or a mix of these things. On the other hand, the reinforcing fibers or particles are incorporated into the matrix and help the composite achieve its desired mechanical, thermal, or other qualities.

4.2 LM06

Due to its high strength, outstanding castability, and strong resistance to corrosion, LM06 is a casting alloy made of aluminum that is frequently used in aerospace and automotive applications. It is a hypereutectic alloy, which implies that a significant amount of silicon (12–13%) is present to encourage the development of small, homogeneous silicon particles that add to the alloy's strength and wear resistance. LM06 is excellent for use in high-temperature applications due to its high melting point and low coefficient of thermal expansion.

4.3 Silicon Nitride

This alloy is a useful material for a variety of manufacturing applications since it is also well-machinable and weldable. High strength, high hardness, and resistance to oxidation, thermal shock, and chemical assault are just a few of the outstanding physical and chemical characteristics of silicon nitride, a high-performance ceramic material. Due to these qualities, it can be used for a range of high-temperature and high-stress applications, such as structural components, cutting tools, and more.

4.4 Molybdenum Disulphide

A chemical with good dry lubricating qualities, a high load carrying capacity, and resistance to wear is molybdenum disulphide (MoS_2). It is frequently utilized in friction materials, coatings, additives, and dry lubricants. Because of its stability and chemical inertness, it can be used in hostile conditions.

5. COMPOSITE CATEGORIZATION

Pure LM6: This composite consists of LM6 as the matrix material without any additional reinforcing elements. It serves as the baseline material for comparison against the other composite variations.

LM6 and Si_3N_4 (2%): In this composite, LM6 is combined with Silicon Nitride (Si_3N_4) in a volume fraction of 2% Si_3N_4 acts as a reinforcing element, enhancing the mechanical and thermal properties of the composite.

LM6 and Si_3N_4 (2%): Similar to the previous composite, this variation incorporates Si_3N_4 as a reinforcing element. However, the volume fraction of $Si_3N_4$is increased to 2%, resulting in further improvements in the composite's properties.

LM6 and Si_3N_4 (4%): Similar to the previous composite, this variation incorporates Si_3N_4 as a reinforcing element. However, the volume fraction of Si_3N_4 is increased to 4%, resulting in further improvements in the composite's properties.

LM6 and Si_3N_4 (6%): Similar to the previous composite, this variation incorporates Si_3N_4 as a reinforcing element. However, the volume fraction of Si_3N_4 is increased to 6%, resulting in further improvements in the composite's properties.

LM6, Si_3N_4 (1%), and MoS_2 (1%): This composite includes LM6 as the matrix material, along with Silicon Nitride (Si_3N_4) and Molybdenum Disulfide (MoS_2) as reinforcing elements. Si_3N_4 present in a volume fraction of 1%, while MoS_2 is also added in a volume fraction of 1%. This combination aims to achieve synergistic effects between Si_3N_4 and MoS2, resulting in enhanced properties.

LM6, Si_3N_4 (3%), and MoS_2 (1%): In this composite, the volume fraction of Si_3N_4 is increased to 3%, while MoS2 remains at a volume fraction of 1%. The higher Si_3N_4 content contributes to improved properties, and the addition of MoS_2 further enhances the composite's performance.

LM6, Si_3N_4 (5%), and MoS_2 (1%): This composite incorporates a higher volume fraction of Si_3N_4, specifically 5%, along with MoS_2 at a volume fraction of 1%. The increased Si_3N_4 content aims to maximize the reinforcing effect, and the inclusion of MoS_2 further complements the composite's properties.

By varying the composition of $Si_3N_4$and introducing MoS_2 as an additional reinforcing element, these composite materials offer a range of possibilities for tailoring of LM6-based composites to meet specific application requirements. These 6 composites are categorized into 2 different samples.

6. SAMPLES

6.1 Rule of Mixture for Sample 1

The sample 1 contain various composites C1, C2 and C3.

Where,

C1 - Lm6 (98%), Si_3N_4 (2%)

C2 – Lm6 (96%), Si_3N_4 (4%)

C1 - Lm6 (94%), Si_3N_4 (6%)

SI.No	YOUNGS MODULUS (Gpa)	POISSON RATIO (no unit)	DENSITY (g/cc)
C1	E= 71	v =0.3	ρ = 2.68
C2	E= 75.78	v=0.3	ρ= 2.6952
C3	E= 80.56	v= 0.3	ρ= 2.7104

Table 1: Rule of mixture of sample 1

6.2 Rule of Mixture for Sample 2

The sample 2 contain various composites C1, C2 and C3. Where,

C1 - Lm6 (98%), Si_3N_4 (1%), MoS_2 (1%)

C2 - Lm6 (96%), Si_3N_4 (3%), MoS_2 (1%)

C1 - Lm6 (94%), Si_3N_4 (5%), MoS_2 (1%)

SI.No	YOUNGS MODULUS (Gpa)	POISSON RATIO (no unit)	DENSITY (g/cc)
C1	E= 72.883	v = 0.29825	ρ = 2.7114
C2	E= 80.76	v = 0.29825	P = 2.7266
C3	E= 85.54	v = 0.29825	ρ=2.7458

Table -2: Rule of mixture of sample 2

7. MODELLING AND MESHING

To access the geometry tools, click the "Geometry" cell in the project schematic. Based on your needs, pick the best geometry production technique. To depict the overall composite geometry, a rectangle solid with the required measurements (17cm x 7cm x 1.5cm) was made. To specify the shape and proportions, use the relevant drawing and extrusion tools.

The regions or components inside the composite that correspond to various materials can be defined once the basic composite geometry has been established. In this instance, you would specify the Si_3N_4 and LM6 area boundaries. The last step was to assign material attributes to each region and component based on the desired composition and the results of the rule of mixture. Define the density, Poisson's ratio, and Young's modulus for LM6 and Si_3N_4 in accordance after this meshed using boundary condition based on literature survey.

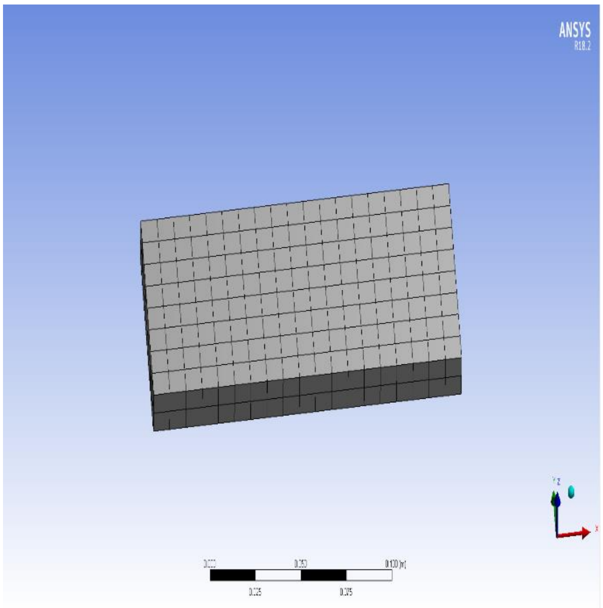

Fig -1: Meshed Composite

8.ANALYSIS

8.1 Static Structural Analysis

A static structural analysis refers to a type of analysis that focuses on determining the behavior and response of a structure or component under static loading conditions. Static structural analysis helps engineers and designers understand how a structure or component will behave under various loading conditions, allowing them to assess its strength, stability, and performance. By simulating and analyzing the static response of a system, it is possible to evaluate factors such as structural integrity, material failure, and overall safety. The result obtained for different sample are illustrated below

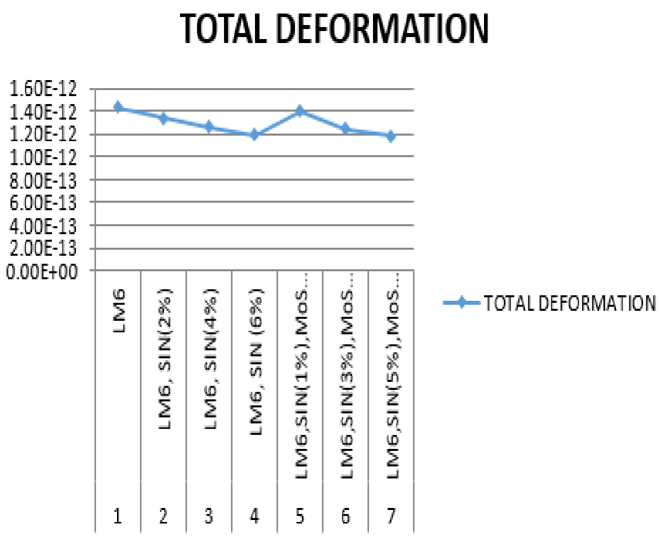

Fig -2: Total Deformation

8.2 Modal Analysis

Modal analysis, also known as eigenvalue analysis or Eigen mode analysis, is a technique used in engineering to study the dynamic characteristics of a structure or system. It involves determining the natural frequencies, mode shapes, and modal damping ratios of a structure or component. In modal analysis, the structure is assumed to vibrate in its natural modes of vibration, which are the inherent vibrational patterns or shapes that the structure exhibits. These modes are characterized by specific frequencies and associated mode shapes, which describe the distribution of displacements and deformations throughout the structure. The results obtained for different samples are

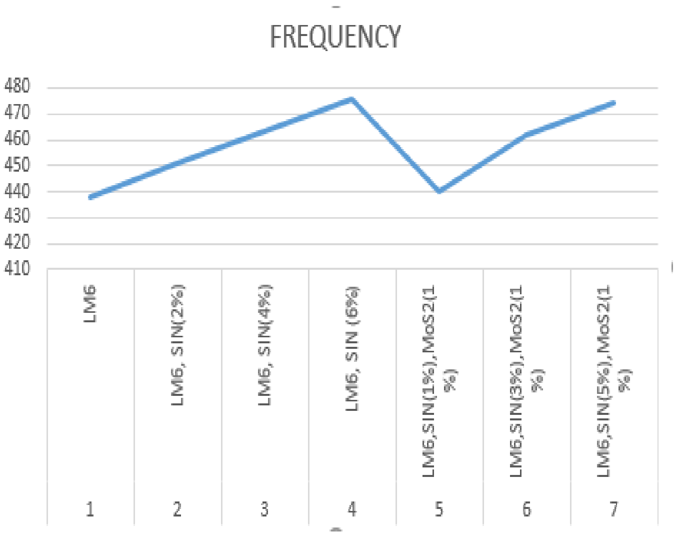

Fig -3: Total Frequency

9. CONCLUSION

Interpreting the data in this project involves understanding the implications of frequency and total deformation values for different composite materials. Frequency values indicate natural frequencies and higher values suggest stiffer materials. Comparing frequencies among materials reveals the effects of Si_3N_4 and MoS_2 additions on vibrational behavior. Total deformation values indicate displacement and deformation under loads, and as **Si_3N_4 and MoS_2 content increases, deformation tends to decrease, enhancing stiffness**. Frequencies obtained from modal analysis represent natural frequencies and provide insights into dynamic behavior and susceptibility to vibrations. Comparing frequencies of different composites reveals variations in stiffness and response. **Si_3N_4 and MoS_2 influence mechanical behavior and dynamic response**, with Si_3N_4 and MoS_2 enhancing stiffness and reducing deformation. These findings inform the design and optimization of composite materials in various engineering fields.

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