International Journal of Engineering Applied Sciences and Technology, 2025
Vol. 10, Issue 04, ISSN No. 2455-2143, Pages 50-56
Published Online August 2025 in IJEAST (http://www.ijeast.com)

FINITE ELEMENT ANALYSIS TO DETERMINE DAMPING PROPERTIES OF HIGH STRENGTH ALUMINUM A356 ALLOY COMPOSITE

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Abstract— **The damping capacity of a material refers to its ability to convert mechanical vibration energy into thermal energy or other energies. The damping capacity is very important to some materials, especially the structural materials. It is well known that mechanical vibration causes much damage in aerospace industry, automotive industry and architectural industry. So, it is urgent to seek for high damping capacity materials to eliminate the damage. Since the specific gravity of Aluminum is approximately 2.7 g/cc, the composites of Aluminum play a very significant role in light weight machine components. Silicon, copper, magnesium, iron, manganese, and zinc are important elements in Aluminum composites. The properties of these alloys can be prepared and these readily can be used in design engineering with the instructions for other alloys. In the present study an analysis tool finite element analysis (FEA) will be used. The work presented in this paper is aimed at the study of effect of vibration characteristics of aluminum alloy A356. The modeling will be done through CREO and analysis will be carried out using ANSYS software. A modal analysis will be carried out to understand the vibration behavior i.e., natural frequency and mode shapes, of the material considered. The mode shapes and natural frequency play an important role in the design of dynamic machines.**

Keywords— **Damping Capacity, Finite Element Analysis. Aluminium Alloy A356, Vibration, Modal Analysis**

I. INTRODUCTION

I. Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road. Vibration is occasionally "desirable". For example, the motion of a tuning fork, the reed in a woodwind instrument or harmonica, or mobile or the cone of a loudspeaker is desirable vibration, necessary for the correct functioning of the various devices. More often, vibration is undesirable, wasting energy and creating unwanted sound – noise. For example the vibrational motions of engines, electric motors, or any mechanical device in operation are typically unwanted. Such vibrations can be caused by imbalances in the rotating parts, uneven friction, the meshing of gear teeth, etc. Careful designs usually minimize unwanted vibrations. The study of sound and vibration are closely related. Sound, or "pressure waves", are generated by vibrating structures (e.g. vocal cords); these pressure waves can also induce the vibration of structures (e.g. ear drum). Hence, when trying to reduce noise it is often a problem in trying to reduce vibration.

Types of Vibration

- Free Vibration
- Forced Vibration

II. PROBLEM STATEMENT

In modern engineering applications, particularly in the aerospace, automotive, and architectural industries, mechanical vibrations pose a significant challenge by causing material fatigue, structural failures, and noise issues. Despite advancements in materials science, there remains a critical need for materials that not only offer strength and lightweight characteristics but also possess high damping capacity to absorb and dissipate vibrational energy effectively. Aluminum alloy A356, known for its favorable strength-to-weight ratio, is widely used in dynamic structures, but its vibration behavior under operational conditions is not yet fully understood. This study aims to address this gap by analyzing the vibration characteristics—specifically natural frequencies and mode shapes—of A356 using Finite Element Analysis (FEA). By doing so, the research contributes to the design of more reliable and vibration-resistant machine components. corner of the 2nd, 3rd inferior wavelet transform.

III. OBJECTIVES

The primary objective of this study is to analyze the vibration characteristics of aluminum alloy A356 using Finite Element Analysis (FEA). The study involves creating a 3D model of the material using CREO and performing a modal analysis in ANSYS software to determine the natural frequencies and mode shapes. The goal is to evaluate the damping behavior of A356 alloy and provide insights that can aid in the design of lightweight, vibration-resistant components for dynamic engineering applications.

IV. LITRATURE REVIEW

On the basis of such considerations, the algorithm uses a different color image multiplied by the weighting coefficients of different ways to solve the visual distortion, and by embedding the watermark, wavelet coefficients of many ways, enhance the robustness of the watermark.

4.1 PREPARATION AND DAMPING BEHAVIOR OF A356.2/RHA COMPOSITES

Siva Prasad D, Rama Krishna A and Srinivasa Prasad B

In an attempt to investigate the possibility of enhancing damping characteristics of structural metals, Rice Husk Ash (RHA) was reinforced with A356.2 alloy using Vortex method. Using this method 4%, 6% and 8% weight percent RHA composites were fabricated. Dynamic Mechanical Analyzer (DMA) is used to study the damping behavior of the as received, A356.2/RHA composites in the frequency ranging from 1Hz to 25Hz at room temperature. The results show that composites exhibit higher damping capacities than the unreinforced alloy. The related mechanisms are also discussed.

4.2 EXPERIMENTAL EVALUATION ONTO THE DAMPING BEHAVIOR OF AL/SIC/RHA HYBRID COMPOSITES

DoraSiva Prasad, Chintada Shoba

In the present study, the damping behavior of hybrid composites has been investigated using dynamic mechanical analyzer (DMA). The composites were fabricated with 2, 4, 6, and 8% by weight of rice husk ash (RHA) and SiC in equal proportions using two stage stir casting process. Damping measurements of all the specimens were obtained by dynamic mechanical analyzer (DMA) at different frequencies in air atmosphere. Scanning electron microscope (model JSM-6610LV) was used to study the microstructural characterization of the hybrid composites. It was observed that the dislocation density, which results from the thermal mismatch between the reinforcement and the matrix and the porosity of composites, has a great influence on the damping capacity of hybrid composites. The dislocation damping mechanisms were discussed with regards to the Granato–Lucke theory.

4.3 FREQUENCY RESPONSES OF ALUMINUM A356 BASED ON HIGH STRENGTH ALLOY COMPOSITE

Maher Rehaif Khudhair

The study analyzed the vibration response of A356 aluminum alloy reinforced with Al–Cu–Mg high-strength alloy particles using FEA (ANSYS). It found that natural frequencies increased with reinforcement, peaking at 10% reinforcement, which showed the best vibration resistance. The increase in modulus of elasticity and decrease in density were key factors enhancing vibration performance. Thus, A356–10% HSAP composite is optimal for vibration-sensitive applications.

4.4 APPLICATION OF FINITE ELEMENT METHOD FOR SIMULATION OF MECHANICAL PROPERTIES IN A356ALLOY

Mohsen Ostad Shabani

The study applied Finite Element Method (FEM) to simulate the mechanical properties of A356 alloy during solidification. It investigated the relationship between secondary dendrite arm spacing (SDAS) and mechanical properties like yield stress, ultimate tensile strength (UTS), elongation, and maximum force (Fmax).

4.5 FINITE ELEMENT ANALYSIS TO DETERMINE DAMPING PROPERTIES OF HIGH STRENGTH ALUMINUM A356 ALLOY COMPOSITE

Lanka Rajendra Prasad

Aluminum is not as strong as other metals, but its damping properties can be improved by alloying. Future research should focus on developing high-strength aluminum alloys with enhanced damping properties.

V. METHODOLOGY

The methodology followed in this study involves a systematic approach to analyze the vibration characteristics of aluminum alloy A356 using computer-aided engineering tools. The process is divided into the following key steps:

Material Selection:

Aluminum alloy A356 is selected for the study due to its widespread use in lightweight structural applications and its potential for high damping capacity.

3D Modeling:

A geometrical model of the test component is created using CREO (a CAD software). The model is developed with appropriate dimensions to simulate real-world applications accurately.

Import and Meshing:

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The CAD model is imported into ANSYS, where meshing is performed to discretize the geometry into finite elements. A suitable mesh size is selected to ensure a balance between computational accuracy and efficiency.

Material Properties Assignment:
The mechanical properties of A356 alloy, including Young's modulus, density, and Poisson's ratio, are defined within the ANSYS environment based on standard material data.

Modal Analysis:
A modal analysis is carried out to determine the natural frequencies and mode shapes of the component. This analysis helps to understand how the material behaves under vibrational loads without applying external damping or excitation.

Results Interpretation:
The obtained mode shapes and natural frequencies are analyzed to assess the damping behavior and vibration response of A356. These results are then evaluated in terms of their implications for the design of dynamic machine components.

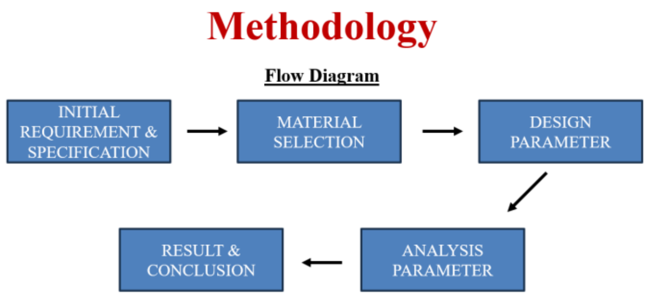

Fig 1. Flow Diagram

VI. INTRODUCTION TO CREO

Creo, short for Creo Parametric, is a powerful and (intelligent 3D CAD software improved to deal with the challenges organizations face as they design, analyze, and share information. Developed by PTC, the original pioneers of parametric CAD, Creo is a powerful software supporting a unified family of product design tools used by thousands of companies worldwide.
The Creo family of design programs, combine parametric and direct modeling techniques. Creo Parametric can easily be customized and extended through the addition of modules and extensions, but the product family also contains stand-alone purpose build design applications such as Creo Simulation, Creo Direct, Creo Layout & Creo Options Modeler. Each stand-alone app serves a different purpose in the product development process. From idea to design to analysis, to effectively sharing your information (manufacturing, quality control, inspection), Creo is a solid foundation for any design group. It supports the needs of manufacturing and product development organizations.

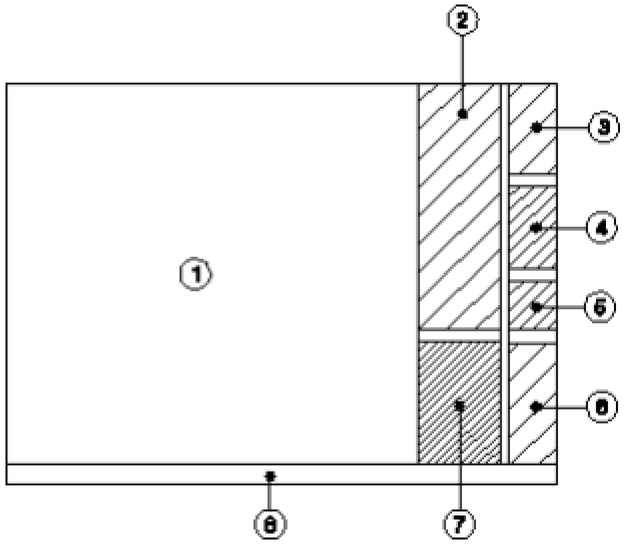

Fig 2. Drafting Interface

COMMENLY USED TOOLS IN CREO:
In Creo Parametric, commonly used tools include those for 3D modeling, such as extrude, revolve, sweep, and loft features. Other frequently used tools include those for drawing, such as orthographic views, technical illustrations, and visualization. Creo also provides tools for simulation and analysis, including Creo Simulation Live and Creo Ansys Simulation.
Additionally, tools for sheet metal design, manufacturing, and data management are available within the Creo environment.
Here's a more detailed breakdown of commonly used tools in Creo:

3D Modeling:
Extrude: Creates a solid or surface by extending a sketch along a path.
Revolve: Creates a solid or surface by rotating a sketch around an axis.
Sweep: Creates a solid or surface by sweeping a sketch along a path.
Loft: Creates a solid or surface by connecting two or more sketches.
Draft: Creates draft angles on surfaces.
Fill: Creates surfaces in areas where there are no existing surfaces.

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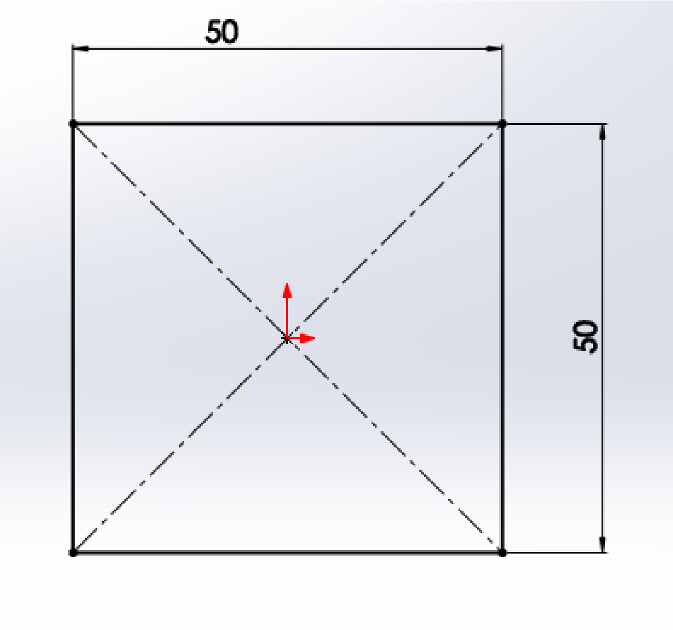

Fig 3. 2D Diagram of Test Specimen

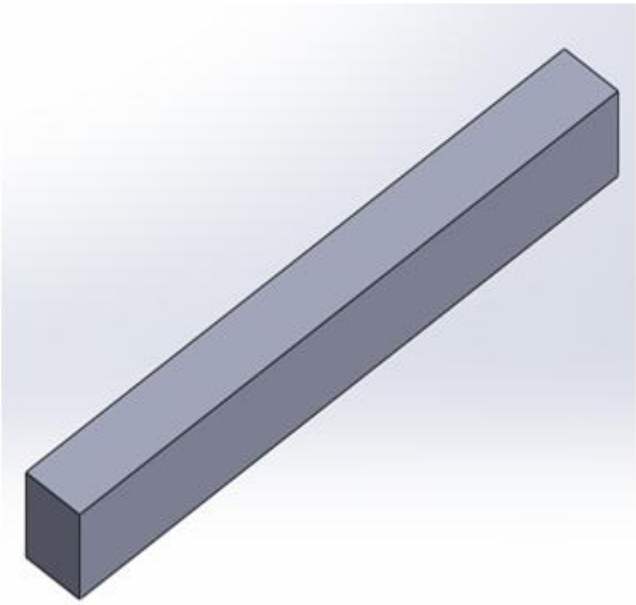

Fig 4. 3D Diagram of Test Specimen

VII. ANSYS WORKBENCH

ANSYS Workbench combines the strength of our core simulation tools with the tools necessary to manage your projects. You will work with your ANSYS Workbench project on the main project workspace, called the Project tab. The project is driven by a schematic workflow, represented visually on a flowchart like diagram called the Project Schematic. To build an analysis, you add building blocks called systems to the Project Schematic; each system is a block of one or more components called cells, which represent the sequential steps necessary for the specific type of analysis. Once you have added your systems, you can link them together to share and/or transfer data between systems. From the cells in the Project Schematic, you can work with various ANSYS applications and analysis tasks. Some of these open in tabs within the Workbench environment, while others open independently in their own windows.

ANALYSIS SYSTEMS:

One way to start an analysis in ANSYS Workbench is to select an analysis system from the Toolbox. When you select one of these analysis types, the corresponding system will appear in the Project Schematic, with all the necessary components of that type of analysis. Some analysis types offer different solvers, noted in parentheses. The features available can differ from one solver to another.

Available analysis systems include:
1.Design Assessment
2.Electric
3.Explicit Dynamics
4.Fluid Flow (CFX)
5.Fluid Flow (Fluent)

When you either double-click or drag an analysis system onto the Project Schematic it appears in the Project Schematic as a system. Components for that analysis type's system are listed as individual cells.
For example, a typical structural analysis might have the following components/cells:
• Engineering Data
• Geometry
• Model/Mesh
• Setup
• Solution
• Results

VIII. MATERIAL SELECTION

Structural steel is a type of steel that is used as a construction material. It is designed to have a good strength/weight ratio (which is also called specific strength) and to be cost-effective in order to be benefited as a structural component in buildings, roads, bridges, etc.
Aluminium alloys are created by combining aluminium with other elements like copper, magnesium, manganese, silicon, and zinc. These additions enhance properties like strength, workability, corrosion resistance, and electrical conductivity, making aluminium alloys suitable for various applications. Some common aluminium alloys include 6061, 5083, 7075, and 5052
A356 aluminum casting alloy is a 7% Si, 0.3% Mg alloy with 0.2 Fe (max) and 0.10 Zn (max). A356 aluminum casting alloy has very good casting and machining characteristics. A356 aluminum casting alloy is used for aircraft parts, pump housings, impellers, high velocity blowers and structural

castings where high strength is required. A356 aluminum casting alloy can also be used as a substitute for aluminum alloy 6061. It is typically used in the heat-treated condition of T5 and T6 hardness properties.

IX. RESULT & DISCUSSION

STRUCTURAL ANALYSIS

The structural analysis is a mathematical algorithm process by which the response of a structure to specified loads and actions is determined. This response is measured by determining the internal forces or stress resultants and displacements or deformations throughout the structure. The structural analysis is based on engineering mechanics, mechanics of solids, laboratory research, model and prototype testing, experience and engineering judgment. The basic methods of structural analysis are flexibility and stiffness methods. The flexibility method is also called force method and compatibility method. The stiffness method is also called displacement method and equilibrium method. These methods are applicable to all type of structures; however, here only skeletal systems or framed structures will be discussed. The examples of such structures are beams, arches, cables, plane trusses, space trusses, plane frames, plane grids and space frames. The skeletal structure is one whose members can be represented by lines possessing certain rigidity properties. These one dimensional members are also called bar members because their cross sectional dimensions are small in comparison to their lengths. The skeletal structures may be determinate or indeterminate.

PROCEDURE

1.Test specimen imported in ansys workbench
2.Meshed model of test specimen
3.Both the ends are assigned with fixed supports
4.UDL load is distributed on the surface of test specimen

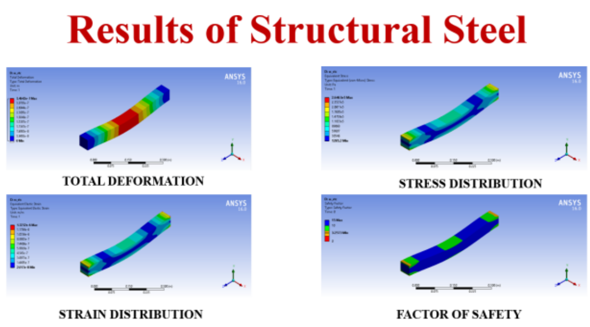

Fig 5. Result of Structural Steel

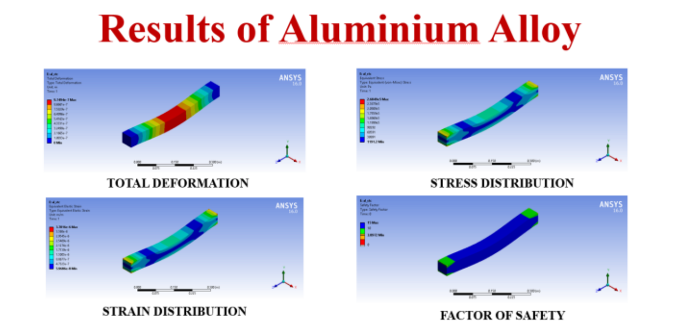

Fig 6. Result of Aluminium Alloy

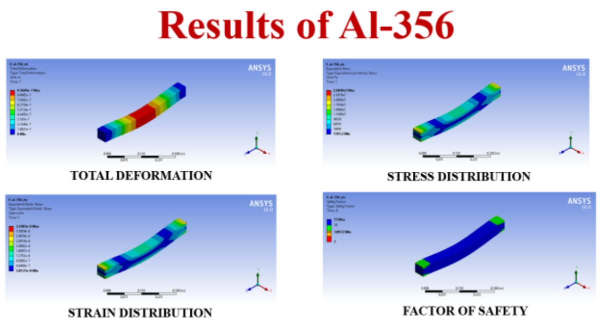

Fig 7. Result of Al 356

Tabulated Result

Sl.no	Total deformation		Stress distribution		Strain distribution		Mass	Factor of safety	
	Min	Max	Min	Max	Min	Max		Min	Max
Structural Steel	0	3.46e-4	1.28e-3	0.26	2.01e-8	1.32e-6	9.81	3.25	15
Aluminium	0	9.74e-4	1.19e-3	0.26	5.96e-8	3.78e-6	3.46	3.89	15
Al 356	0	9.56e-4	1.19e-3	0.26	5.85e-8	3.7e-6	3.33	3.89	15

Fig 8. Result of Structural Analysis

MODAL ANALYSIS

Modes are inherent properties of a structure, and are determined by the material properties (mass, damping, and stiffness), and boundary conditions of the structure. Each mode is defined by a natural (modal or resonant) frequency, modal damping, and a mode shape (i.e. the so-called “modal parameters”). If either the material properties or the boundary conditions of a structure change, its modes will change. For instance, if mass is added to a structure, it will vibrate differently. To understand this, we will make use of the concept of single and multiple-degree-of-freedom systems.

PROCEDURE
1.The design of test specimen is imported in ansys workbench environment
2.Meshed model of test specimen
3.Fixed support is provided at both ends of test specimen

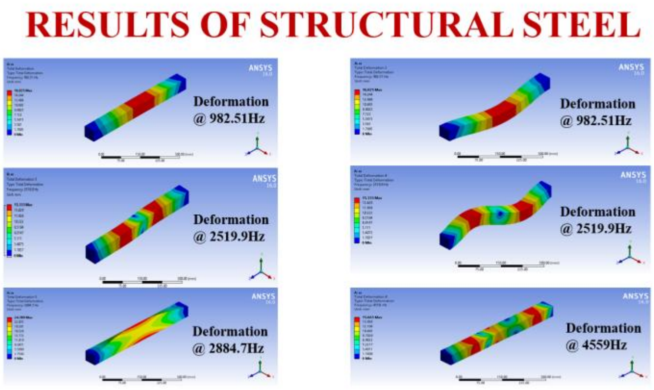

Fig 9. Result of Structural Steel Modal Analysis

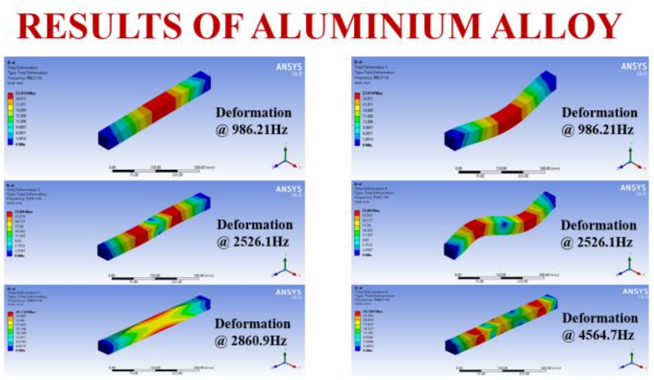

Fig 10. Result of Aluminium alloy Modal Analysis

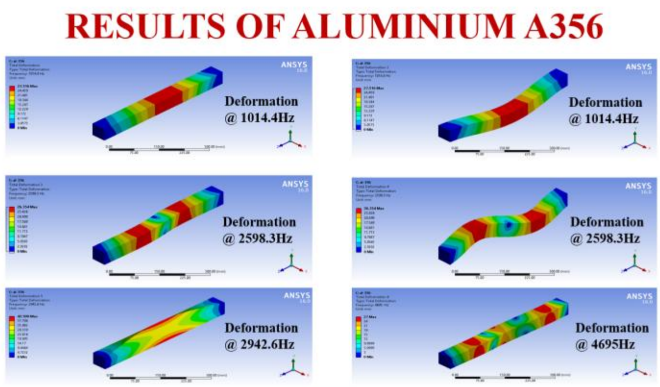

Fig 11. Result of Al 356 Modal Analysis

Result and Discussion

Comparative Table

Mode	Structural Steel (Hz / Deform mm)	Aluminium Alloy (Hz / Deform mm)	Aluminium A356 (Hz / Deform mm)
1	982.51 / 16.02	986.21 / 27.01	1014.4 / 27.51
2	982.51 / 16.02	986.21 / 27.01	1014.4 / 27.51
3	2519.9 / 15.33	2526.1 / 25.89	2598.3 / 26.35
4	2519.9 / 15.33	2526.1 / 25.89	2598.3 / 26.35
5	2884.7 / 24.78	2860.9 / 41.73	2942.6 / 42.50
6	4559.0 / 15.66	4564.0 / 26.50	4695.0 / 27.00

Result and Discussion:
The table presents a comparison of the natural frequencies and deformation values across six vibration modes for Structural Steel, Aluminium Alloy, and Aluminium A356. The analysis highlights how each material responds to vibrational loads, as measured in Hz for frequency and mm for deformation.

Key Observations:
Natural Frequency:
Aluminium A356 consistently exhibits the highest natural frequencies across all six modes, indicating superior stiffness and a better ability to resist vibrational excitation compared to structural steel and generic aluminium alloy.
Structural steel shows the lowest natural frequencies, suggesting it is less suited for high-frequency vibration applications where stiffness is critical.

Deformation Behavior:
Aluminium A356 demonstrates moderate deformation values, generally lower than the other aluminium alloy but higher than structural steel in most modes.
Structural steel, while having lower frequency, shows lower deformation in several modes, indicating high rigidity but poor vibration isolation.
The other aluminium alloy lies between structural steel and A356 in terms of both frequency and deformation.

Overall Performance:
Aluminium A356 offers an optimal balance between high natural frequency and manageable deformation, making it highly suitable for dynamic machine components where both lightweight and vibration control are required.
The data clearly supports the use of A356 in environments subject to mechanical vibrations, aligning with the objectives of this study.

X. CONCLUSION

The test specimen of standard dimensions is created using 3d modelling software called creo, the basic concepts of vibration and mechanical properties of material which has high damping characteristics are analyzed by different reference works. Our work flow is like testing the natural frequency of specimen made of stainless steel, aluminium alloy, aluminium A356.

For performing this study we have selected Finite element analysis concept software which is called ANSYS workbench. By studying the modal characteristics of the test specimen made of different materials, the structural properties and the frequency experienced by structural steel and its comparative deformations are lies on the considerable limit, while comparing this result with aluminium alloy, it also lies in an allowable limit. The properties like weight distribution ratio and ease of manufacturing makes the aluminium alloy 356 to implement in a real time environment.

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