INVESTIGATION OF STRUCTURAL DAMPING IN A356 ALLOY USING FEA METHODS

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Abstract

This study investigates the damping capacity of aluminum A356 alloy composites, a key property for structural materials in industries like aerospace, automotive, and construction. Aluminum composites, known for their low specific gravity, offer an excellent balance of strength and weight. The study uses Finite Element Analysis (FEA) to model the alloy in CREO and conduct modal analysis in ANSYS. The focus is on determining the natural frequencies and mode shapes, which are crucial for designing dynamic systems. Results aim to provide insights into the alloy's vibrational behavior under varying loads. This research contributes to the development of high-performance materials for vibration-sensitive applications.

Keywords: A356 aluminum alloy,Damping capacity,Aluminum composites, Finite Element Analysis (FEA),Modal analysis,Natural frequencies,Mode shapes,CREO modeling,ANSYS simulation,Vibrational behavior

1. INTRODUCTION

Vibration

Vibration refers to the repeated motion of a body or system over a period of time. Common examples include the oscillation of a pendulum or the vibration of a stretched string. The study of vibration is concerned with analyzing such repetitive motions and the forces involved in their behavior. This field is critical in various engineering applications, particularly where dynamic forces and mechanical performance are key considerations.

Fundamental Components of Vibrating Systems

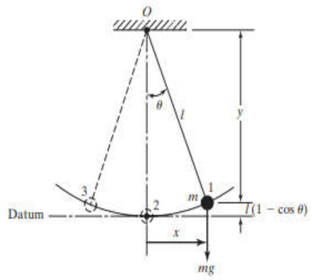
A typical vibrating system consists of three primary components: an element to store potential energy (such as a spring), an element to store kinetic energy (mass), and a mechanism to dissipate energy (damper). The system continuously alternates between kinetic and potential energy during motion. In the presence of damping, some energy is lost during each cycle, which results in a gradual reduction in the amplitude of vibration unless additional energy is introduced to sustain it.

To consider the motion of a simple pendulum. When displaced and released, the pendulum bob, initially possessing only potential energy, converts this into kinetic energy as it swings through its lowest point. The motion continues to alternate between these energy forms, producing an oscillatory movement. Over time, air resistance and other damping forces reduce the amplitude of motion, eventually bringing the system to rest. This demonstrates how damping plays a crucial role in real-world vibrating systems, affecting both their behavior and design.

A SIMPLE PENDULUM

VIBRATION ANALYSIS PROCEDURE

A vibratory system is a dynamic one for which the variables such as the excitations (inputs) and responses (outputs) are time dependent. The response of a vibrating system generally depends on the initial conditions as well as the external excitations. Most practical vibrating systems are very complex, and it is impossible to consider all the details for a mathematical analysis.



LITERATURE REVIEW

1.Finite Element Analysis of Damping Properties of High Strength Aluminum A356 Alloy Composite ShivaPrasad, ShivaKumar, Ch. Santosh Kumar Reddy Aluminum composites are widely utilized in various applications due to their excellent strength-to-weight ratio. Several studies have focused on improving the mechanical properties of these composites by altering alloying elements. The finite element analysis (FEA) technique, used in this study, simulates and analyzes the vibration characteristics of aluminum alloy A356 composites. ANSYS software was used for modal analysis to assess the natural frequencies and mode shapes of the material. The study concluded that increasing copper and silicon content in the alloys led to a reduction in damping properties, with Al 380 alloy composites showing the least vibration.

2. Preparation and Damping Behavior of A356.2/RHA Composites Siva Prasad D, Rama KrishnaA, SrinivasaPrasad B.This study explores the enhancement of damping properties in A356.2 aluminum alloy by reinforcing it with Rice Husk Ash (RHA). Composites with 4%, 6%, and 8% weight percent RHA were fabricated using the vortex method. The dynamic mechanical analyzer (DMA) was used to measure damping behavior at frequencies ranging from 1Hz to 25Hz. The results indicated that RHA reinforcement significantly increased the damping capacity of the composites compared to the unreinforced alloy.

3. Experimental Evaluation of Damping Behavior of Al/SiC/RHA Hybrid Composites Dora Siva Prasad, Chintada Shoba.This study investigates the damping behavior of hybrid composites made by combining Rice Husk Ash (RHA) and Silicon Carbide (SiC) in an aluminum matrix. The composites were fabricated using a two-stage stir casting process and analyzed with DMA at different frequencies. The results highlighted that dislocation density, thermal mismatch between the reinforcement and matrix, and porosity played significant roles in determining the damping capacity. The study also discussed the dislocation damping mechanisms based on the Granato-Lucke theory.

4.Evaluation of Damping Behavior of Al-Mg-Si Alloy-Based Composites Reinforced with Steel, Steel-Graphite, and Silicon Carbide Particulates Kenneth Kanayo Alaneme, Adetomilola Victoria Fajemisin This research compares the damping behavior of Al-Mg-Si alloys reinforced with different metallic and ceramic particles, such as steel, steel-graphite, and SiC. The results, obtained through DMA, showed that SiC-reinforced composites exhibited the best damping capacity, despite steel-containing composites having higher storage modulus values. The study also emphasized that temperature and test frequencies significantly affected the damping performance of these composites.

5.Frequency Responses of Aluminum A356-Based High Strength Alloy Composite(HSAP) Maher Rehaif Khudhair & M. Gopi Krishna Mallarapu In this study, the vibration characteristics of A356 alloy reinforced with high strength alloy particulates (HSAP) were analyzed using finite element analysis (FEA) and modal analysis. The composites were produced through stir casting and hot extrusion, and the results showed that the natural frequency increased with the modulus of elasticity. The study concluded that A356-10% HSAP composites displayed superior vibration characteristics compared to other compositions.

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.

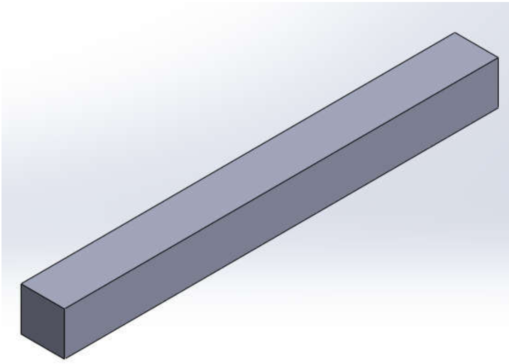
SIMULATION

PTC's simulation software is designed uniquely for the engineer, complete with the common Creo user interface, engineering terminology, and seamless integration between CAD and CAE data, allowing for a more streamlined process. Best of all, the results are accurate and reliable and can be easily calculated with very little input from non-simulation experts.

The simulation software is a complete structural, thermal and vibration analysis solution with a comprehensive set of finite elements analysis (FEA) capabilities that allow you to analyze and validate the performance of your 3D virtual prototypes before you make the first part.

FLEXIBILITY

Designers who are involved in many phases of the product development process, PTC Creo provides scalable access to the right software. Subscription licensing enables flexibility to use what you need when you need it. For those involved in specific parts of the product development process, there are apps designed to meet individual needs for your role in the product development process - you can use the right tool at the right time.



Rectangular test specimen is created form the drawn sketch with the help of extrude tool

MECHANICAL PROPERTIES OF STRUCTURAL STEEL

PROPERTIES	VALUES
Ultimate tensile strength	505 MPa
Density	8.0 g/cm3
Modulus of elasticity	200 GPa
Shear strength	152 MPa
Yield strength (0.2% offset)	215 MPa
Melting point	1454 °C
Elongation	35%

PROPERTIES OF ALUMINIUM ALLOY

Component	Wt. %	Component	Wt. %	Component	Wt. %
Al	95.8-98.6	Mg	0.8-1.2	Si	0.4 - 0.8
Cr	0.04 - 0.35	Mn	Max 0.15	Ti	Max 0.15
Cu	0.15 - 0.4	Other, each	Max 0.05	Zn	Max 0.25
Fe	Max 0.7	Other, total	Max 0.15		

PROPERTIES OF ALUMINIUM ALLOY

Physical Properties	Metric
Density	2.7 g/cc
Hardness, Brinell	95
Hardness, Knoop	120
Hardness, Rockwell A	40
Hardness, Rockwell B	60
Hardness, Vickers	107
Ultimate Tensile Strength	310 MPa
Tensile Yield Strength	276 MPa
Elongation at Break	12 %
Elongation at Break	17 %
Modulus of Elasticity	68.9 GPa
Notched Tensile Strength	324 MPa
Ultimate Bearing Strength	607 MPa
Bearing Yield Strength	386 MPa
Poisson's Ratio	0.33
Fatigue Strength	96.5 MPa
Fracture Toughness	29 MPa-m½
Machinability	50 %
Shear Modulus	26 GPa
Shear Strength	207 MPa

A356 Aluminum Casting Alloy Chemical Composition

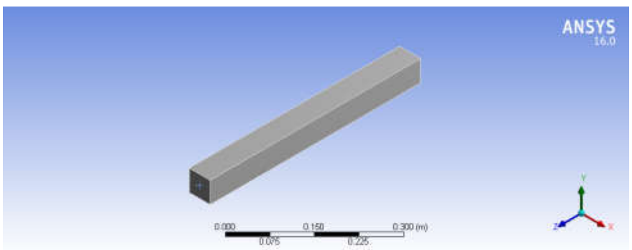
Chemical Composition of A356 Aluminum Casting Alloy

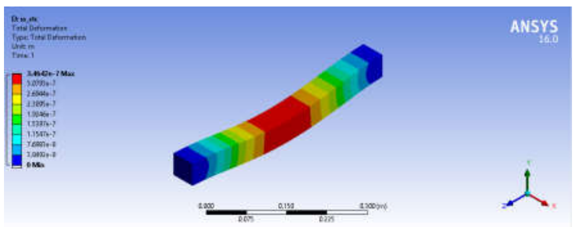
Si	Mg	Fe	Zn
7	0.3	0.20 Max	0.10 Max

A356 Aluminum Casting Mechanical Properties

Temper	Ultimate Tensile (ksi)	Yield Strength (ksi)	Brinell Hardness (500 Kg)	Shearing Strength (ksi)
T6	33	24	70	26

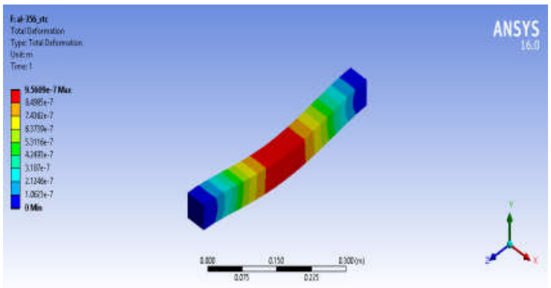
STRUCTURAL ANALYZING PROCEDURE



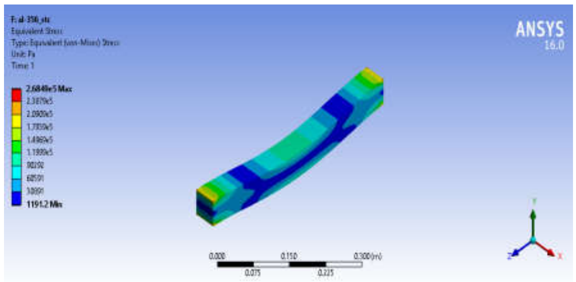


TOTAL DEFORMATION

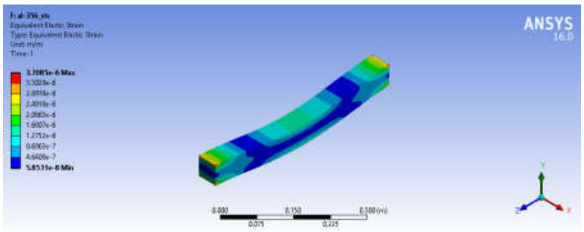
RESULTS OF AL-356



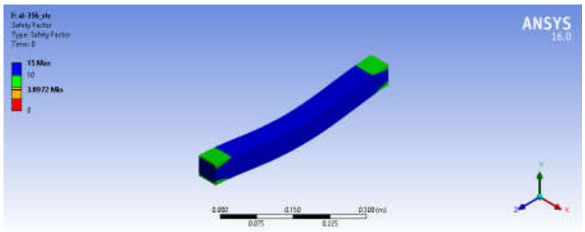
TOTAL DEFORMATION



STRESS DISTRIBUTION



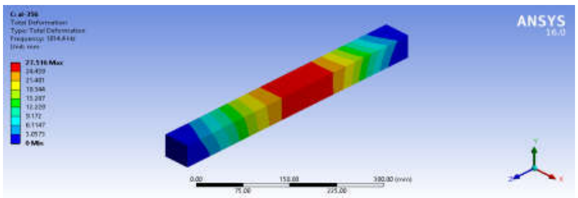
STRAIN DISTRIBUTION

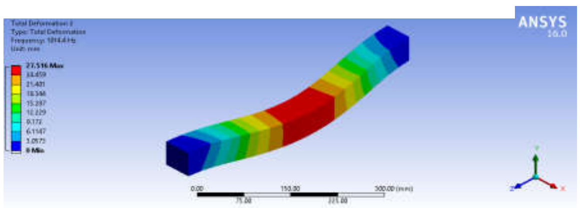


TABULATED RESULTS

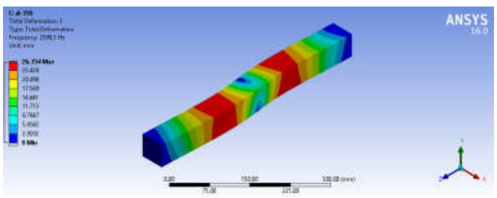
Sl.No	Total deformation		Stress distribution		Strain distribution		Mass	Factor of safety	
	Min	Max	Min	Max	Min	Max		Min	Max
1	0	3.46e-4	1.28e-3	0.26	2.01e-8	1.32e-6	9.81	**3.25**	**15**
2	0	9.74e-4	1.19e-3	0.26	5.96e-8	3.78e-6	3.46	**3.89**	**15**
3	0	9.56e-4	1.19e-3	0.26	5.85e-8	3.7e-6	3.33	**3.89**	**15**

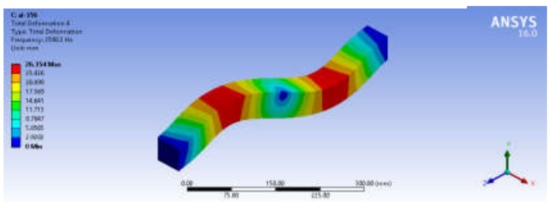
RESULTS OF ALUMINIUM A356



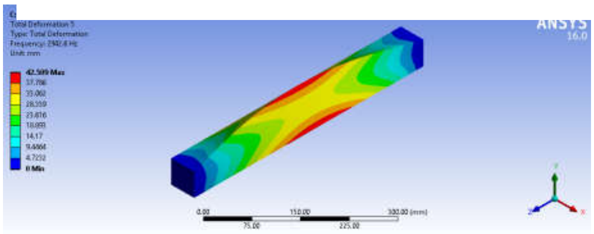


Deformation @ 1014.4Hz

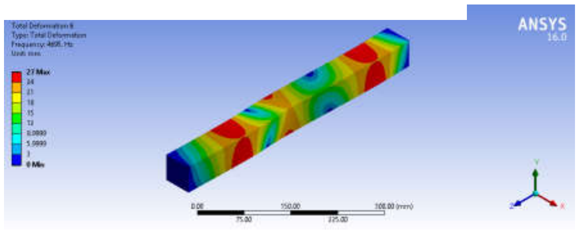




Deformation @ 2598.3Hz **Deformation @ 2598.3Hz**



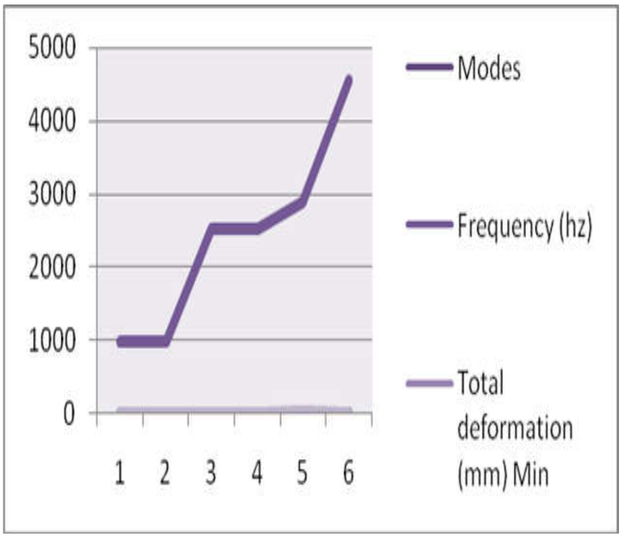
Deformation @ 2942.6Hz



Deformation @ 4695Hz

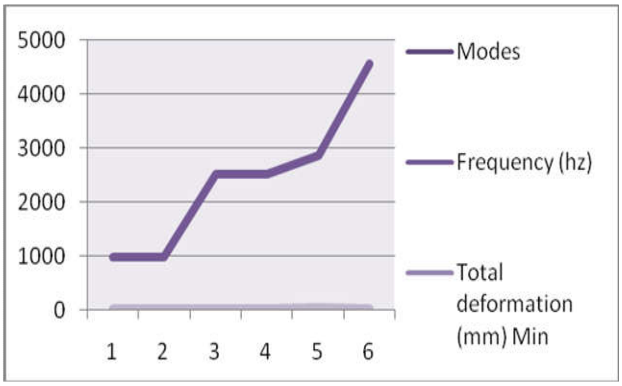
RESULTS OF STRUCTURAL STEEL

Modes	Frequency (hz)	Total deformation (mm)	
		Min	Max
1	982.51	0	16.02
2	982.51	0	16.02
3	2519.9	0	15.33
4	2519.9	0	15.33
5	2884.7	0	24.78
6	4559	0	15.66



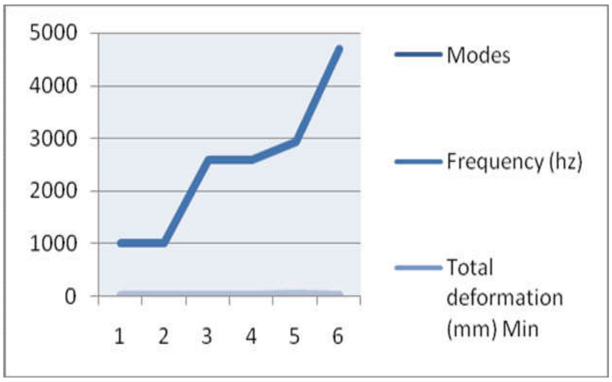
TABULATED RESULTS OF ALUMINIUM ALLOY

Modes	Frequency (hz)	Total deformation (mm)	
		Min	Max
1	986.21	0	27.01
2	986.21	0	27.01
3	2526.1	0	25.89
4	2526.1	0	25.89
5	2860.9	0	41.73
6	4564	0	26.5



TABULATED RESULTS OF ALUMINIUM A 356

Modes	Frequency (hz)	Total deformation (mm)	
		Min	Max
1	1014.4	0	27.51
2	1014.4	0	27.51
3	2598.3	0	26.35
4	2598.3	0	26.35
5	2942.6	0	42.5
6	4695	0	27



CONCLUSION

In this study, a test specimen with standard dimensions was modeled using Creo 3D software, and the vibration and mechanical properties of materials with high damping characteristics were analyzed through various reference works. The workflow involved evaluating the natural frequencies of specimens made from stainless steel, aluminum alloy, and aluminum A356. To perform the analysis, we utilized the Finite Element Analysis (FEA) software, ANSYS Workbench. By studying the modal characteristics of these test specimens, we found that the structural properties and frequency responses of stainless steel and aluminum alloys remained within acceptable limits, with their respective deformations also being within the allowable range. Notably, the aluminum A356 alloy demonstrated favorable characteristics, such as a good weight distribution ratio and ease of manufacturing, which make it a viable material for real-time applications. These findings suggest that aluminum A356 alloy is a promising candidate for various engineering applications requiring high damping properties.

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