ORIGINAL RESEARCH PAPER

Engineering

EXPERIMENTAL VIBRATION ANALYSIS AND MODAL ANALYSIS OF SHEET METAL STRUCTURE REINFORCED WITH ELASTIC MATERIAL

KEY WORDS: Corrugated sheets, CAD, Catia V5, CAE, FEA, Optimization, Ansys, FFT.

Gokul V. Mahajan Asst. Professor, Dept. of Mechanical Engg, SOET, Sandip University Nasik

ABSTRACT

Sheet metal structures are subjected to various static and dynamic loads during their operation due to this they encounter resonant condition at various operating frequencies. Resonance leads to harmonic excitation which induces deformation and stress loading which leads to fatigue failure. Reinforcement of sheet metal structure with elastic material such as rubber, foam helps in achieving structural stiffness. Stiffness alteration loads to change in dynamic characteristics, natural frequencies, harmonic resonance etc. Modal and Harmonic analysis will be simulated using FEA analysis (ansys workbench). Impact hammer and FFT analyzer will be used for validating natural frequencies for structure with and without reinforcement. Result and conclusion will be drawn. Suitable future scope will be suggested.

I. INTRODUCTION

Nowadays, addressing vibration and noise issues is essential to the improvement of performance and operational perception in advanced engineering structures and systems. Passive and active structural damping can attenuate a system's vibration and noise through the proper use of materials that posses enhanced damping properties.

In recent research, the most popular method to make this attenuation more predictable has been the use of damping material; this typically involves the application of high-damping materials like elastic materials. For almost half of a century, researchers have conducted studies on topics including: analytical or numerical modeling techniques of different damping. Among the different elastic damping methods, constrained-layer damping structures are the most efficient approach when introducing damping to a system.

Many studies focus on the constrained-layered elastic structure. The majority of these studies are based on the three-layer constrained sandwich beam due to its ability to include all of the factors that influence the system damping properties. It turns out that relatively few works have focused on the multiple-layer constrained sandwich beam and its ability to further reduce noise and vibration.

When an unacceptable vibration problem needs to be controlled, it is firstly desirable and often necessary to understand its whole nature. Then it can solve, if an added damping system is to be effective, the increased damping must be significantly larger than the initial damping. Then, it must be decided whether the problem would be best solved by passive or active control methods. The passive control involves modification of the stiffness, mass and damping of the vibration system to make the system less responsive to its vibratory environment. If the unacceptable vibration is dominated by one or more resonance of the structure, it can be often adequately controlled by increasing the damping of the system.

II. LITERATURE REVIEW

Gregoire Lepoittevin [1], this thesis deals with the design of composite laminates with integrated damping layers. The damping capability of structural elements is an important design aspect. It enables to reduce the amplitude of vibrations which increases the long-term reliability and fatigue life. In transportation systems, it also improves the acoustical comfort of the passengers. A typical solution is to bond a viscoelastic material layer on the surface of the load-carrying structure. When the damping treatment is constrained by a stiff layer, high damping rates can be obtained. With the use of fiber-reinforced composite materials, it is possible to have one of the layers made of a soft damping layer. In that case, the damping treatment is constrained by composite laminates that have also to fulfill mechanical requirements. The goal of this PhD thesis is to propose design guidelines for composite laminates with integrated damping treatments. The objective is to obtain a structural component having simultaneously high mechanical and vibration damping properties at the lowest possible weight. The first part of the work deals with the design and the optimization of segments of constrained layer damping treatment. It is shown that free edges of the damping layer have to be placed where the bending curvature of the load-carrying structure is the highest. The results also demonstrate that there is a number of segments of constrained layer damping treatments for each bending modes that maximizes their modal loss factor. An optimization technique has been developed with the goal to maximize the damping rate by adjusting the segments' position. This enables to further increase the damping rates. In the second part, a numerical model of a composite beam with a soft core layer is validated using an analytical solution. The presence of the damping layer tends to decouple the sub-laminates: they behave as two separate bodies experiencing the same bending curvature. This effect vanishes by increasing the length-to-thickness ratio of the structure. In the third part, the influence of the different damping layer design variables on the laminates deflection, maximal flexural force, and stability and in-plane stiffness's is studied. Different integration solutions are considered: a damping layer integrated with open edges (like a sandwich configuration), a damping layer integrated with closed edges along its width and a damping layer integrated with closed edges both along its length and width. The results show that two distinctive design rules have to be followed depending on whether the goal is to achieve high mechanical properties or high damping rates. The damping layer should be integrated with open edges, should be placed in the middle of the laminate lay-up, should be significantly long and should have a low shear modulus to obtain high damping rates. The damping layer should be integrated with closed edges, should be placed as far away as possible from the plates mid- plane, should be short and should have a high shear modulus to obtain high mechanical performances. The most promising solution is for a damping layer integrated with all edges closed. This enables to reduce the decoupling effect. As a consequence, the structural bending stiffness and strength and stability properties are significantly improved. Nonetheless, the damping material has to have special properties. It must have simultaneously high shear modulus to ensure high mechanical properties and high loss factor to ensure a high damping rate. Additionally, such damping treatment has to have much larger dimensions than a classical constrained layer damping treatment. Therefore, the latter is the most suitable solution as it ensures to have high mechanical properties, high damping rate at the lowest weight.

Tian-Jun Yu [2] Multi-pulse homoclinic orbits and chaotic dynamics of a supercritical composite panel with free layer damping treatment in subsonic flow are investigated considering one to two internal resonances. In viscid potential flow theory is employed to exhibit the aerodynamic pressure and Kelvin's model is used to describe the viscoelastic property of the free damping layer. By Hamilton's principle, the governing equation of the composite panel in the subcritical regime is derived. In the supercritical regime, the buckling configuration is solved analytically and the PDE is obtained by introducing a displacement transformation for nontrivial equilibrium configuration. Then the governing equation in the first supercritical region is transformed into a Discretized nonlinear gyroscopic system via assumed modes and then Galerkin's method. The method of multiple scales and canonical transformation are applied to reduce the equations of motions to the near-integrable Hamiltonian standard forms. The Energy-Phase method is employed to demonstrate the existence of chaotic dynamics by identifying the existence of multi-pulse jumping orbits in the perturbed phase space. The global solutions are finally interpreted in terms of the physical motion of the gyroscopic continua and the dynamical mechanism of chaotic pattern conversion between the forward traveling wave motion and the complex bidirectional traveling wave motion are discussed.

Yang Liu [3], the chatter occurs during milling operation when the axial depth of cut is too large and/or the spindle speed approaches one of natural frequencies of the machining system. The critical axial depth of cut and stable spindle speed ranges for chatter occurrence are influenced by dynamic stiffness and natural frequency of the milling tool holder. In this work, a novel constrained layer damping tool holder was developed to increase chatter stability of end milling operation. Firstly, optimum design geometrical parameters were analytically solved with respect to optimum damping and constraining layer materials. Then the developed damping tool holder was manufactured. Lastly, modal tests and cutting experiments were carried out to verify the effectiveness of chatter suppression with the developed damping tool holder. The frequency response, cutting forces and machined surface quality were measured and compared. It is found that the dynamic stiffness and critical axial depth of cut for the developed damping tool holder are 600 % higher than those of the conventional mono-solid tool holder with steel alloys. The natural frequency of the developed damping tool holder has increased by 19 %, which can allow wider spindle speed ranges for stable end milling operations.

Ayodele Adessina [4], the aim of this paper is to present a finite element model based on first order shear theory (zig-zag approach) to compute the damping characteristics of sandwich structures with multi-layered frequency-dependent viscoelastic cores. The model is validated versus a layer wise finite element model and used to study damping and rigidity of a laminated glass configuration with a multi-layered visco-elastic core composed of acoustic PVB and PVB. It is shown that the rigidity index of the structure (defined as the dimensionalized inverse of the maximal transverse displacement under a static load) evolves linearly with the viscoelastic layers' thicknesses and quadratically versus elastic layer's thickness. The first mode damping and resonant frequency show a non monotonous behaviour. In particular, the existence of an optimal faces thickness for damping is shown while a quadratic behaviour of frequency versus acoustic PVB layer thickness is reported.

III. PROBLEM STATEMENT

In order to stay competitive in the contemporary marketplace, manufacturers of advanced engineering products need to place a strong emphasis on their consumer's level of comfort when using their product. The presence of excessive noise can greatly reduce a consumer's perception of comfort. Thus, there is an increasing demand for systematic research on the application of damping structures that can ensure a perception of comfort in the consumers. Any analysis of multiple-layer damping structures must take into consideration to both the vibration as well as the noise aspects of the problem. Sample of flat sheet metal and stamped shape with viscoelastic material will be analyzed using FEA. Modal analysis of these components will be done using Ansys/ Hypermesh. Experimental, Free – Free vibration will be performed on component using hammer, accelerometer, and FFT Analyser. Comparative analysis will be done for FEA and Experimental results.

IV. METHODOLOGY

Step 1:- I started the work of this project with literature survey. I gathered many research papers which are relevant to this topic. After going through these papers I learnt about Experimental Vibration & Modal Analysis of sheet metal structure reinforced with elastic material.

Step2:- After that the components which are required for my project are decided.

Step 3:- After deciding the components, the 3 D Model and drafting will be done with the help of CATIA software.

Step 4:- The Modal & Harmonic Analysis of the component will be done with the help of ANSYS using FEA.

Step 5:- The experimental observations will be taken.

Step 6:- Comparative analysis will be made between simulation and experimental results and then Results and conclusions will be drawn.

V. FINITE ELEMENT ANALYSIS

The Finite Element Method is a numerical approximation method, in which complex structure divided into number of small parts that is pieces and these small parts are called as finite elements. These small elements connected to each other by means of small points called as nodes. As finite element method uses matrix algebra to solve the simultaneous equations, so it is known as structural analysis and it's becoming primary analysis tool for designers and analysts.

The three basic FEA process are
a) Pre processing phase
b) Processing or solution phase
c) Post processing phase

Modal analysis is done to determine the natural frequencies and mode shapes of a structure. The natural freq. and mode shapes are important parameters in the design of a structure for dynamic loading conditions.

A. FEA Pre Processing:

The pre-processing of the sheet metal is down for the purpose of the dividing the problem into nodes and elements, developing eqn. for an element, and applying boundary conditions, initial conditions for applying loads. The information required for the pre-processing stage of the sheet metal is as follows,

- Material properties: The values of young's modulus, poisons ratio, density, and yield strength for steel are taken from material library of the FEA package.

Material properties

Material- Structural Steel
Young's Modulus- 200 GPa
Poisons Ratio- 0.3
Density- 7850 kg/m3
Yield Strength- 520 Mpa.

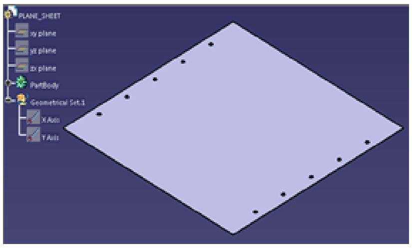


Fig. 1 Geometry of Plane Sheet

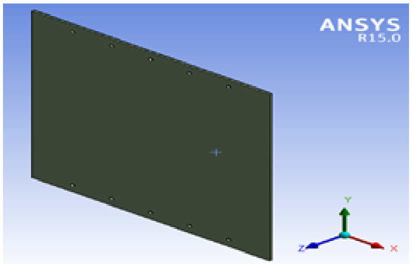


Fig.2 Geometry of sheet with visco elastic material

Finite Element Method (FEM):It is a numerical technique for finding approximate solutions to boundary value problems for partial differential eqn. It is also referred to as finite element analysis (FEA). FEM subdivides a large problem into the smaller, parts, called finite elements. The simple equations that are model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then the uses variation methods from the calculus of variations to approximate a solution by minimizing an associated error function.

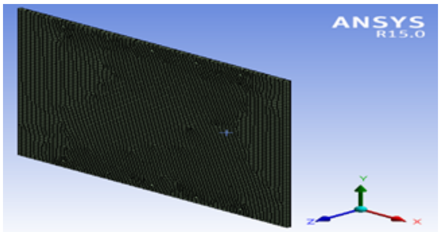


Fig 3 Discretized Model

Element type- Hexahedron, Tetrahedron
No. of Elements- 10140
No. of Nodes- 56877

Constraint: The nodes around the side panel holes have a rigid element connecting them to the centre of the hole which has of its degree of freedom fixed. The element which is used to fix side panel and vehicle is fixed and used as a rigid element.

The minimum and maximum are set, together with other mesh parameters such as element type and material. The selected object is as ready for further analysis.

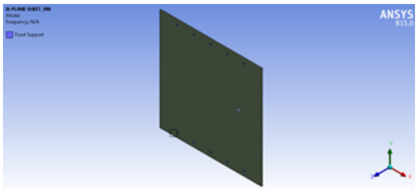


Fig 4 Boundary Condition

B. Post Processing:

The acceptability of the design of the sheet metal needs to be considered from the results of the analysis.

Model acceptance criteria: Natural frequency of the structure should be increase with reinforcement of elastic material

a) Modes:

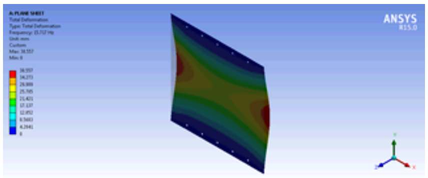


Fig 5Mode of structure without reinforcement Resonant mode at 15.717 Hz

C. Reinforced Model Analysis:

Reinforced Model:

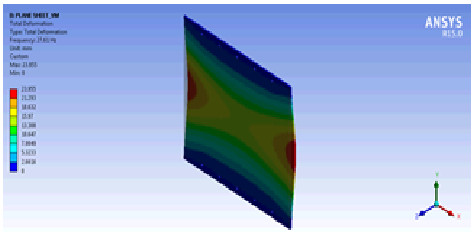
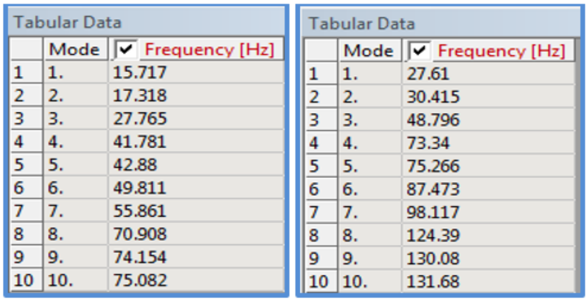


Fig 6Mode of structure with reinforcement Resonant mode at 27.61Hz



Tabular Data

	Mode	☑ Frequency [Hz]
1	1.	15.717
2	2.	17.318
3	3.	27.765
4	4.	41.781
5	5.	42.88
6	6.	49.811
7	7.	55.861
8	8.	70.908
9	9.	74.154
10	10.	75.082

Tabular Data

	Mode	☑ Frequency [Hz]
1	1.	27.61
2	2.	30.415
3	3.	48.796
4	4.	73.34
5	5.	75.266
6	6.	87.473
7	7.	98.117
8	8.	124.39
9	9.	130.08
10	10.	131.68

Fig 7 Frequencies obtain by FEA without and with reinforcement

VI.RESULT AND CONCULSION

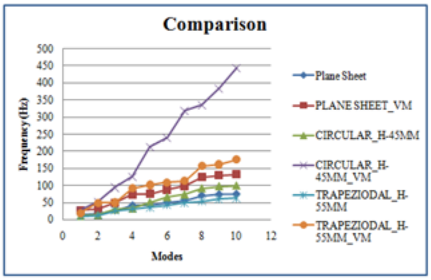


Fig.8.Comparison graph of all materials

- Plane sheet with Visco-Elastic Material is stiffer than plane sheet.
- Circular sheet with Visco-Elastic Material is stiffer than circular sheet.
- Trapezoidal sheet with Visco-Elastic Material is stiffer than trapezoidal sheet.
- Among all, circular with reinforcement is stiffer.

VII. REFERENCES

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