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FREE VIBRATION ANALYSIS OF PERFORATED PLATE USING FEA & EXPERIMENT

Mr. Ashish Rameshrao Selkar[1] Prof. P. D. Tambe[2]

1 .PG Student, Department Of Mechanical Engineering, SKNSITS, Lonavala

2. Professor, Department Of Mechanical Engineering, SKNSITS, Lonavala

Email id; ashish.selkar99924@gmail.com

ABSTRACT

Perforated plates are extensively used in industrial application such as screening materials, and acoustics proofing. It is also used in nuclear engineering field. The perforated structures usually supported equivalent or a component, and a reactor coolant flows through the perforated plates. In this project we will do free vibration analysis of perforated plate with different penetration pattern like circular, rectangular etc. & changing percentage of perforated region to get different natural frequency & mode shape. Also carry out experimental analysis on test specimens using FFT analyzer.

I INTRODUCTION

In the world of engineering design, the common use of a purely linear vibrating system usually results in a sub-optimum design, as nonlinearities are a common occurrence in real-life. Linear systems are described as systems where all system invariants, such as

frequency-response functions, damping ratios, mode shapes, and resonant frequencies; are governed by their respective linear differential equations. However, simply because a system may act in a linear manner within certain parameters does not substantiate the fact that the system is truly linear. As a result of only looking at systems in their linear range, nonlinearities are often overlooked. This can easily be done because nonlinearities may be caused by something as simple as geometry or friction. On the other hand, it can be a result of something as complex as the interactions of two different interfacing materials. Furthermore, nonlinearities are often dependent on the frequency at which the system is vibrating and the energy applied to the system. The more energy that is applied to the system the greater the chance of leaving a linearly acting region for a nonlinear one. Therefore, it is imperative that the engineering design process focus on methods to improve nonlinear design. In classical vibration analysis the theory of linear systems has been paramount and within this theory lies the concept of linear normal modes (LNMs). One important property of LNMs is their ability to decouple the equations of motion, or create independent linear vibrating systems regulated by their Eigen solutions. As a result of decoupling the equations of motion, two principles arise that are quite useful in linear vibration analysis. The first being that of invariance, where when motion is initiated on an individual LNM all other LMNs are quiescent for all time. The other principle is that of modal superposition, and it is defined as the ability to combine all individual LNM motion for both free and forced oscillations. However, as previously stated a linear analysis of a system will only produce a sub-optimum design and therefore an analysis technique for nonlinear systems is necessary. One such analysis technique is that of nonlinear normal modes (NNMs). Nonlinear normal modes are a powerful tool for structural design that allows an engineer to easily comprehend a structure's free and forced response for a variety of nonlinear dynamic behavior and relate them to the LNMs that are so widely used. This thesis purposes a variation on established testing techniques for experimentally extracting the backbone curves to estimate NNMs, using an extension of force appropriation common in linear experimental modal analysis (EMA), in conjunction with the phase lag quadrature criterion. This is accomplished by modifying the frequency and amplitude distribution of the excitation and allows for the modal parameters to be extracted from the isolated mode. The phase lag quadrature criterion states that when a phase shift of 90 degrees occurs between the excitation force and the acceleration of the response then resonance has been achieved.

The test specimen which the method will be tested on is a rectangular perforated plate provided by Cummins. The specimen was excited with modal shakers using a stepped-sine harmonic excitation at various forcing amplitudes to isolate single NNMs. The NNMs are then estimated using the backbones of the nonlinear frequency responses. Multiple modes were tested to verify the robustness of the method. A finite element model was also generated to estimate the NNMs which are then compared to the experimental results and updated to attempt to properly capture the nonlinearity. The results of the work done in this thesis are conveyed as follows. First, a linear analysis of the perforated plate was performed. Theoretically, numerically, and experimentally obtained natural frequencies and mode shapes were compared to verify the finite element model in the linear vibration region. This was followed by stepped-sine excitation of the rectangular perforated plate on a small modal shaker. The NNMs were then extracted from the nonlinear frequency responses and compared to the NNMs generated by the finite element model. Upon comparison it was seen that the physics of the plate were not properly modeled and an updated finite element model was developed. It was also seen in the model that the type of nonlinearity changed at higher forcing amplitudes and as a result, the rectangular plate was tested on a larger modal shaker to observe if in fact, the type of nonlinearity actually changed and if it could be captured by the NNM. Finally, conclusions of the method and future work on how to improve the experimental method are presented.

II REASON FOR VIBRATION ANALYSIS

Lightly damped structures can produce high levels of vibration from low level sources if frequency components in the disturbance are close to one of the system's natural frequencies. This means that well designed and manufactured sub-systems, which produce low level disturbing forces, can still create problems when assembled on a vehicle. In order to avoid these problems, at the design stage it is necessary to model the system accurately and analyze its response to anticipated disturbances.

III OBJECTIVES

To compare resonance frequency, damping ratio & material properties of perforated plate. To design of perforated plate with different penetration pattern like circular, rectangular, etc. for increasing lifespan of perforated plate. To get different natural frequency & mode shape by changing percentage of perforated region. Obtain highly efficient perforated plate having good environmental and structural properties. To design perforated plate have higher shear loads and also bear the characteristics of higher vibration damping capacity.

IV. METHODOLOGY

1. Experimental analysis

Here we are carried out following steps:

- Selection of perforation pattern
- Test rig for perforated plate
- Mounting of FFT analyzer
- Input signal of excitation by Impact hammer
- Output signal by accelerometer

- Readings & visualization of vibration
- Data collection

A. Perforation pattern selection**:** For analysis of perforated plate we select the tromell machine plate
B. Mounting of FFT analyzer: FFT analyzer is used for measuring resonance frequency. FFT analyzer gets input with respect to time and provides output in frequency spectrum in from of graph or equations.

C. Input signal of excitation by Impact hammer: Input Signal which required for FFT analyzer is given by impact hammer.

D. Output signal by accelerometer: The resonance due to impact hammer forming vibration and this amount of vibration is detect by the accelerometer

E. Readings & visualization of vibration: This amount of vibration is visualized by FFT analyzer.

F. Data collection: These readings of vibration are collected from FFT Analyzer and note it down.

FFT Analyzer
Fast Fourier Transform (FFT) analyzer is used to do the experimental validation. FFT analyzer validates the input signal, computes the magnitude of its sine and cosine components and displays the spectrum of the measured frequency components. This method carries advantage of being fast and accurate. The method is faster than traditional analog spectrum analyzers.

2. Finite Element Analysis
The finite element method has become a powerful tool for the numerical solution of a wide range of engineering problems. It has developed simultaneously with the increase in use of the high speed electronic digital computers and with the growing emphasis on numerical methods for engineering analysis.

Steps in FEM As Follows
- 3D Part Modeling
- Assembly
- Material Selection
- Property Discretization (i.e. Meshing)
- Boundary Conditions (Loads, Constraints)
- No. of modes shapes
- Solver
- Results-Mode shapes, Natural Frequencies, Deformation
- Conclusion
- 3D Part Modeling: 3D Part modeling is carried out in CATIA V520 software.

- Assembly: After 3D part modeling making assembly of those parts in CATIA V520 software.

- Material Selection: Select the material for perforate plate in FEA software like ANSYS 15.0.

- Property Discretization (i.e. Meshing): Meshing is carried out of number of modes of given component. And also mention the number of modes, by carried out meshing the software solving the equations and gives the frequency.

Advantages of FEM:

The advantages of finite element method are listed below:

1. Finite element method is applicable to any field problem: heat transfer, stress analysis, magnetic field and etc.

2. In finite element method there is no geometric restriction. The body or region analyzed may have any shape.

3. Boundary conditions and loading are not restricted. For example, in a stress analysis any portion of the body may be supported, while distributed or concentrated forces may be applied to any other portion.

Limitations of FEM:

The limitations of finite element method are as given below:

1. To some problems accurate results are not obtained to the approximations used

2. For vibration and stability problems the cost of analysis by FEA is prohibitive.

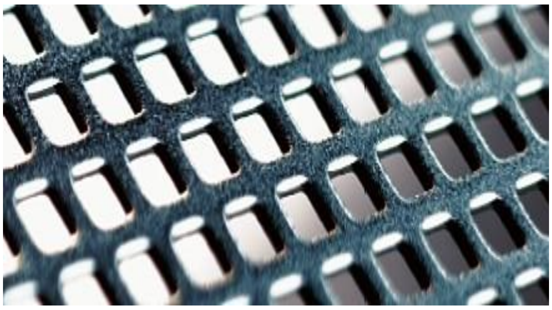
3. Stress values may changes from fine mesh to its counterpart.

V ENVIRNMENTAL ASPECTS

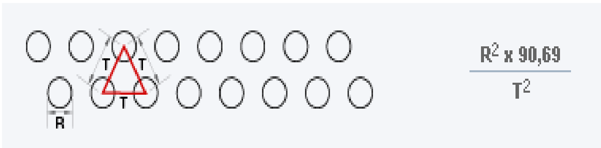
Utilising aluminium is suitable from the environmental point of view, because it can be easily recycled and re-melted to produce something new. As recycling does not damage the metal's structure, aluminium can be recycled 100 %, without any loss of its natural qualities. Choice of alloys for architectural applications, decorative purposes and visual parts for facades, where guaranteed colour uniformity between several production batches is required, high end raw material alloys may be obligatory. RMIG uses its purchasing power worldwide, sourcing raw materials from mills and suppliers, which ensures a colour uniformity for anodised products on pre anodised coils, strip, sheets and products that are anodised after perforation. Sheets, coils and slit material can be processed and supplied with PVC foil, protecting your high value products against scratches. As most grades can be supplied in different temper designations, we can help to find the right alloy in combination with the temper and surface treatment and thus the best choice and solution for your demands.

VI CALCULATION OF OPEN AREA

The formulae on this page are used to calculate the open area of a user defined perforation. The results are calculated automatically by clicking the "Submit" button when you have entered all the relevant figures.



Calculation of open area: round holes, triangular pitch



Top of Form

Bottom of Form

Calculation of open area: round holes, rectangular pitch

Top of Form

Bottom of Form

Calculation of open area: square holes, rectangular pitch

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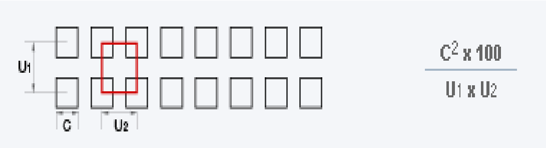

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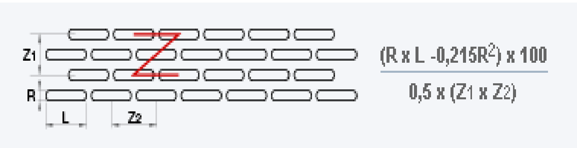
Calculation of open area: square holes, staggered pitch

Top of Form

Bottom of Form

Calculation of open area: slot holes, staggered pitch



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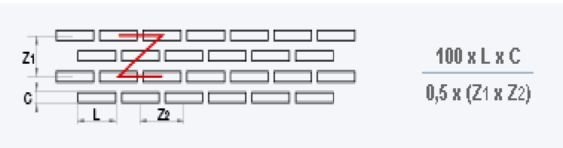
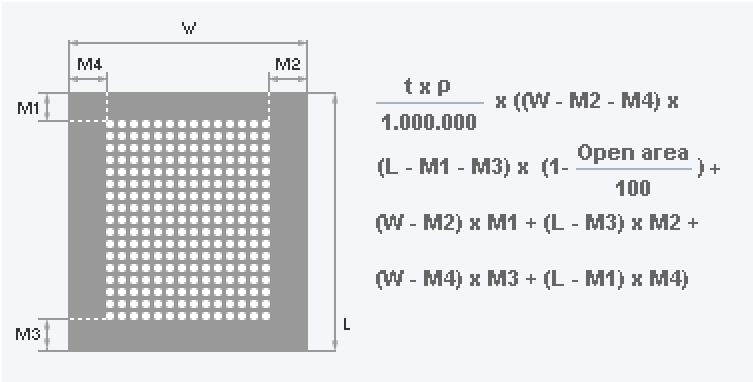
Calculation of open area: rectangular holes, staggered pitch



VII WEIGHT OF A PERFORATED SHEET

This formula is used to calculate the weight of a perforated sheet, important information especially when planning transportation. The results are calculated automatically by clicking the "Submit" button when you have entered all the relevant figures.

Calculation of weight of a perforated sheet



VIII. EXPECTED OUTCOMES

1. The perforated plate natural frequencies are to be calculating by using the FEM & FFT analyser. The dynamic performance will increase by changing design of perforation an as also varying in thickness of perforated plate..

2. The vibration frequency of modified perforated plate will be less than existing plates

3. The stresses induced in the perforated plate are less than permissible yield strength of material.

IX REFERENCES

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