MODELLING AND EXPERIMENTAL INVESTIGATION ON PERFORATED PLATE MOBILITY

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical engineering (Structure and Materials)"

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This report is submitted in fulfillment of the requirements for the award Bachelor of Mechanical Engineering (Structure and Materials)

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DECLARATION

"I hereby declare that the work in this report s my own except for summaries and quotations which have been duly acknowledged."

Signature: ……………………..

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Date: ……………………..

"You have to learn the rules of the game. And then you have to play better than anyone else."

Albert Einstein

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ABSTRACT

Porous materials are usually applied to noise control. The application of perforated plate is widely used in sound absorption purposes as it reduces sound radiation. However, perforation of the plate has a decreasing effect on the plate stiffness thus increasing its vibration. Therefore, a modeling and experimental investigation on perforation's effects is performed. This report discusses the effect of the perforation on the plate mobility. The perforation ratio could be affected by the numbers of holes, diameter of the holes, and arrangement of the perforation. In this project, Finite Element Analysis – Patran and Nastran was employed to obtain the discrete surface vibration velocity on a single analytical model. The natural frequency of the Finite Element Analysis solid plate model was compare with the theoretical calculation to validate the accuracy of the modeling. The result obtained from the Finite Element Analysis was compared with the solid plate to show the effect of perforation on plate mobility, which increases as the perforation ratio increases. An experimental investigation was carried out to validate the results from the analysis earlier.

ABSTRAK

Bahan berliang biasanya digunakan untuk mengawal tahap bunyi. Aplikasi plat berlubang digunakan secara meluas dalam tujuan penyerapan bunyi kerana ia mengurangkan radiasi bunyi. Walaubagaimanapun, perlubangan plat meninggalkan kesan pengurangan kekakuan plat dan menyebabkan getarannya meningkat. Dengan itu, satu analisis pemodelan dan eksperimen terhadap kesan perlubangan panel telah dilaksanakan. Laporan ini membincangkan kesan perlubangan terhadap tahap getaran plat. Kadar nisbah perlubangan boleh dipengaruhi oleh pelbagai factor, seperti bilangan lubang, diameter lubang, dan susunan perlubangan. Dalam projek ini, ‘Finite Element Analysis’ - Patran dan Nastran telah digunakan untuk mendapatkan halaju diskret getaran permukaan pada model analisis tunggal. Frekuensi tabii model plat pepejal FEM telah dibandingkan dengan pengiraan teori untuk mengesahkan ketepatan model. Hasil yang diperolehi dari FEM akan bandingkan dengan plat yang tidak berlubang untuk menunjukkan kesan penembusan terhadap pergerakan plat, yang meningkat apabila nisbah penembusan meningkat. Satu eksperimen telah dijalankan untuk mengesahkan keputusan dari analisis yang dijalankan sebelum ini.

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LIST OF STYMBOL

A	Cross section area
a	Length of plate
$[B]$	Damping matrix
B	Bending stiffness
B^*	Effective bending stiffness
b	Width of plate
c	Damping coefficient
d	Holes diameter
ς	Damping factor
η	Damping loss factor
E	Young's Modulus
$E*$	Effective Young's Modulus
F	Excitation force
$i=\sqrt{-1}$	Imaginary unit
$[K]$	Stiffness matrix
k	Stiffness
L	Lengt
$[M]$	Mass matrix
M	Total mass of plate

m	Mass of the system
m_a	Mass per unit area
p_x	Perpendicular pitch
p_y	Parallel pitch
ρ	Density
$\rho *$	Effective density
p,q	Vibration mode
S_x	Area of plate surface
t	Thickness
ν	Poisson's ratio
$\nu *$	Effective Poisson's ratio
$U(\omega)$	Complex displacement vector
ω	Frequency
ω_n	Natural frequency
$\omega_{p,q}$	Natural frequency for the mode (p,q)
$\omega*_{p,q}$	Effective natural frequency for the mode (p,q)
x	Displacement
$\dot{x}$	First derivatives of x
$\ddot{x}$	Second derivatives of x
Φ_n	N-th mass-normalized mode shape
$[\phi]$	Phase Matrix

LIST OF ABBREVATION

DAQ	Data Acquisition System
FE	Finite Element
FEA	Finite Element Analysis
FEM	Finite Element Method
FRF	Frequency Response Function
FYP	Final Year Project
XLE	Perpendicular ligament efficiencies
YLE	Parallel ligament efficiencies

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CHAPTER 1

INTRODUCTION

1.1 Background

Sound is an audible sense that perceived by human brain through ears. Sound travels through matter by wave. Wave is an oscillation of pressure that can be reflected, refracted or attenuated. The difference between sound and noise is the desired and undesired waveform respectively. Noise is mean by any unwarranted disturbance within a useful frequency band (NIOSH, 1991). Despite that, noise can be varies according to the human ears' sensitivity. Noise is generated from vibrating structures as show in Figure 1.1.

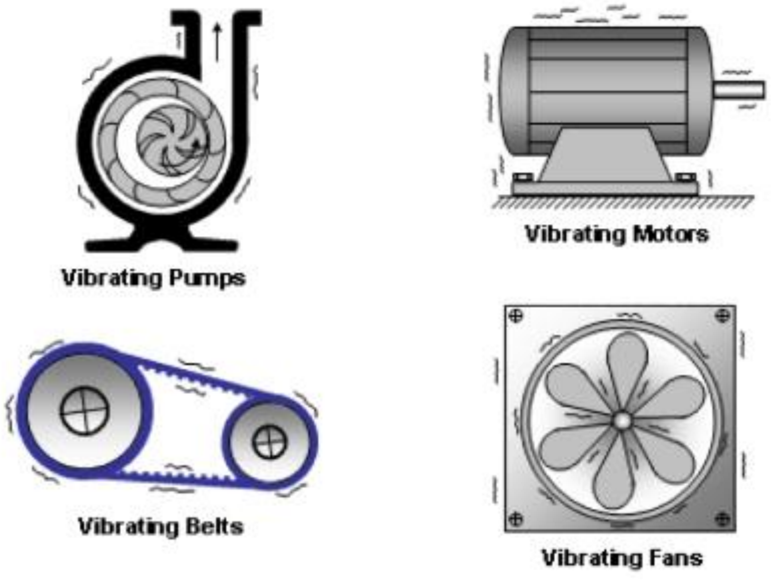

Figure 1.1: Example of vibrating structure

Noise can be present in any human activity, e.g., occupational noise and environmental noise. In the United States, occupational hearing loss is the most common work-related injury where there is approximately 22 million U.S. workers exposed to hazardous noise level at work (WHO, 2004). It is recommends that all work expose to noise should be controlled below a level equivalent to 85 dBA for eight hours to minimize the risk of hearing loss (NIOSH, 2012). Therefore, in order to prevent hearing loss, noise control technology is introduced to aim to reduce noise to an acceptable level.

Prior to the design of noise control, the noise sources must be identified and evaluated. Occupational noises are usually generated from sources that associated with structural vibration. Mechanical vibration noise occurs when the components resonating at their natural frequencies. Thin-plate like structure is one of the significant sources of noise in structural vibration.

One of the common noise control technique is to introduce holes into the structure. Perforated plates can be seen in industrial applications, for example, the solid protective cover over the belt drive and flywheel is replaced with a wire mesh cover as seen in Figure 1.2. Porous material applies the sound absorption principal, where it is used to absorb the sound by reducing its intensity. The holes allow the sound waves to pass right through it. The potential for using these alternative structures allows the ability to blend into different situation to ensure adequate performance.

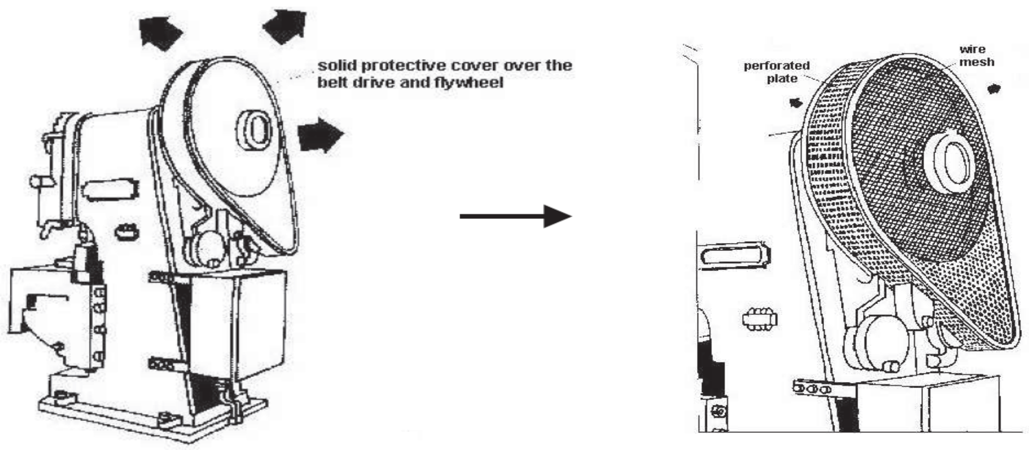

Figure 1.2: Example of perforated structure used in machinery

1.2 Problem Statement

Noise characteristic of structures are determined by mass, stiffness and damping. Perforated panels are commonly used in sound absorption purposes. It is important in reducing the noise level in order to create an adequate working environment. However, the introduction of perforation into the solid panels significantly reduces the stiffness of the plate. Stiffness is defined as the rigidity of a structure. Now consider the area of the plate significantly decreases due to the perforation effect, the rigidity of the panel decreases. Hence, when the panel is excited by an external force, this will results an increase of vibration in the panel itself.

The effect of the dynamics of the plate after perforation is rarely discussed. This project is conducted to analyze and to discuss the effect of perforation on the plate mobility.

1.3 Objectives

To investigate and to model the effect of perforation on the plate mobility using Finite Element Method (FEM)

1.4 Scope of project

As there is no established analytical model is available to calculate the mobility of the perforated panels, the dynamics of the perforated panel will be investigated using the result obtained from Finite Element Method (FEM). FEM will be employed to obtain the discrete surface vibration velocity. Direct frequency response analysis is used as the solution. Different holes geometries are stimulated to investigate their effect on the plate mobility. The perforation ratio can be affected by the number of the holes, diameter of the holes and arrangement of the perforation patterns. The mobility of the perforated panel is then compared against that of the solid plate in one-third octave band frequency. Experimental work will be conducted to validate the results from FEM.

The effect of perforation into a solid panel will change the dynamic properties of the panel. Many had discussed the effective Young's modulus, the Poisson's ratio, and the density after the perforation effect. However, this project will not concentrate on these dynamic properties. This project aims to investigate the change of vibration level due to the instruction of holes into a solid panel.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Stiffness is the measurement of rigidity of an object. Stiffness arises from any structural component that deforms elastically under action of forces. For an elastic structure with a single degree of freedom, stiffness is

$$k = \frac{F}{x} \tag{2.11}$$

Equation (2.11) shows the relationship between stiffness of the structure and the displacement response of the structure. Hooke's Law define that stiffness is the deflection that proportional to the load applied. A decrease in the stiffness, result an increases in the displacement response, if the force applied on the structure remain constant.

Introduction of perforation into the panel significantly reduces the cross section area. The material property Young's modulus and length of the panel remained constant; stiffness of the plate is directly proportional to the cross-section area. A reduction in cross-section results in a decreases in stiffness. This is lead to a higher amplitude as the panel has a lower resistant to the applied load.

When a structure is excited with force, the result of the motion of the structure may be expressed in terms of the level of vibration. The resulting motion