UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

VARIABILITY IN VIBRATION INPUT POWER FROM THE STRUCTURE-BORNE SOUND SOURCE ON PLATE AND BEAM STRUCTURES

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A thesis submitted
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DECLARATION

I declare that this thesis entitled, ”Variability in vibration input power from the structure-borne sound source on plate and beam structures” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not submitted in candidate of any other degree.

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATION

To my beloved parent, husband, daughter, whole family and friends

ABSTRACT

Structure-borne source which transmits vibration power to the supporting structure especially in buildings plays a major role in contributing structure-borne noise. The structure-borne sources are also capable of causing damage to the receiver structures. In order to prevent noise radiation and structural failure, it is important to characterise the structure-borne sound source and to recognize its potential input power. However, the knowledge of the force excitation behaviors from the structure-borne source which creates variability in the input power is still lacking. To give an effective insight of the structural mechanism excited by the structure-borne source, some uncertainties such as the amplitude, excitation phase and location of the excitation force which create the variability in the input power are modelled in this study. Quantification of the uncertainties of the maximum-minimum bands, frequency-averaged mean and variance are obtained from the variability of input power in the infinite and finite structures. It is shown that the variability of the input power reduces as the frequency increases. It is also found that the quantifications of the variability from the finite structure can also be approached using the infinite structure.

For characterisation of the structure-borne sound source, thin and thick reception structures are used for the velocity source and the force source assumptions in the reception plate test. It is shown that, the reception plate for the force source assumption, the averaging spatial response across the plate area having low modal density is found to be problematic due to high variability of the plate velocity. Therefore, to obtain a more representative spatially averaged mean-squared velocity, only response points closed to the contact points are taken into account in the calculation. The results show that the measured source mobility from the reception plate is improved. Characterisation using a beam structure is also found feasible in the 'reception structure technique'.

ABSTRAK

Sumber bawaan-struktur yang memindahkan kuasa getaran ke struktur sokongan terutamanya di bangunan memainkan peranan utama dalam menyumbang pencemaran bunyi bising yang disebabkan oleh bawaan-struktur. Sumber getaran oleh struktur mampu menyebabkan kerosakan kepada struktur penerima. Pencirian terhadap sumber bunyi bawaan-struktur dan mengenal pasti potensi kuasa input adalah sangat penting untuk mencegah radiasi bunyi dan kerosakan sesuatu struktur. Walaubagaimanapun, pengetahuan mengenai tingkah laku pengujaan daya daripada sumber bawaan-struktur yang mewujudkan kepelbagaian dalam kuasa input masih lagi berkurangan. Untuk memberikan gambaran yang efektif terhadap mekanisma sesuatu struktur, beberapa ketidaktentuan seperti amplitud, fasa pengujaan dan kedudukan daya pengujaan yang mewujudkan kepelbagaian dalam kuasa input dimodelkan dalam kajian ini. Kuantifikasi jalur maksimum-minimum, purata-frekuensi min dan varians diperolehi daripada kepelbagaian kuasa input dalam struktur terhingga dan tak-terhingga. Didapati bahawa, kepelbagaian kuasa input berkurang semasa frequensi meningkat. Ianya juga didapati bahawa kuantifikasi daripada struktur terhingga juga boleh diperolehi dan dipadankan dengan menggunakan struktur yang tak-terhingga.

Untuk pencirian sumber bunyi bawaan-struktur, struktur penerima tebal dan nipis digunakan untuk andaian sumber halaju dan sumber daya dalam ujian kaedah plat penerimaan. Ia telah menunjukkan bahawa, dalam kaedah penerimaan plat untuk andaian sumber daya, purata respon ruangan di seluruh kawasan plat yang mempunyai kepadatan modal yang rendah didapati bermasalah disebabkan oleh kepelbagaian halaju plat yang tinggi. Oleh itu, untuk mencari 'min-halaju kuasa dua' yang lebih efektif, hanya pengukuran respon ruangan berhampiran dengan pusat perhubungan (berhampiran motor) diambil dalam pengiraan. Keputusan menunjukkan bahawa mobiliti daripada sumber yang diukur daripada plat penerimaan telah ditambahbaik. Pencirian menggunakan rasuk juga didapati boleh dilakukan dalam ujian 'kaedah penerimaan plat'.

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LIST OF ABBREVIATIONS

Hz	**H**ertz
kHz	**k**ilo **H**ertz
MOF	**M**odal **O**verlap **F**actor

LIST OF SYMBOLS

a	Length of panel
b	Width of panel
B	Bandwidth
c_L	Longitudinal plate wave speed
E	Young's modulus
F	Force
F_b, f_B	Blocked force
g	Statistical distribution
h	Thickness of panel
$H_n^{(2)}$	Hankel function of the second kind
$i, j = \sqrt{-1}$	Imaginary unit
I	The second mass moment inertia of the structure
k	Acoustic wavenumber
kL	Contact point separation
K_n	n-th order modified Bessel function of the second kind
L	Distance between the contact points
m'	Mass per unit length of panel
m''	Mass per unit area of panel

M	Total mass of panel
n	Number of modes
n_d	Modal density
p, q	Number of natural frequency modes
P_{in}	Input power
$\underline{P_{in}}$	Minimum input power
$\overline{P_{in}}$	Maximum input power
Re	Real part
T	Transpose conjugate
v	Velocity
v_f	Free velocity
x_n	Arbitrary n-contact points at x-axis
y_n	Arbitrary n-contact points at y-axis
$Y_i = Y_p$	Input mobility
Y_t	Transfer mobility
$\left\langle {v_R}^2 \right\rangle$	Spatial average of mean-squared velocity
$Y_R^{\Sigma}, Y_S^{\Sigma}$	Effective mobility for the receiver and source
z, Z	Impedance

ω	Angular frequency or natural frequency
ρ	Density
η	Damping loss factor
ν	Poisson's ratio

φ	Relative phase
λ	Wavelength
ϕ, θ	Phase
μ	Mean
σ	Standard deviation
Φ	Normalised mode shape

LIST OF PUBLICATIONS

Journal Articles

Putra, A., Saari, N. F., Bakri, H., and Dan, R. M., 2013. Characterisation of structure-borne sound source using reception plate method. *The Scientific World Journal*, Vol.2013, Article ID 742853.

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CHAPTER 1

INTRODUCTION

1.1 Background

Noise and vibration in buildings are among the engineering problems need to be solved to provide comfort environment as well as to prevent any unwanted structural damage. Noise in buildings can be divided into two categories based on its transmission path i.e. as airborne and structure-borne noise (Wang, 2010).

The airborne noise is defined when the sound wave generated by a noise source travels through the air and reaches the receiver directly, or it can first reach the wall structure and causes the wall to vibrate and the vibration eventually radiates noise. The noise radiated due to unstable flow from the air conditioning ventilation is the example of the direct airborne noise.

Structure-borne noise however, plays a major part in contributing to the noise pollution in buildings. Most of the noise is often generated by the vibration waves from vibrating and rotating components of mechanical services in buildings. The structure-borne sound originates due to internal force which is acting within a vibrating machine. From the vibrating sources, the vibrational energy is passed to the supporting structure and propagates through the wall, floor and other neighbouring structures in the buildings. Illustration of the airborne and structure-borne noise is shown in Figure 1.1.

The vibration of these structures then causes annoying noise radiation and risks to environment, people's activity and health effect (Flindell and Walker, 2005). Examples of the structure-borne sources in the buildings are fans, compressor, hydraulic equipment, electrical motors, heating pump and washing machines as seen in Figure 1.2.

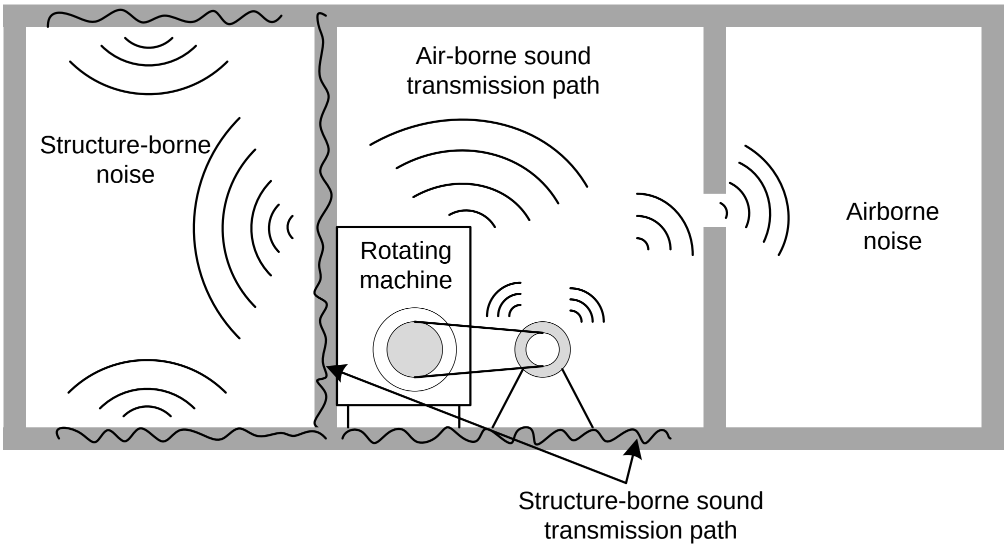

Figure 1.1 An illustration of airborne and structure-borne sound transmission path (Source: Author's original work).

For a long period, the structure-borne sources are capable of injecting high level vibration input power that is hazardous to the receiver structures. The symptoms of structural damage are sometimes not visible and unexpected accident might be occurred due to the lack of knowledge especially the information of input power injected from the machines. Thus, sufficient information about the vibration input power from the structure-borne sound sources is important as a preliminary control measurement. This allows the structural engineers to take a precaution and preventive actions by ensuring the supported structure is strong enough to absorb the potential of the vibration power and also to comply with the acceptable radiated noise levels.