EFFECT OF ACCELEROMETER MASS ON THIN PLATE VIBRATION

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ABSTRACT

Accelerometer is widely used as a vibration measurement transducer. The disadvantage of contact type accelerometer is its mass can cause the natural frequencies of the structure to change from their correct values. Generally this effect is ignored in the experimental studies based on the assumption that the accelerometer mass is negligible compared to the mass of the test structure. However when lightweight structure is tested, this effect is significant. The purpose of this study is to investigate the effect of accelerometer mass on thin plate vibration. The natural frequency and its corresponding mode shape were the parameters of interest. Two thin plates of different thickness and various boundary conditions were investigated by using experimental modal analysis and finite element analysis. The accelerometer mass was added and mounted at three different locations. Results show that the thinner the plate, the more sensitive it is to the mass loading effect. The accelerometer mass shows significant effect on some of the modes of the structure while other modes remain unchanged. The accelerometer mounted at a point of peak deflection of the plate showed large changes of natural frequencies and its corresponding mode shapes. There are no significant changes of natural frequency and mode shapes for accelerometer attached at nodal line of the particular mode. It is concluded that, the effect of accelerometer mass depends on the location of the accelerometer, vibration mode, magnitude of accelerometer mass and test structure.

ABSTRAK

Meter pecut banyak digunakan sebagai sensor untuk mengukur getaran. Keburukan meterpecut jenis sentuhan ialah beratnya boleh menyebabkan frekuensi tabii sesuatu sistem akan berubah daripada nilai sebenar. Secara amnya, kesan berat meter pecut ini diabaikan di dalam kajian eksperimen berdasarkan andaian bahawa berat meter pecut adalah terlalu kecil jika dibandingkan dengan berat sesuatu struktur kajian. Walaubagaimanapun apabila struktur kajian adalah terlalu ringan, kesan berat meter pecut ini amat ketara. Tujuan kajian ini adalah untuk mengkaji kesan berat meter pecut terhadap getaran plat nipis. Parameter pemerhatian adalah frekuensi tabii dan bentuk modnya. Dua plat nipis dengan ketebalan yang berbeza dan keadaan sempadan yang pelbagai dikaji dengan menggunakan eksperimen analisis ragaman dan analisis unsur terhingga . Berat meter pecut ditambah dan dipasangkan pada tiga kedudukan yang berbeza di atas plat nipis.Keputusan menunjukkan plat yang lebih nipis adalah lebih sensitif terhadap kesan berat meter pecut. Berat meter pecut memberi kesan ketara kepada sesetengah mod struktur manakala sesetengah yang lain ia tidak memberi kesan. Meter pecut yang dipasangkan pada titik maksimum pesongan plat menunjukkan perubahan yang besar berlaku kepada frekuensi tabii dan bentuk modnya.Walaubagaimanapun, tiada perubahan yang ketara terhadap frekuensi tabii dan bentuk modnya jika meter pecut dipasangkan pada titik nod mod tersebut. Kesimpulannya, kesan berat meter pecut bergantung kepada kedudukan meter pecut, mod getaran, magnitud berat meter pecut dan struktur kajian.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Accelerometers are transducer that measures the acceleration of a vibrating body. It is widely used for vibration measurement because of its small size, high sensitivity and large usable frequency range. In most cases, the systems that undergo experimental measurement are affected by transducer. This is true, especially if the testing structure is a small and lightweight. Then, the effect of accelerometer mass becomes significant when measuring lightweight structure.

Lightweight structures are those structures that optimize the load carrying capacity of the elements by large deflection, allowing the load to be taken primarily in tension. It is characterized by having small mass relative to the applied load which is determines through an optimization process. Lightweight structures include cable, membrane, shell, thin plate and folded structures as well as space grids, domes and trusses system.

Since, the accelerometer is the contacting transducer types, it must be rigidly attached to the structure. The coupling between the accelerometer and the original system will create a new system and lead a certain changes in its dynamic response.

Theoretically, the natural frequency is related to the square root of the ratio of stiffness to mass. Thus, if the mass of the accelerometer is added to the structure to make a measurement, it will lower the natural frequency which is illustrated in Figure 1.1. From the figure, it shows the heavier accelerometer which is in red line has a natural frequency shifted to the left, which indicates a lowered natural frequency compared with the lightweight accelerometer mass. As the frequencies are increased, the effect can be seen obviously.

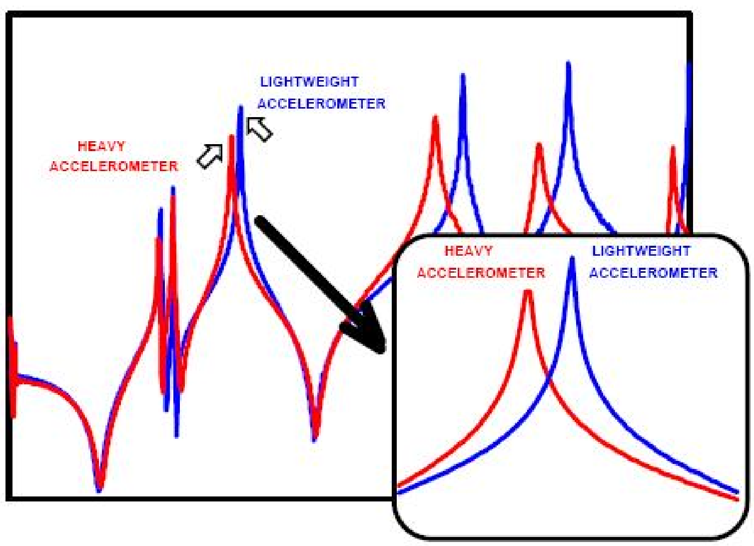

Figure 1.1: Frequency response function with two different mass of accelerometer

Thus, this project studied the effect of accelerometer mass on thin plate vibration. Thin plates are one of the lightweight structures and commonly used as structural components in many branches of modern technology namely mechanical, aerospace, electronic, optical, marine and structural engineering.

1.2 Objectives Of The Study

The aim of this study is to investigate the effect of accelerometer mass on thin plate vibration. The natural frequencies and the corresponding mode shapes of the plate are the parameters of interest.

1.3 Scope Of The Study

The scopes for this study include :

i. Determine the first sixth of natural frequencies and mode shapes by experimental and numerical analysis.
ii. Only rectangular thin plate is considered.
iii. Apply various boundary conditions on plate.

1.4 Outlines Of The Thesis

This thesis is composed of seven chapters which are as follows:

In chapter 1, general review of this study is discussed. The literature review about transducer mass loading and concentrated mass is presented in chapter 2.

Chapter 3 introduces the theoretical background about the concepts of transducer mass loading, theory of thin plate, modal analysis and finite element analysis. The understanding of the theoretical background is important to make this study achieves its objective.

Chapter 4 gives a brief explanation about the methodology used in this study. The experimental modal analysis was done by using impact hammer. The natural frequency and its associate mode shape was extracted by using modal analysis software namely MEôscope VES Version 4.0. While, for finite element analysis it was done by using ABAQUS software.

The results of first sixth natural frequency and mode shape of the test plates with various boundary conditions obtained through the experimental and finite element analysis were tabulated in the table in chapter 5.

Chapter 6 presents the analysis of data to look at the effect of accelerometer mass, location of accelerometer and thickness of the plates on the natural frequency and mode shape.

In chapter 7 the presented study is summarized. Recommendation for further research in this are also included.

CHAPTER 7

CONCLUSION AND RECOMMENDATION

The objective of this study is to investigate the effect of accelerometer mass on thin plate vibration, where the natural frequencies and its corresponding mode shapes become the parameters of interest. Two different plate thickness were examined which are plate A (4mm thickness) and plate B (3mm thickness) with various boundary condition.

The results demonstrated that an accelerometer mass affect some of the modes of a structure while other modes remain unchanged. Accelerometer attached near the anti node has larger changes in natural frequency. Thus, the mode shapes for that particular mode also show significant changes. However for accelerometer attached near a nodal line of a particular mode of the structure, numerical results showed that the natural frequencies of the mode remains unchanged. As a result, no significant changes of mode shape at this particular mode.

Based on the literature review, it was noted that accelerometer mass should not be more than 1/10 of the mass of the structure [14]. This study showed that this rule may not be reliable for the certain vibration mode. The vibration mode that effect by mass loading must be corrected by using correction method presented in reference [5]. Thus, the lightest accelerometer mass as possible has to be used to decrease the mass loading effect.

The results also demonstrated that thinner plates are more sensitive to the mass loading effect. The effect can be avoided or minimized by using the lightest accelerometer as possible or using non contact transducer.

As mention earlier in the introduction, this study look at the effect of accelerometer mass, effect of the location of accelerometer and effect of light sample on the natural frequency and mode shape at various boundary condition. Two adjacent edges clamped and free (CCFF) boundary condition gave higher changed in fundamental natural frequency compared to free edges (FFFF) with the same added mass. This is possibly due to the mass are more dominant than stiffness as added mass increased for CCFF boundary condition. It can be concluded that the effect of accelerometer mass depends on the location of the accelerometer, vibration mode and the structure. The studies on the effect of the accelerometer mass on the dynamic properties of the structures indicate that both natural frequency and mode shapes should be considered.

To improve this study in future it is recommended to use a non contact transducer to measure the response. Either than that, the shaker also can be used instead of hammer to provide constant force for vibration excitation. It is also recommended to study the effect of the accelerometer mass on damping by using the non-contact transducer. However the study should only considered the free boundary condition. This is due to damping also exist at clamped support thus will produce inconsistency in data if clamped boundary condition is used.

REFERENCES

1. Døssing,O. Prediction of Transcducer Mass Loading Effects and Identification of Dynamic Mass. *Proceeding of the 9th IMAC,*1991, Schenectady NY, Union College. 306-311

2. Silva et al. Cancellation of Mass Loading Effects of Transducer and Evaluation of Unmeasured Frequency Response Functions. *Journal of Sound and Vibration,* 2000; 16(5) : 761-779.

3. Ashory. M.R Assessment of the mass loading effects of accelerometers in modal testing, *Proceeding of the 20th International Modal Analysis Conference*, 2002 : 1027-1031.

4. Baldanzinni.N and Pierini.M. An Assesment of Transducer Mass Loading Effects on the Parameters of an Experimental Statistical Energy Analysis (SEA) Model. *Mechanical System and Signal Processing,* Firenze, 2002; 16(5): 885-903

5. Cakar.0 and Sanliturk.K.Y. Elimination Of Transducer Mass Loading Effects From Frequency Response Functions. *Mechanical System and Signal Processing*, 2005; 19 : 87-104

6. Vechio.A et al. Impact of Test Data Uncertainties on Modal Models Extracted from Multi-Patch Vibration Test. *Proceeding 1st INCE Symposium,* Le Mans, 2005.

7. Bregant.L et al. Non contact Sensors Comparison For Dynamic Testing Of Lightweight Structures; *Proceedings Of Isma 2006*; 1861-1869

8. Chai G.B. Frequency Analysis of Rectangular Isotropic Plates Carrying a Concentrated Mass. *Computers and Structures*, 1995; 56(1) : 39-48.

9. Low.K.H. An Improved Model For The Frequency Estimate Of Mass Loaded Plates By A Combined Use Of Equivalent Center Mass And Stiffness Factors. *International Journal of Mechanical Sciences*, 2001; 43: 581-594.

10. Wong.W.O. The Effects of Distributed Mass Loading on Plate Behavior. *Journal of Sound and Vibration*, 2002; 252(3) : 577-583

11. Døssing,O. Structural Testing Part 1 : Mechanical Mobility Measurement. Bruel and Kjaer.

12. Blevins.D.R. *Formula for Natural Frequency and Mode Shape*, Van NastraudReinhold Company, New York, 1979.

13. Herman Van der Auweraer. Structural Dynamics Modelling Using Modal Analysis : Application, Trends and Challenge. *IEEE Instrumentation and Measurement Technology Conference*. Budapest, Hungary, May 21-23; 2001.

14. Mark.S and Torben.R.L Piezoeleric Accelerometer and Vibration Preamplifier Theory and Application Handbook, Bruel and Kjaer, Denmark 1987

15. Avitabile,P.. Experimental Modal Analysis. *Sound and Vibration.* January 2001.

16. Maia,N. and Silva,M. *Theoritical and Experimental Modal Analysis.* Great Britain : Research Studies Press Ltd, 140; 1997.

17. Ewin,D.J. *Modal Testing : Theory and Practice*, Research Studies Press Ltd, 1984.

18. ABAQUS Analysis Userö Manual. www.engin.umich.edu /v6.6.