VIBRATION ANALYSIS ON JOINT

ZULFIKA BIN ISMAIL
(7308)

This project is submitted in partial fulfillment of the requirement for the degree of Bachelor of Engineering with Honours (Mechanical Engineering and Manufacturing System)

FACULTY OF ENGINEERING
UNIVERSITY MALAYSIA SARAWAK
KOTA SAMARAHAN
SARAWAK
DEDICATION

Dedicated to my beloved family
ACKNOWLEDGEMENTS

Firstly, I would like to thank my supportive supervisor, Dr Mohd Shahril for his advice and guidance throughout the various stages of completing this project.

Next, I would like to express my gratefulness to all my family members especially my parents for their concern, support and encouragement.

I would also like to thank all the staff technicians, Sabriman, Ireman, Zaidi, Hasmiza, Abang Masri and Rhyier and not forgetting Liu (Master Student) for their superb ideas and knowledge, constructive and literary criticisms and helpful suggestion in the development of this project.

Lastly, to those who have helped me and supported me in completing this project, especially my friends for their efforts in bringing some tremendous ideas, thank you very much.
ABSTRAK

Kebelakangan ini, banyak jenis penyambungan bagi dua bahan telah direka. Dalam situasi sebenar, kebanyakan jenis penyambungan yang sedia ada pada struktur tidak begitu sesuai apabila diaplikasikan penggunaannya dengan tugas, tekanan, beban dan sebagainya. Struktur penyambungan yang akan digunakan perlu diuji beberapa kali sebelum menggunakan dalam aplikasi yang sebenar. Kaedah ujian yang dijalankan mestilah bukan kaedah ujian pemusnahan. Tetapi di dalam kes ini, kerosakan mungkin akan berlaku pada struktur bahan tersebut.

Teknik ‘vibration monitoring’ adalah kaedah yang paling biasa digunakan dan lebih ekonomi untuk mengenalpasti keadaan struktur sambungan yang diuji. Teknik ini melibatkan pemerhatian pada perubahan frekuensi sebenar bahan setelah dikenakan getaran bergantung kepada jenis sambungan dan dimensi pada struktur bahan berkenaan.

Teknik ‘vibration monitoring’ digunakan untuk mendapatkan frekuensi maksimum sebenar pada mode pertama untuk beberapa jenis rasuk. Frekuensi maksimum sebenar pada mode pertama yang diperoleh daripada eksperimen yang dijalankan akan dibandingkan dengan nilai yang telah diperoleh dalam kaedah teori. Hanya sedikit perbezaan diperoleh daripada perbandingan tersebut di mana perbezaan tersebut hanya melibatkan kurang daripada sepuluh peratus.

Perubahan dimensi pada struktur rasuk juga akan menyebabkan perubahan pada frekuensi sebenar di mana ia turut dipengaruhi oleh panjang dan berat bahan berkenaan.
ABSTRACT

Nowadays, there are many types of joint which have been designed. In practical conditions, these types of joint structure that have been designed are not suitable when applied to stress, load, tension and other conditions. These structures of joint need to be tested several times with loads, stresses, bending and others before using it in a real situation. These tests are should be a non-defective test.

Vibration monitoring technique is a very common, useful and economic way in order to monitor the condition of the joint structures for testing purpose. This technique involves changes in monitoring of natural frequency of a material due to applied vibration according to the types of joint and the dimension of the structure beam respectively.

The vibration monitoring technique is used to determine the maximum natural frequency at first modes for the several types of beam. The maximum natural frequency and the first modes obtained from experimental method will be compared to the calculated values from theoretical method. Only low percentage of difference between the experimental and theoretical method are obtained which are below than ten percent.

The changes of the dimension of the beam structure will caused the natural frequency changes accordingly. This will corresponds to the length and the weight of the material.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CONTENT</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>iv</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>v</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>vi</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>vii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xiv</td>
</tr>
</tbody>
</table>

## Chapter 1 \ INTRODUCTION

1.1 Project Background 1
1.2 Vibration Technique 4
1.3 Vibration Monitoring System 4
1.4 Aims and Objectives 6
1.5 Project Outlines 6

## Chapter 2 \ LITERATURE REVIEW

2.1 Vibration 8
2.2 Vibration Concept 9

viii
2.2.1 Free Vibration 10
2.2.2 Forced Vibration 10
2.3 Vibration Energy Exchange 10
2.4 Mode Shape 12
2.5 Dependence of Natural Frequency on Material, Geometry, Support, Loading and Mode of Vibration
2.5.1 Fixed and Free End Boundary 17
2.5.2 Hinged Both End Boundary 18
2.5.3 Fixed Both End Boundary 19
2.5.4 Fixed and Hinged Beam Boundary 19
2.5.5 Hinged and Free Beam Boundary 20

Chapter 3 METHODOLOGY
3.1 Introduction 21
3.2 Equipment 21
3.2.1 Handheld Two Channel Frequency Analyser SA-78 21
3.2.2 Vibration Exciter 23
3.3 Method of Support 25
3.4 Method To Determine The Natural Frequency 25
3.4.1 Theoretical Method 26
3.4.2 Experimental Method 26

3.5 Experimental Setup 28

3.6 Types of Slender Beam 29
  3.6.1 Plain Beam 29
  3.6.2 Glue Bonded Joint Beam 30
  3.6.3 Rivet Bonded Joint Beam 30

3.7 Natural Frequency Analysis 31

Chapter 4  RESULTS AND DISCUSSIONS

4.1 Introduction 33
4.2 Theoretical Result 34
  4.2.1 Maximum Natural Frequency on First Modes 35
4.3 Increasing and Decreasing the Length of Slender Beam 36
  4.3.1 The Length of Slender Beam Are Increased 37
  4.3.2 Decreasing the Length of Slender Beam 39
4.4 Experimental Result 41
  4.4.1 Plain Beam Result 41
  4.4.2 Glue Beam Result 44
4.4.3 Rivet Beam Result

4.5 Result Comparison Between Theoretical and Experimental Method

4.6 Discussion

Chapter 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

5.2 Recommendations

REFERENCES

BIBLIOGRAPHY

APPENDIX

Appendix A - Glue Beam Results
Appendix B – Plain Beam Results
Appendix C – Rivet Beam Results
Appendix D – Plain Beam Results When Length increased to 200mm
Appendix E – Glue Beam Results When Length increased to 200mm
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Tables</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Values for Different Types of Beam</td>
<td>34</td>
</tr>
<tr>
<td>4.2 Maximum Natural Frequency by Using Theoretical Method for</td>
<td>35</td>
</tr>
<tr>
<td>Different Types of Beam</td>
<td></td>
</tr>
<tr>
<td>4.3 Comparison of First Mode Values for Different Types by Using</td>
<td>36</td>
</tr>
<tr>
<td>Theoretical Method</td>
<td></td>
</tr>
<tr>
<td>4.4 Maximum Natural Frequency and First Mode by Using</td>
<td>37</td>
</tr>
<tr>
<td>Theoretical Method</td>
<td></td>
</tr>
<tr>
<td>4.5 Comparison of the Maximum Natural Frequency between</td>
<td>38</td>
</tr>
<tr>
<td>Theoretical and Experimental Method When Length Increased to 200 mm</td>
<td></td>
</tr>
<tr>
<td>4.6 Percentage of Difference Maximum Natural Frequency between</td>
<td>38</td>
</tr>
<tr>
<td>Theoretical and Experimental Method When Length Increased to 200 mm</td>
<td></td>
</tr>
<tr>
<td>4.7 Maximum Natural Frequency and First Mode by Using</td>
<td>39</td>
</tr>
<tr>
<td>Theoretical Method</td>
<td></td>
</tr>
<tr>
<td>4.8 Differences between Theoretical and Experimental Method when</td>
<td>40</td>
</tr>
<tr>
<td>Length decreased to 150 mm</td>
<td></td>
</tr>
</tbody>
</table>
4.9 Percentage of Difference Maximum Natural Frequency between Theoretical and Experimental Method when Length decreased to 150 mm

4.10 Plain Beam Readings

4.11 Glue Bonded Joint Beam Readings

4.12 Rivet Bonded Joint Beam Readings

4.13 Differences of Natural Frequency between Theoretical and Experimental Method

4.14 Differences of First Modes by Theoretical and Experimental Method

4.15 Percentage of Differences between Theoretical and Experimental Method of Test Beam
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>11</td>
</tr>
<tr>
<td>2.2</td>
<td>13</td>
</tr>
<tr>
<td>2.3</td>
<td>13</td>
</tr>
<tr>
<td>2.4</td>
<td>14</td>
</tr>
<tr>
<td>2.5</td>
<td>17</td>
</tr>
<tr>
<td>2.6</td>
<td>18</td>
</tr>
<tr>
<td>2.7</td>
<td>19</td>
</tr>
<tr>
<td>2.8</td>
<td>19</td>
</tr>
<tr>
<td>2.9</td>
<td>20</td>
</tr>
<tr>
<td>3.1</td>
<td>22</td>
</tr>
<tr>
<td>3.2</td>
<td>23</td>
</tr>
<tr>
<td>3.3</td>
<td>24</td>
</tr>
<tr>
<td>3.4</td>
<td>24</td>
</tr>
<tr>
<td>3.5</td>
<td>25</td>
</tr>
<tr>
<td>3.6</td>
<td>27</td>
</tr>
</tbody>
</table>

2.1 Exchange between kinetic and potential energies in the vibrating beam.  
2.2 First three modes shape of a slender beam clamped at both ends  
2.3 First three modes shape of a slender beam clamped at the left end and pinned at the right end  
2.4 First three modes shapes of a slender beam pinned at both ends  
2.5 A free end beam and modes shape  
2.6 A Pinned both ends beam and modes shape  
2.7 A fixed both ends beam and mode shape  
2.8 A fixed and hinged beam and mode shape  
2.9 A hinged and free beam and mode shape  
3.1 Handheld Two-Channel Frequency Analyzer  
3.2 Vibration exciter used to supply the continuous vibration  
3.3 Exciter and test beam configuration  
3.4 Erudite MKII connect with exciter  
3.5 Cantilever test beam  
3.6 Diagram of Experimental Procedure  

Demo (Visit http://www.pdfsplitmerger.com)
3.7 Completed experimental setup
3.8 Plain Beam
3.9 Glue Bonded Joint Beam
3.10 Rivet Bonded Joint Beam
4.1 Plain Beam Result by Experimental Method
4.2 Glue Bonded Joint Beam Result by Experimental Method
4.3 Rivet Beam Result by Experimental Method
CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Joining method is very important in engineering field. Many types of joints have been designed for many applications but sometimes the types of joint chose are unsuitable for design materials and application. Adhesive bonded joint is one example of these of joints. This research will use adhesive bonding joints using epoxy glue types and rivet joint. Adhesives form an integral part of a wide variety of fabricated products, offering the potential to create new and challenging designs.

Adhesives bonded joints account for total adhesive and sealant, with wide application such in automotive, aerospace, domestic appliance, biomedical, dental, consumer, electronic, construction, general industrial, industrial machine, marine and sports equipment applications. Glue is a simple example of adhesives bonded joints which has good adhesion to a variety of substrates. This can be applied quickly with excellent properties, and are cost effective. However, the adhesive selection process can be overwhelming due to the many types of adhesives available. The accuracy of the results of adhesive bonded will depends on the conditions under which the bonding
process is carried out. Bonding conditions are prescribed by the manufacturer of the adhesive.

There are many reasons why adhesive bonded joining are employed. It is a common in civil and mechanical engineering field. Increased production speed is one of a thousand of an example of reason why joining are used. In comparison with other fabrication methods, adhesive assembly is essentially fast. Even if curing is required, this can often be accommodated combined with other processing stages. Additional, by using adhesive bonded joining had several advantages such as dissimilar materials can be joined, improved fatigue resistance, vibration damping, and easily automated or mechanized.

The project will analyse the joint by meant of using vibration analysis in order to be able to observe the behavior of the joints. Vibration is the terms that describe oscillation in a mechanical system. It is defined by the frequency, and the amplitude. Either the motion of physical object or structure or alternatively, an oscillating force applied to mechanical system is vibration in a generic sense. The time-history of vibration may be considered to be sinusoidal or a simple harmonic. The frequency is defined in term of cycle per unit time and the magnitude in term of amplitude (the maximum value of a sinusoidal quality). The vibration encountered in practice often does not have this regular pattern.

Natural vibration always occurs due to the presence of two modes of energy storage. That is called kinetic and potential energy. During the motion, stored energy...
will be transferred from one to another. The unit for vibration is frequency in Hertz (Hz). Repetitive motions usually occur at relatively low frequency, but at any repetitive motions such as at high frequency with low amplitude falls into the general class of vibration. Beside that, vibrations can naturally occur in an engineering system and may be or may not be representative of its free and natural dynamic behavior.

In this research, aluminum is being used as the specimen. Aluminium, symbol Al, the most abundant metallic element in the Earth's crust. The atomic number of aluminium is 13 and the element is in group 13 (IIIA) of the periodic table. Aluminium is a lightweight, silvery metal. The atomic weight of aluminium is 26.9815; it melts at 660° C (1220° F), boils at 2467° C (4473° F), and has a relative density of 2.7. Aluminium is a strongly electropositive metal and extremely reactive. In contact with air, aluminium rapidly becomes covered with a tough, transparent layer of aluminium oxide that resists further corrosive action. For this reason, materials made of aluminium do not tarnish or rust. The metal reduces many other metallic compounds to their base metals.

The oxide of aluminium is amphoteric and can show both acidic and basic properties. The most important compounds include the oxide, hydroxide, sulphate, and mixed sulphate compounds. Anhydrous aluminium chloride is important in the oil and petrochemical industries. Aluminium is found commonly as aluminium silicate or as a silicate of aluminium mixed with other metals such as sodium, potassium, iron, calcium, and magnesium, but never as a free metal.
In the experimental test, analysis of the vibration characteristics of aluminum and all its faults will be introduced. By using approximate equipments, faults for aluminum beam will be obtained.

1.2 VIBRATION TECHNIQUE

Vibration monitoring technique will be used in this research to evaluate the behaviour or changes in mechanical and physical characteristics of the test sample. Vibration testing is one of the methods to evaluate the structure in the form of vibration, which will respond with the energy supplied. In addition, a test will be designed and will be tested.

The vibration exciter will be used in this research. The sensor is located along the beam and will be connected to the computer where the software will convert the response from the beam. The function of vibration exciter is to supply the vibration needed. The computer will then be used to analyse the results as well as to view the real time results.

1.3 VIBRATION MONITORING SYSTEM

The purpose of vibration monitoring is to establish the running condition of machinery in a fashion which is objective and scientific. While experienced opinions as to how a machine is operating is helpful, these opinions do not take the place of scientific "metering" to obtain the true condition of rotating machinery. Also, there are
no better criteria for operational soundness in rotating machinery than by how much it 
vibrates. It is generally accepted that it is under utilization for this technology.

In manufacturing technology, the great concern is a vibration level of 
machineries. The vibration monitoring system is designed to be used as a permanent 
installation to monitor the vibration level and to be used for economical method to warn 
of problem of machinery. Other than that, monitoring system will provide a warning 
before serious damage occurs. To analyse that situation, sophisticated equipment will be 
used. Scheduled vibration measuring with portable equipment may be less costly 
initially but the cost of a trained technician to take regular readings will cost more in the 
long run.

The technique can be gives more appreciable cost savings over a permanent 
installation of sophisticated vibration analysers. Usually acceleration, velocity, and 
displacement are three parameters always measured in machine protection. The higher 
the vibration and the higher the energy wasted are used to represent of wasted energy. 
When the energy is being translate to movement, either in turn before or after, the 
damage will occur. Other than that, if the amount of energy in condition of machine can 
be determined, that will give us some good idea and information.

In this research, vibration monitoring technique is used to determine the 
vibration behaviour and the changes in properties. All information as mentioned before 
in this chapter is concern with independent of vibration frequency and spectrum. There
are no such simple mathematical relationship between energy and acceleration or energy and displacement.

1.4 AIMS AND OBJECTIVES

The main aim of this research is to develop and understand the geometry, weight and the length with respect to the natural frequency. Beside that, the research will focused in the vibration characteristic of the aluminum.

The research will focus deeper into the types of joints, in proportionally, this research will enables one to make approaches to the actual concept of how to analyze the vibration on joints, comparison between using formulation and experiment method or using equipments, and effectiveness of output representation. Technically, this research's objective also includes the application of conditioning monitoring.

Lastly, the most important prospect of handling this research is to familiarize the student to mechanical and manufacturing engineering of the field, where designing, creating, implementing, manufacturing and building a new innovative system or new innovative method from time to time is always possible.

1.5 PROJECT OUTLINE

The documentation in this report is organized systematically to portray the development stages that summarized the whole research were done. Chapter 1 is an
introduction of the research which includes the aim and objectives of the research is briefly explained and review to the whole research. In Chapter 2, the review is more on the research and studies concerning and regarding to the project has been carried out on the basic fundamental and characteristics of the vibration.

Chapter 3 will briefly about the methodology used in this research. This chapter would be the most important part of this report, because the material and equipment designed is being considered and explained sequentially. Furthermore, this chapter includes techniques or principles used and typical of the equipments that are being used. Every parts of the research design is explained thoroughly in respective sub chapter.

After completing the designing stage, the realization of the entire material design, where testing, analyzing and troubleshooting will carried out to detect any potential faulty of the design will be further explained in Chapter 4. Discussion on modification and improvement of the design as well as results on each stage of the experiment are also included in this chapter.

Lastly, Chapter 5 are concludes the entire report and research ends this report. Beside with the conclusion are have some appropriate recommendations and improvement to support the research for future development.
2.1 VIBRATION

Vibration is the study about repetitive motion of the machine, the object movement relative to a stationary frame or nominal position. Vibration is evident everywhere and greatly affects the nature of engineering design. The vibration properties are often limiting factors in the performance. Vibration can be harmful and minimized. Beside that, it can be extremely useful and desired.

The physical explanation of vibration concerns the interrelation between both of potential energy and kinetic energy. Vibrating system must have a component that store potential energy and releases it as kinetic energy in the form of motion. Vibration can occur in many directions. When ever the vibration will occurs, they are commonly several forces involved, which determine the characteristics of the vibration. These forces are:

a) The exciting forces, such as unbalances or misalignment.

b) The mass of the vibrating system.

c) The stiffness of the vibrating system.
Design in vibration refers to adjusting the physical parameters of a device to cause vibration response to meet a specified shape and performance criteria.

2.2 VIBRATION CONCEPT

The vibration is the periodic motion of the body or system of connected bodies displaced from a position of equilibrium. In general, there are two types of vibration; there is free vibration and forced vibration. Free vibration occurs when the motion is maintained by gravitational or elastic restoring forced, such as the vibration on the elastic rod. Forced vibration is caused by an external periodic or intermittent force applied into the system.

Both of these types of vibration may be either damped or undamped. Undamped vibration can be continuing indefinitely because friction effects are neglected in the analysis. Since in the reality both internal and external frictional forces are present, the motion of all vibrating bodies is actually damped.

Therefore, this chapter is mainly concerned with describing the fundamental principles of vibration behaviour of the above types of the vibration motion and those concepts that are most often involved in vibration testing. These vibration concepts are important and will be used in developing a general vibration testing model.
2.2.1 Free Vibration

Simple harmonic motion or oscillation is showed by structures that have elastic restoring forces. Such system can be modeled by spring mass schematic where it is the most basic vibration model of a structure and can be used to a number of devices, machine and structures. When a spring-mounted is distributed from it equilibrium position, its ensuring motion in the absence in any imposed external forces is termed free vibration. In every actual case of free vibration, there exists some damping force due to mechanical and fluid friction which tends to diminish the motion. In the next sub-topic, will consider the ideal case where the damping forces are small enough to be neglected.

2.2.2 Forced Vibration

Although there are many significant applications of free vibrations, forced vibration is also considered to be one of the most important types of vibrating motion in engineering work. The principles which describe the nature of this motion may be used to analyze the forced which cause vibration in many types of machines and structures.

2.3 VIBRATION ENERGY EXCHANGE

The energy can change from one form to another. In the structure, sum of the potential and kinetic energies are remain constant. It will be occurring when dissipative processes are ignored. The periodic exchange of kinetic and potential energies in the structure will reflect with the natural frequency. From the equilibrium position, the potential energy is directly related to elastic strain. It including with the deformation of
the structure. The kinetic energy is proportional to the square of the speed with which the structural mass is deforming.

\[ PE = 0, \quad KE = 0 \]

a) No vibration subjected to the beam. Potential and kinetic energy is equal to zero.

\[ PE = \text{Max}, \quad KE = 0 \]

b) Position of beam will change after external force subjected. Kinetic energy is zero but potential energy change to maximum.

c) Continuous beam to vibrate. Kinetic energy is zero and potential energy become to maximum. The vibration will be continuous and position of beam return to (a).

**Figure 2.1:** Exchange between kinetic and potential energies in the vibrating beam. [1]