DESIGN AND FABRICATION OF VIBRATION EXPERIMENTAL TEST RIG FOR TEACHING AND LEARNING

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DECLARATION

I declare that this project report entitled "Design and Fabrication of Vibration Experimental Test Rig for Teaching and Learning" is the result of my own work except as cited in the references

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APPROVAL

I hereby declare that I have read this project report 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 & Materials).

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DEDICATION

To those who inspired it and my beloved parents

ABSTRACT

Vibration that occurs in most machines, structure and dynamic system is undesirable that may lead to fatigue and failure of structure and machine, energy losses and the reduction in performance of structure or machines. The vibration effect to a structure is usually not be detected at early stage and main reason lead to collapse building. The factors are mostly because of poor or no isolation from the vibration sources to the attached structure. The custom-built test rig for faults detection is readily available but limited for example because of cost, too huge, heavy and complex to control. The purpose of this project is to design and to fabricate a simple test rig to verify the performance of looseness, unbalance, transmissibility and resonance based on the experimental data by using vibration analysis. The test rig also was built for teaching and learning purpose. Therefore, it was design to make lifting easier and can be placed anywhere especially can be bring to class for teaching and learning purpose. In this project, induction motor was used as important component in test rig to represent the failure in structural that occur. The vibration experimental test rig was designed by using SolidWorks 2013 software. Then, it was fabricated based on desired dimension before undergo testing process. For testing process, the test rig was analyzed using Data Physics SignalCalc Ace .The finding shows that the performance of unbalance and looseness can be verified when compared it with normal condition of induction motor when the vertical peak shows obviously different value especially for unbalance condition with the value 0.003004 $(mm/s)^2$ .The value for unbalance faults is higher compare to looseness and normal condition.The finding also shows rubber can be a good isolator or shock absorber in transmissibility experiment but also can be vibration problem if the stiffness of isolator, the mass of the isolated equipment and the running frequency is not consider.

ABSTRAK

Getaran yang berlaku di dalam kebanyakan mesin,struktur dan dinamik sistem adalah yang tidak diingini yang boleh membawa kepada kerapuhan dan kegagalan struktur atau mesin, kehilangan tenaga dan penurunan prestasi struktur dan mesin.Kesan getaran kebiasaanya tidak dikenalpasti di peringkat awal dan menjadi punca utama kepada keruntuhan sesebuah bangunan.Faktor terjadinya sedemikian adalah disebabkan oleh kekurangan atau tiada pengasingan dari sumber getaran kepada struktur yang diletakkan.Alat ujikaji pelantar untuk mengesan kesalahan adalah sedia ada tetapi terhad seperti harga yang mahal,terlalu besar dan berat,sulit untuk mengawal,mengambil masa dan kebanyakkannya adalah untuk kedudukan tetap sahaja.Oleh itu,tujuan projek ini adalah untuk mereka bentuk dan mereka alat ujikaji pelantar untuk mengesahkan prestasi kelonggaran. ketidakseimbangan, kebolehpindahan dan resonans berdasarkan data kajian dengan menggunakan kaedah getaran analisis.Selain itu,alat ujikaji pelantar ini dicipta untuk tujuan pengajaran dan pembelajaran.Oleh itu, ia telah direka supaya mudah untuk diangkat dan dibawa kemana-mana terutamanya boleh dibawa ke kelas untuk tujuan pembelajaran dan pengajaran.Di dalam projek ini, motor induksi telah digunakan sebagai komponen penting untuk mewakilkan kegagalan didalam struktur yang berlaku. Alat ujikaji pelantar getaran ini telah direka menggunakan perisian SolidWorks 2013. Kemudian ia telah dicipta berdasarkan ukuran sebelum menjalankan proses ujian. Untuk proses ujian, alat ujikaji pelantar ini telah dianalisis menggunakan perisian Data Physics signalcalc Ace.Dapatan menunjukkan prestasi ketidakseimbangan dan kelonggaran boleh disahkan apabila dibandingkan dengan kedudukan normal motor induksi apabila puncak menegak menunjuk jelas perbezaan nilai puncak terutamanya untuk kedudukan ketidakseimbangan dengan nilai. 0.003004 $(mm/s)^2$ .Nilai bagi ketidakseimbangan adalah tinggi berbanding dengan kelonggaran dan kedudukan normal.Hasil dapatan juga turut menunjukkan getah boleh menjadi pengasingan yang baik atau penyerap kejutan di dalam eksperimen kebolehpindahan tetapi juga boleh membawa masalah getaran apabila kekakuan pengasingan,berat peralatan terpencil dan juga kekerapan yang digunakan tidak di ambil kira.

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FFT	Fast Fourier Transform
FT	Fourier Transform
Rms	Root Mean Square
Cpm	Cycle per minutes
Cps	Cycles per second
Hz	Hertz
FBD	Free body of diagram
SDOF	Single degree of freedom
DOF	Degree of freedom
FRF	Frequency response function
APS	Auto power spectrum

LIST OF SYMBOL

w	=	Width
l	=	Length
t	=	Thickness
c	=	Damping coefficient
ξ	=	Damping ratio
F_e	=	Excitation force
F_t	=	Force transmitted
m	=	Mass
k	=	Spring stiffness
ω	=	Operating frequency
ω_n	=	Natural frequency
T_f	=	Transmissibility

CHAPTER 1

INTRODUCTION

1.1 Background

Vibration that occurs in most machines, structure and dynamic system is undesirable. This because, the vibration that occurs is not only lead to unpleasant motion, noise or dynamic stress which may lead to fatigue and failure of structure and machine but also lead to energy losses and the reduction in performance of structure or machines. Case of system failing or not meeting performance targets has been increased and mostly happened due to resonance, fatigue or excessive vibration of one component or another (C. Beards, 1996). Rotating machines (compressor, pump, and engine) which are placed to the building structure may cause the unwanted vibration that lead to fatigue or degrade the performance of the structure. This is because, when vibration occurs, the machines will create a propagation of vibration waves to the structure. Besides that, the vibration that effect the structure is usually cannot be detected at early stage which leads to main reason of building collapse.

There a lot of factors that lead to the vibration problem in a building and. The factors are mostly because of poor or no isolation from the vibration sources to the attached structure in which when the sources operating are near or at the natural frequency, the machine will vibrate more vigorously because of the machine's vibration amplitude that will be amplified. The poor isolation of this vibration source can easily transfer the vibration energy to the building structure and can cause structural damage or noise radiation.

Many cases of structural failure have been reported due to the vibration and one of it is Sampoong Department Store, Korea in 1995. The accident has caused 937 peoples to be injured with a death toll of over 500 people. The accident occurs due to the structural failures of the store that start up because of vibration from heating and cooling system at rooftop and also from dragged air condition which create huge crack after get complain from surrounding building. Same problem also may occur at office building, hotels and factory. Therefore, it is important to carry out the vibration analysis of any proposed structure and machines so the vibration can been detected at early stage to avoid any further damage. In addition, vibration analysis has been as the most reliable method of assessing the overall health of a rotor system which has been used in rotating machines faults diagnosis for decades (Lagan, 1999). Besides that, vibration analysis is the easiest method to use, relative low cost and able to provide an accurate technique to detect fault compare to other method like sudden shut down when there is failure in rotating machines. This is because, it is not only affect the whole process but it also may lead to system failing and loss. For example in factory, such shutdowns are costly, in terms of production time, maintenance cost and wasted raw materials.

The purpose of this project is to design and fabricate a simple test rig to simulate certain fault such as looseness and unbalance and also transmissibility and resonance by using vibration analysis for both structure and machines since the custom-built test rig to detect fault in structure or machines is too huge and most of it for static state. Besides, the test rig was built for teaching and learning purpose. There is no equipment available for students to learn and know how to detect faults in structures in classes for learning process. Most of the machine was placed in laboratory and cannot be lift. Therefore, this test rig can be used in the classes in future to give more understanding to students.

In this project, induction motor is used as important component in test rig to represent the failure in structural that occur because of vibration when the faults such as unbalance, looseness, resonance and transmissibility are added. The test rig in this project can be used to demonstrate physically the theory learned in the class for teaching and learning since it still limited for an engineering curriculum. By having this test rig, students can improve their knowledge and skills on how to detect the faults.

1.1 Problem Statement

Custom-built test rigs that simulate machine faults for condition monitoring are now readily available, but are also costly. Most of the institutions are not affordable to buy it for teaching and learning purpose. Besides, although students are able to conduct and control the experiment, the device is too complex to control, time consuming on unrelated faults and leaves no time for other topics to be covered in the course. In addition, there is no simple test rig available to detect the faults in Faculty of Mechanical Engineering of UTeM for the practical learning. In order to assist students' understanding of the basic principles of vibration condition monitoring, a simple test rig with common machine is designed and constructed.

1.2 Objectives

The objectives of this project area follow:

1) To design the vibration experimental test rig for detecting looseness, unbalance, resonance and transmissibility.
2) To fabricate the test rig
3) To verify the performance of the test rig using experimental data.

1.3 Scope of Study

The scopes of this project are to design a test rig to simulate the unbalance, looseness, transmissibility and resonance by vibration analysis. Others faults phenomenon are not covered in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter presents the review cases study of the structural failure because of vibration. The review also regarding theory of faults diagnosis of unbalance, looseness, resonance and transmissibility in test rig and method used to detect its by using vibration analysis. The review is from the recent and past journals, technical papers and references books that have been studied to understand the related topic area of this project. Plus, this chapter also will go through deeply regarding on how to inserting the faults in induction motor in order to simulate the unbalance faults, looseness faults, resonance and transmissibility of test rig.

2.2 Case Study of Structural Failure

Building failure happen when the building loses its capacity to perform its proposed capacity. Consequently, building failure can be divided into groups based on their nature and source which are as physical failure and performance failure (Ramsom, 2007). Physical failure is also known as structure failure that result in loss of certain characteristics while performance failure means mean a reduction in function below an established acceptable limit.

Failure of structure can occur due to a lot of reasons and most of it because of poor judgment, poor detailing, poor inspection and maintenance in structure and also because poor communication among designer, engineer and inspector. For instance, Kings Bridge in Melbourne is one of the relatively few examples of failure in service. The failure of King's Bridge was due to carelessness in fabrication and inspection of the bridge. It was

also found that the most likely and most dangerous cracks were regularly missed by inspectors, who had carefully got the less harmful longitudinal cracks cut out and repaired.

Besides that, there is also another collapse of bridge which known as Quebec Bridge in Canada that has killed 75 workmen. This happens due to the assuming's error made during the dead load's calculations. Even though the error was noticed beforehand by the designer, but he chooses to ignore it and rely on the margin of safety inherent in his design. Moreover, the tragedy of the Silver Bridge in 1967 happens has crate a huge uproar in the United States because the accident happens unnoticed and unrecognized. Therefore, it can be concluded here that the failures can happen du the poor detailing, poor inspection and poor judgments from responsible person. In addition, this failure of structural also may occur because of vibration.

Structural vibration occurs when dynamic forces produces by machineries like compressors, pumps, and engines because the component in machineries vibrates. There are many cases of structural failure because of vibration for example in 2013, eight-story building, Rana Plaza at Dhaka, Bangladesh collapse and death reported are 1129 people. The main reason for the failure is the load in the building is very large which is from the extra floor added and also from the machineries installed to the building. Actually, the building was designed to four story building at first for the loads of office and retail space. However, it was renovated for industrial capacity later in which the first and second floors were occupied by banks and retail space, while the third until eighth floors were occupied by garment factories. This has created a larger load for the factories to afford because of hundreds of employees, heavy sewing equipment, and large stockpiles of garments and fabrics (Schwier 2013). In addition, four large diesel generators were installed on the roof of the Plaza for the electricity back up since the electricity of the building tends to went out regularly. However, the roof cannot support the weight of the generators placed since each

of generator weighing several metric tons (Motlagh 2014). Furthermore, when the generator is activated, it caused an obvious shaking to the structure that leads a further threatening to the structure. Thus, the vibration produced by this generators ultimately unsettled the building and starts up the progressive collapse (Schwier 2013).

Figure 2.1: Rana Plaza collapse in Bangladesh (Schwier 2013)

Same reason happens to the Sampoong Department Store in Korea. Originally, it was designed for a residential apartment with four floors. However, a changed has been made in order to build a huge department store in which another floor has been added. This floor was added for skating rink house at first but changed to traditional Korean restaurant which heated the concrete floor. Then, the building's air conditioning unit was installed on the roof. The addition of air conditioning units has created a load that was four times higher than the design limit. Two years before the collapse, the air conditioning units were moved by dragging it across the roof instead of using crane. This is where the cracking started to occur (Anonymous 2000). Based on these two cases study, the failure occurs due to the heavy load which is exceeding limit design and also from propagation vibration waves from the machineries in the building that installed. The machinery installed in every building gives huge impact to collapse due to the vibration that occurs. Therefore, it's very important to detect the failure in machineries in building like shopping complex, factory and others to avoid this problem.

Figure 2.2: Sampoong Department Store collapse in South Korea (Anonymous n.d.)

In addition, Tacoma Narrow Bridge which is collapse in 1940-an also happens because of structural vibration due to strong wind. The random turbulence which is wind pressure with a wind speed of about 60 km/h (below the design wind speed) simply excited the natural frequency of bridge called resonance (Anonymous 2000).Then, the bridge began twisting and oscillating aggressively. As a result, entire structure crash into the river below.

Based on the cases study, the failure of structure occur when lack of necessary inspection detailing and judgment which create many type of problem due to the size of shape or the choice of material, unstable structure to support load, overstresses construction that reach critical stress level, looseness of bearing and also from the vibration that happen in building because of machineries. The flaws in structure cannot be detected at early stage because of lack necessary inspection, ignorance of management and unnoticeable defects. Therefore, a test rig with induction motor as important component is design to detect the failure of structure at early stage. A test rig is an apparatus or equipment used for measuring the performance of any mechanical equipment. Test rig can be placed in laboratory but since the purpose of this project for teaching and learning, it can be place anywhere especially can be bring to classes for teaching and learning purpose.