CONDITION MONITORING ON VIBRATION CHARACTERISTICS OF COMPOSITE STRUCTURES

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Universiti Malaysia Sarawak
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This project report entitled **"CONDITION MONITORING ON VIBRATION CHARACTERISTICS OF COMPOSITE STRUCTURES"** was prepared by **Wong Ging Huo** as a partial fulfillment for the Bachelor of Engineering with honors (Mechanical) is hereby read and approved by:

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Date

CONDITION MONITORING ON VIBRATION CHARACTERISTICS OF COMPOSITE STRUCTURES

WONG GING HUO

This project report is submitted in partial fulfillment of the requirement for the degree of Bachelor of Engineering (Hons.) Mechanical Engineering from the

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Dedicated to beloved family

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Abstract

Composite structures have been widely adopted for the support of structural members mainly in bridges and buildings. Since the damage of the composite structures such as cracks is usually harmful, a non-destructive evaluation method based on vibration analysis to monitor the vibration behavior of composite structures was proposed. Therefore, for the case of this project, testings were carried out by using the equipment namely Erudite MKII in which effects of cracks in different types of rectangular composite structures were systematically examined. Through vibration testing method, it is expected to find the relationship between the presence of the cracks together with their resonant frequencies which in turn would enable the following up of preventive maintenance that would prevent any catastrophic failures from occurring.

Abstrak

Struktur komposit telah digunakan secara meluas dalam pembinaan struktur anggota terutamanya pada jambatan dan bangunan. Memandangkan kemudaratan pada struktur komposit seperti rekahan adalah merbahaya, satu kaedah penilaian bukan pembinasaan telah diusulkan. Kaedah ini merupakan asas kepada analisis getaran dan boleh digunakan untuk mengawasi ciri-ciri getaran bagi struktur komposit yang diuji. Oleh yang demikian, dalam projek ini, ujian getaran dijalankan dengan radas Erudite MKII di mana peralatan ini dapat menguji kesan rekahan dalam pelbagai jenis struktur komposit dengan sistematik. Melalui kaedah ujian getaran tersebut, hubungan yang wujud di antara kehadiran rekahan dengan frekuensi resonans bagi setiap jenis struktur komposit dapat diperolehi. Dengan itu, langkah penyelenggaran dapat diambil untuk mengelakkan sebarang bahaya seperti rekahan daripada berlaku.

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CHAPTER 1

INTRODUCTION

1.1 Background

A steel designated as a mild steel has a carbon content in the range approximately from 0.10 % to 0.15 %. Sometimes, mild steels are also referred to as low carbon steels. They are characterized by low strength and high ductility, and are nonhardenable by heat treatment except by surface-hardening processes. Because of their good ductility, mild steels are readily formed into intricate shapes. These steels are also readily welded without danger of hardening and embrittlement in the weld zone. Although mild steels cannot be through-hardened, they are frequently surface-hardened by various methods (carburizing, carbonitriding, and cyaniding, for example) which diffuse carbon into the surface. Upon quenching, a hard, wear-resistant surface is obtained. [7]

The use of composite structures in various construction elements has increased substantially over the past few years. These materials especially mild steels are particularly widely used in situations where a large strength-to-weight ratio is required for structural members mainly in bridges and buildings and for parts to be carburized.

For example, the development of mild steels in the 1960's made it possible to overcome the major weakness of concrete in bridge construction that is low tensile strength. Of these steel bridges, the steel girder or beam bridge is the most common type of bridge for highways or railroads since it is one of the most simple and economical structures to build.

However, as a result of introduction of larger vehicle such as trucks with heavier loads and after undergoing for a long period of loading, the steel bridge with the supporting structural member may undergo a series of serious vibratory motion about its equilibrium position. Therefore, damages such as cracks are likely to occur. If any of these possible damages, faults or even cracks are present and sustained by these steel bridges, these may affect the physical geometry of the component, and hence the resonant frequency.

Therefore, for this project, in order to analysis and monitor the vibration characteristics of mild steel components, faults will be introduced intentionally throughout the experimental test. The faults onto the specimen are obtained by manually machined i.e. by using machine tool like hammer and drill. The faults that will be machined are, cracks on the specimen surface and voids or cavities within the specimen.

Since such surface discontinuities as presented on the specimen surface can act as stress raisers, that is, they can reduce mechanical strength, especially bend strength and fatigue strength, and they can act as initiating points for fatigue failure. Therefore, a good steel member, must resist a complex combination of tension, compression, bending, shear, and torsion forces. For this reason, it is essential to have an effective and appropriate monitoring practice in order to determine the design capacity and ability of steel members in carrying the load.

1.2 Non-Destructive Testing

Non-destructive testing (NDT) forms an integral part of quality control, a term used to describe the procedures which contribute to total quality assurance. A formal definition of the subject, agreed by the International Committee for Non-destructive Testing (ICNDT) and accepted later by the International Standards Organization (ISO) states: Non-destructive testing (NDT) is a procedure which covers the inspection and/or testing of any material, component or assembly by means that do not affect its ultimate serviceability.

Non-destructive testing (NDT) has three major functions for research, development and applications testing in composite structures. They are:

- Initial inspection of test specimens and confirmation of the structural integrity of new components;
- Monitoring sample tests in progress, or components subjected to service loads;
- Analyzing test results after failure, or proof loading of components during their service life.

This method may be divided into two general groups. The first group consists of tests used to locate defects. In it are various simple methods of examination such as visual inspection of the surface as well as the interior by the use of drilled holes, tests involving the application of penetrants to locate surface cracks, the examination of welded joints by use of a stethoscope to detect changes in sounds caused by hidden flaws, and highly technical methods involving radiographic, magnetic, electrical, and ultrasonic techniques.

The second group of nondestructive tests consists of those used for determining dimensional, physical, or mechanical characteristics of a material or part. In this group are tests for the thickness of paint or nickel coatings on metallic bases, the thickness of materials from only one surface, the determination of moisture content of wood by electrical means, certain hardness tests, proof tests of various kinds, surface-roughness tests, and methods employing forced mechanical vibrations to determine the changes in natural frequency of the system due to changes in the properties of the material. One type of vibration test uses the sonic analyzer for determining the natural frequency, from which the modulus of elasticity can be computed.

1.3 Vibration Techniques

For this project, Vibration Technique is used as an approach to determine the vibration behavior of composite structures and the effects due to damage incurred in some of the members of that structure. One of the definition of the Vibration Testing given by Kenneth G. McConnell states: Vibration Testing is the art and science of measuring and understanding a structure's response while exposed to a specific dynamic environment; and if necessary, simulating this environment in a satisfactory manner to ensure that the structure will either survive or function properly when exposed to this dynamic environment under field conditions.

It is a light-weight, low cost, simple to use vibro-diagnostic device, which enables to locate fatigue cracks, defects in multi-layer structures, failure of elements and other structural problems. In addition, it can also be used to detect the oscillation of a structure up to 25 kHz and is thereby very suitable to analyze the condition monitoring of most of the structures.

Generally, this techniques requires several hardware components. They are consists of a vibration exciter for providing a controlled input to the structure, a force transducer to convert the mechanical motion of the structure into an electrical signal, a signal conditioning amplifier to match the characteristics of the transducer to the input electronics of the digital data acquisition system, and a frequency analyzer, in which signal processing and modal analysis programs reside.

CHAPTER 2

AIMS AND OBJECTIVES

The main aim of this study is to examine the vibration behavior and characteristics of composite structures which are made of mild steel as apply in the construction of bridges and buildings. Such evaluation is important to enable any determination of vibration analyses of composite structures to be predicted in a systematic manner. This can be achieved by investigating the possibility of applying suitable monitoring technology to the monitoring of composite structures. Therefore, for the case of this project, vibration testing method is used as an approach to monitor the vibration behavior of these composite structures.

The analyses of this vibration test is established based on the relationship between the fundamental natural frequencies of the composite structures and the dimension of the composite structures. With this relationship, we can predict the acceptable load that can be withstand by mild steel systems in the condition of vibratory motion.

To further enhance the analysis, this study also aims to investigate ways of determining the effects due to damage on the performance and safety of the composite structures and to control its effects using vibration analyses. In the case of a composite structure with crack, this fundamental frequency will change and the experiments will be repeated to establish again the relationship between the extent of the cracks with the difference of resonance. In return, it is hope that by the end of this analyses, maintenance schedule can be followed up from time to time to prevent any failures from occurring.

CHAPTER 3

LITERATURE REVIEW

3.1 Vibration Concepts

A vibration is the periodic motion of a body or system of connected bodies displaced from a position of equilibrium. In general, there are two types of vibration, free and forced. Free vibration occurs when the motion is maintained by gravitational or elastic restoring forces, such as the vibration of an elastic rod. Forced vibration is caused by an external periodic or intermittent force applied to the system. Both of these types of vibration may be either damped or undamped. Undamped vibrations can continue indefinitely because frictional effects are neglected in the analysis. Since in 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 behavior of the above types of 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.

3.2 Free Vibration

Simple harmonic motion or oscillation, is showed by structures that have elastic restoring forces. Such system can be modelled by a spring mass schematic where it is the most basic vibration model of a structure and can be used to describe a number of devices, machines and structures. When a spring-mounted body is disturbed from its equilibrium position, its ensuring motion in the absence of 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 3.2.1, we consider the ideal case where the damping forces are small enough to be neglected. In 3.2.2, we treat the case where the damping is appreciable and must be accounted for.

3.2.1 Undamped Free Vibration

Lets begin by considering the simplest type of vibrating motion, i.e. the horizontal vibration of the simple frictionless spring-mass system of Figure 3.1.

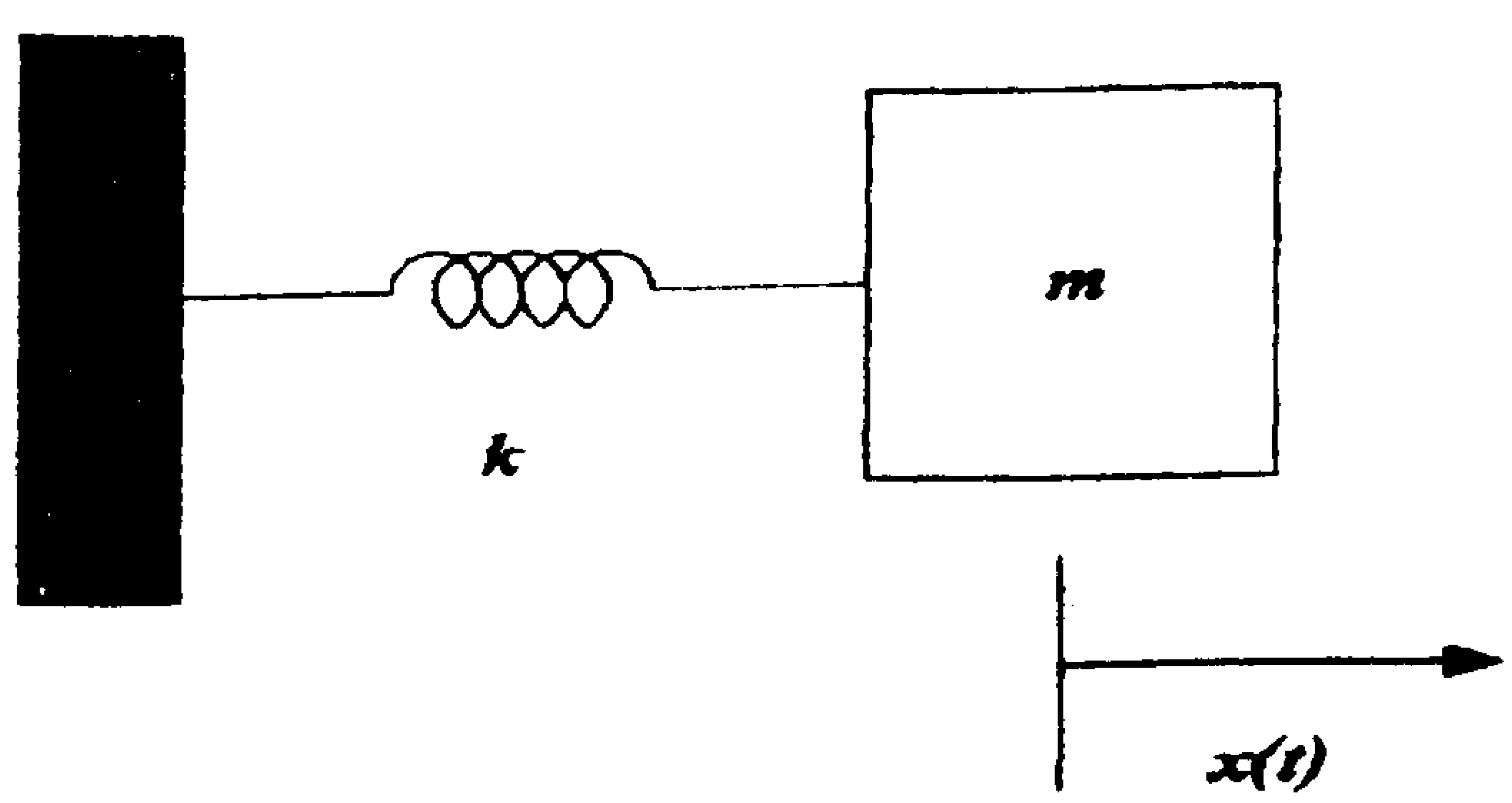

Figure 3.1: Spring-mass schematic