MODAL ANALYSIS OF PIPE JOINT SPIRAL WOUND GASKET

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I certify that the project entitled "*Modal Analysis of Pipe Joint Spiral Wound Gasket"* is written by *Nabil Fahmi bin Mohtar*. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This project report deals with dynamic behaviour of spiral wound gasket using theoretical and experimental analysis method. This project report is to study the dynamic properties and behaviour of spiral wound gasket by using modal analysis and compare with the finite element analysis. The structural three-dimensional solid modelling of spiral wound gasket was developed using the SOLIDWORK drawing software. The finite element analysis was then performed using ALGOR (FEA). The finite element model of the components was analyzed using the linear modal analysis approach. Finally, the experimental modal analysis was performed using Impact Hammer Testing method. The natural frequency of the mode shape is determined and comparative study was done from both method results. The comparison between natural frequencies of finite element modelling and model testing shows the closeness of the results. From the results, the percentage error had been determined and the limitation in the natural frequency of the spiral wound gasket is observed.

ABSTRAK

Laporan projek ini berkaitan dengan perilaku dinamik *spiral wound gasket* menggunakan kaedah analisis teori dan eksperimen. Laporan ini adalah untuk mempelajari sifat dinamik dan perilaku *spiral wound gasket* dengan menggunakan analisis modal secara eksperimen dan membandingkannya dengan analisis elemen secara teori. Pemodelan struktur tiga-dimensi *spiral wound gasket* dilukis menggunakan perisian melukis SOLIDWORK. Analisis elemen modal kemudian dijalankan dengan menggunakan perisian ALGOR. Analisis di dalam perisian ini menggunakan pendekatan analisis linier modal. Kemudian, analisis modal secara eksperimen dilakukan dengan menggunakan kaedah Hammer Kesan Ujian. Frekuensi dan bentuk mod ditentukan dan kajian perbandingan dilakukan dari kedua-dua keputusan kaedah. Perbandingan antara frekuensi dari pemodelan elemen secara teori dan ujian model secara eksperimen menunjukkan keputusan yang hampir sama. Dari hasil tersebut, peratus perbezaan antara kedua kaedah telah direkod dan had frekuensi asas *spiral wound gasket* telah diamati.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

f	Frequency
F	Force
D	Diameter
P	Pressure
t	Thickness

LIST OF ABBREVIATIONS

ASME	American Society of Mechanical Engineers
SWG	Spiral Wound Gasket
CAD	Computer Aided Diagram
IGES	Initial Graphics Exchange Specification
3D	3 Dimensional
DOF	Degree of Freedom
DAS	Data Acquisition System
FEA	Finite Element Analysis
PTFE	Polychlorotrifluoroethylene
ANSI	American National Standard Institute
DIN	German Institute for Standardization
BS	British Standard
NPS	Nominal Pipe Size
FFT	Fast Fourier Transform
FYP	Final Year Project
UMP	University Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

In the Oil & Gas industry, pipes are widely used in refinery piping, exploration, crude oil transmission, line pipe, flow lines, injection lines (water and gas), gas transmission lines, offshore platform piping, floating production storage and off-loading, sub-sea piping and piping on vessels. There are many types of pipe joints used in the piping system. Some of them are push-on joints, mechanical joint, flanged joint, restrained joints, restrained push-on gasket, field-welded restrained joints, ball and socket joints and grooved and shouldered joints. In the pipe joints field, spiral wound gaskets are commonly used as their connecter. This kind of gasket had been improved and modified to give assurance of the safety of the distribution system.

Spiral wound gaskets are very efficient as sealing devices, not least because of the high loads which are used to compress and retain them in the place. Spiral wound gaskets comprising alternate turns of a profiled metal strip and softer filler material strip are commonly used in industrial sealing applications where they are positioned, for example, between a pair of pipe flanges and compressed by the use of bolts to hold the flanges together. Basic type spiral wound gasket consists of a thin metallic strip and soft non-metallic filler (graphite, asbestos, ceramic, polychlorotrifluoroethylene (PTFE), etc.) that are simultaneously wound on a rotating mandrel. The metal hoop is pre-formed with a V or W shaped profile which allows the gasket to act as a spring between the flanges. Further, the hoop provides the basic structural element for the gasket while the non-metal filler material seals small imperfections on the flange surfaces. They are available in all standard flanges of sizes.

Spiral wound gaskets have good compressibility and rebound elasticity. It can keep very good sealing performance under some tough conditions of circulating alternation such as high temperature, low temperature, high vacuum and impact vibration. In this project, we will investigate the stability and detect the vibration that occurred in the spiral wound gasket. The vibration occurred is obtained by performing dynamic analysis using ALGOR Finite Element Analysis (FEA).

1.2 OBJECTIVES OF STUDY

The purpose of this research is to study the dynamic properties and behavior of spiral wound gasket by using modal analysis and compare with the finite element analysis.

1.3 SCOPES OF PROJECT

This projects focus on the following points:

(i) The plan of spiral wound gasket is created using SOLIDWORK.
(ii) The theoretical data from dynamic analysis using ALGOR will be taken.
(iii) Experimental analysis which is modal analysis is performed to the spiral wound gasket.
(iv) Comparative study will be conduct between the previous result and the result from modal analysis.

1.4 PROBLEM STATEMENT

In the piping system, high vibration levels occurred frequently in the fields. Vibration has been identified as the dominant cause of piping failures. Excessive piping vibration can cause real problems. Threaded connections can loosen. Flanges can start leaking. Pipes can be knocked off their supports. Gasket will be defected. And in extreme cases, a pipe fatigue failure can occur. Gaskets are the weakest link in the piping system of a process plant. Therefore, it is important not to ignore the design and selection of the gaskets to prevent flange-leakage problems and avoid costly shutdowns.

In Simonen and Gosselin (2001) piping vibration fatigue was reported as the cause of piping failures 29 percent of the time in US nuclear plants between 1961 and 1996. In small bore pipes, 2 inch and less, vibration fatigue accounted for 45 percent of the piping failures. With such a high failure rate it is important that the cause of the vibration be eliminated and studied whenever possible (Herbert, 2001).

During the last three decades considerable advances have been made in the applications of numerical techniques to analyze pressure vessel and vibration piping problems. Among the numerical procedures, finite element methods and modal analysis are the most frequently use (Jaroslav, 2004).

Modal analysis is done to obtain the actual dynamic properties. The dynamic properties which consist of natural frequency, mode shape and damping are unknown on the design. The frequency of vibration of the spiral wound gasket is directly related to the stiffness and the mass of it while the mode shapes are related to the defect location. Therefore vibration testing needs to be carried out to obtain the data of those dynamic properties. The parameters that describe each mode are natural frequency or resonance frequency (modal) damping mode shape; these are called the modal parameters. By using the modal parameters to model the structure, vibration problems caused by these resonances (modes) can be examined and understood (Inman, 2007). The purpose of this project is to determine the natural frequencies of the spiral wound gasket for structural health monitoring and evaluation.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A significant of this chapter is based on preliminary of piping system, vibration in piping system, spiral wound gasket characteristic and ALGOR finite element analysis. Basics understanding in the study must be recognizable before running the finite element analysis of the spiral wound gasket in ALGOR.

The review of this study is based on preceding work of vibration in piping system and briefly elaborated about the spiral wound gasket performance, their functional requirements and selecting material, application of spiral wound gasket, how they are manufactured, studying of each element in spiral wound gasket, several potential gasket-related problems, the cause of the leakage in piping system and the technique that will be used to analyzed are ALGOR finite element analysis and experimental analysis which is modal analysis.

2.2 BASIC VIBRATION THEORY

Any system has certain characteristics to be fulfilled before it will vibrate. To put in simple words, every system has a stable position in which all forces are equivalent, and when this equilibrium is disturbed, the system will try to regain its stable position. To remain stable, structure exhibits vibration at different magnitude when excited, the degree of vibration varies from point to point (node to node), due to the variation of dynamic responses of the structure and the external forces applied.

Therefore, vibration may also be described as the physical manifestation of the interchange between kinetic and potential energy. (Silva, 2005)

The majority of structures can be made to resonate, i.e. to vibrate with excessive oscillatory motion. Resonant vibration is mainly caused by an interaction between the inertial and elastic properties of the materials within a structure. Resonance is often the cause of, or at least a contributing factor to many of the vibration and noise related problems that occur in structures and operating machinery. To better understand any structural vibration problem, the resonant frequencies of a structure need to be identified and quantified. (Inman, 2007)

2.3 PIPING SYSTEM

Piping systems are generally can be defined as interconnected piping subject to the same set or sets of design conditions. Piping refers to assemblies of piping components used to convey, distribute, mix, separate, discharge, meter, control, or snub fluid flows. Piping components refers to mechanical elements suitable for joining or assembly into pressure-tight fluid-containing piping systems. Components of the piping systems are include pipe, tubing, fittings, flanges, gaskets, bolting, valves, and devices such as expansion joints, flexible joints, pressure hoses, traps, strainers, in-line portions of instruments, and separators. Systems and components of the piping system do not include any equipment excluded from ASME B31.3 or B31.9 or ASME Boiler and Pressure Vessel Code. (ASME B16.20, 1993.)

2.4 GASKET

A gasket is a mechanical seal that fills the space between two mating surfaces, may also be called a seal, generally to prevent leakage from or into the joined objects while under compression. Gaskets are commonly produced by cutting from sheet materials, such as gasket paper, rubber, silicone, metal, cork, felt, neoprene, nitrile rubber, fiberglass, or a plastic polymer such as polychlorotrifluoroethylene (PTFE). Gaskets for specific applications may contain asbestos. It is usually desirable that the gasket be made from a material that is to some degree yielding such that it is able to deform and tightly fills the space it is designed for, including any slight irregularities. A few gaskets require an application of sealant directly to the gasket surface to function properly. (Daniel, 1996) Gaskets come in many different designs based on industrial usage, budget, chemical contact and physical parameters:

2.4.1 Spiral Wound Gasket (SWG)

Spiral wound gaskets are special semi-metallic gaskets. They are made of a preformed metallic strip and a soft filler material, wound together in a V-shaped under pressure, and optionally with an inner and/or outer guide ring. The metal strip holds the filler, resulting in excellent mechanical resistances, resilience and recovery, therefore they are very suitable for application featuring heavy operating conditions. The outer centering ring controls the compression and holds the gasket centrally within the bolt circle. The inner retaining ring increases the axial rigidity and resilience of the gasket. Spiral wound gasket should always be in contact with the flange and should not protrude into the pipe or project from the flange. Europiping Industrial Technologies (EIT, 2000).

Spiral wound gaskets are very efficient as sealing devices, not least because of the high loads which are used to compress and retain them in the places. It would be desirable to use a spiral wound gasket in applications such as in vehicle exhausts at junctions between pipes and catalytic converters for example. However, the available clamping loads are very low due to the relatively flimsy securing flanges which are normally available, the low number of clamping bolts (usually four or less) and the relatively small section and thread areas of those bolts that are available. The established sealing systems for such exhausts are mica foil on a tanged core or exfoliated graphite on a tanged steel core. Due to the relatively low bolt load available and the contact area of these gaskets, the surface stress achieved on these gaskets is low and the sealing unsatisfactory. The Flexitallic Group (TFG, 2000). Figure 2.1 shown is a spiral wound gasket manufactured according to standard ASME B16.20 and Figure 2.2 is the cross section of the spiral wound gasket that shows the v-shaped profile in the sealing elements.

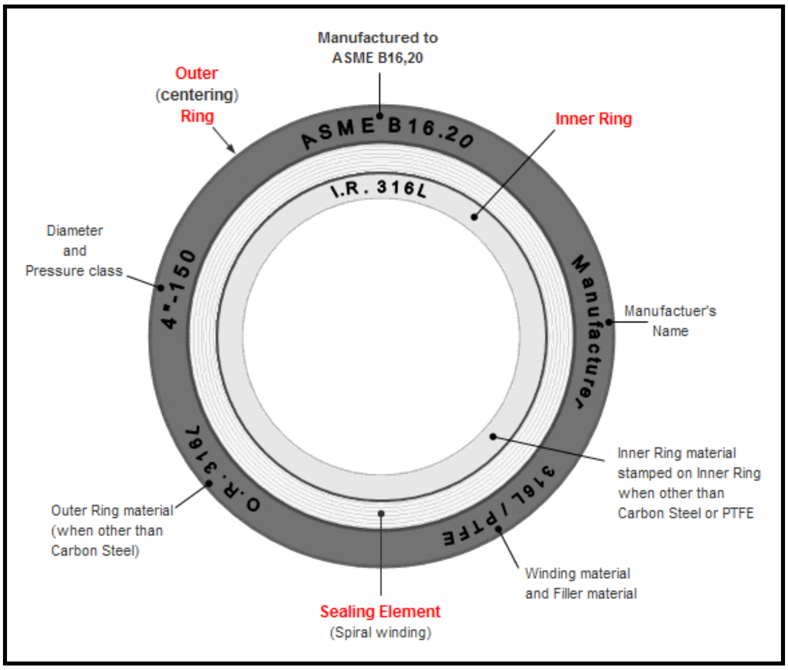

Figure 2.1: ASME B16.20 Spiral wound gasket

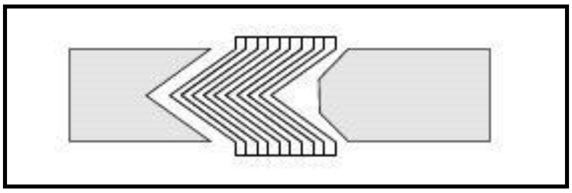

Figure 2.2: Cross section of spiral wound gasket; V-shaped profile

Source: The Flexitallic Group (2000)

2.4.2 Spiral Wound Gasket Styles

Basically, there are four basic types of spiral wound gasket that has been manufactured widely in the market as shown in Figure 2.3. Four basic types of spiral wound gaskets are plain gaskets, outer ring gaskets, inner and outer ring gaskets, and inner ring gaskets. Each design of spiral wound gaskets has a specific application in the pipe flange industry.

i. Plain gasket - Spiral winding only. This style of gasket consists of the winding/sealing element only. It has no guide ring (centering ring) or inner ring. It is most commonly used in tongue and groove and male/female flanges.
ii. Inner ring gasket - This gasket is similar to the plain gasket, however, it has an inner ring. Its application is similar to the plain gasket.
iii. Outer ring gaskets - The outer ring gasket is the most common profile of spiral wound gasket and used extensively in ANSI B16.5 flanges. The gaskets consist of a metal guide ring (or sometimes referred to as a centering ring) and a spiral wound sealing element. This profile is normally used in raised and flat faced flanged. The outer ring is often made of carbon steel (painted or zinc plated to prevent corrosion) but can be made of alloys for higher temperature and more severe medium applications.
iv. Inner and outer ring gaskets - This gasket is identical to the outer ring gasket, however an inner ring has been inserted to enhance gasket performance. The inner ring is added to prevent the possibility of the gasket imploding into the pipe during installation, to protect the sealing element from extreme temperatures and mediums, fill the void between flanges to prevent erosion of the flange, and to reduce the possibility of failure. The inner ring is normally made of the same alloy as the winding. The DIN 2699 standard (German) specifies inner rings in all spiral wound gaskets. Inner rings are required for gasket with PTFE filler according to ASME B16.20 standards, and considered important for graphite fillers. This profile is normally used in raised and flat faced flanges. TianYi Chemical Industrial (TCI, 2006).