FAILURE ANALYSIS OF PIPE JOINT SPIRAL WOUND GASKET USING FINITE ELEMENT ANALYSIS (FEA)

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Thesis submitted in fulfillment of the requirements
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I certify that the project entitled "*Failure Analysis of Pipe Joint Spiral Wound Gasket using FEA*" is written by *Zainulariffin Bin Awang*. I 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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Examiner Signature

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

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STUDENT'S DECLARATION

I declare that this report titled "*Failure Analysis of Pipe Joint Spiral Wound Gasket using FEA*" is my result of my own research except as stated in the references. This thesis/report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This study describes the research and evaluation of the gaskets used in pipe systems. Referring to the title "*Failure Analysis of Pipe Joint Gaskets Spiral wound*", this gasket is suitable for use in piping systems Spiral wound gasket designs are typically used in flat faced pipe flanges. They are also often used in pump applications with recessed flanges. Spiral wound gasket is an important component in the pipe system, this is because it functions as an additional component during the installation process pipe. It works to prevent the occurrence of leakage in the pipe connection system. These gaskets also have the distinct advantages that can withstand the high temperatures and pressures because the material used for manufacturing is gasket material that can withstand the high temperatures and pressures. Gasket is made up of several main sections, "inner ring, filler, and outer ring." Each section has its own features to prevent the leakage occurred. This matter to avoid the accident happened to the workers in this sector. The methodology of this project through the drawing spiral wound gasket using solid works and convert the drawing into Algor software. The mechanical test like tensile test, hardness test and metallurgical test also conduct in this project. All of the result has been discussed in this project and has been compared with other result. The mechanical test result has been record in this project, this is needed for the comparison between the analysis result. For the Algor analysis, it has been through the simulation to find stress and strain for the spiral wound gasket. For this analysis pressure (100 kN and 500 kN) has been applied in both directions. This is important to compare the value of the analysis to know the better type of gasket. From all analysis and result the gasket can be selected follow on the durability of the gasket from the result. Spiral wound gasket with inner ring has been recommended for using in the flanges system because it more durability than the spiral wound gasket without inner ring.

ABSTRAK

Kajian ini menerangkan tentang penyelidikan serta penilain terhadap gasket yang digunakan dalam sistem paip. Merujuk kepada tajuk "*Failure Analysis of Pipe Joint Spiral wound Gasket",g*asket ini kebanyakannya digunakan dalam sistem pipe dan ianya amat penting kerana dapat mengelakkan daripada kebocoran berlaku. Gasket ini adalah sebagai medium tambahan dalam sistem pipe, ini adalah untuk mencegah berlaku kebocoran pada penyambungan pipe. Gasket ini juga mempunyai kelebihan yang tersendiri iaitu dapat berfungsi dalam suhu yang tinggi dan tekanan yang tinggi. Ini menyebabkan gasket ini dipilih untuk digunakan pada sistem penyambungan pipe. Gasket ini mempunyai beberapa komponen asas seperti "inner ring", "filler" dan " outer ring". Kesemua komponen ini mempunyai ciri-ciri tersendiri dalam mengelakkan kebocoran dalam sistem penyambungan pipe. Hal ini amat penting utuk mengurangkan kebarangkalian berlaku kecelakaan kepada pekerja-pekerja yang bekerja di dalam sektor ini. Disamping itu juga, penggunaan gasket ini dapat mengurangkan kos penyelenggaraan berbanding menggunakan gasket lain kerana gasket ini mempunyai ketahanan yang tinggi. Antara langkah-langkah yang terlibat dalam proses kajian ini adalah seperti. membentuk gasket ini dengan menggunakan software iaitu Solidwork. Software ini adalah untuk membentuk 3-dimensi, setelah selesai dalam proses membentuk gasket, objek ini ditukarkan pula kepada Algor software. Software ini berfungsi untuk analisis gasket ini untuk menguji "stress" dan "strain" pada gasket ini. Selain daripada itu, ujian mekanikal juga dijalankan dalam kajian ini. Antara ujian-ujian yang dijalankan adalah seperti "tensile test", "hardness test" dan "metallurgical test". Ujian ini dijalankan adalah untuk mencari ciri-ciri yang terdapat pada gasket ini. Segala keputusan yang diperolehi melalui kesemua ujian dicatatkan utuk pemerhatian. Ini adalah amat penting untuk perbandingan nilai yang diperolehi. Untuk ujian software, dua beban yang berbeza dikenakan iaitu sebanyak (100 kN dan 500 kN). Perbezaan beban ini adalah untuk menentukan jenis gasket yang sesuai utuk digunakan dalam sistem paip. Ini amat penting untuk memilih gasket yang sesuai untuk digunakan kerana ianya dapat mengelakkan kebocoran berlaku. Melalui kesemua data yang diperolehi gasket yang terbaik dapat diperolehi daripada perbandingan nilai analisis software. Gasket "with inner ring" dipilih untuk digunakan dalam sistem pipe kerana ianya dapat bertahan pada tekanan yang tinggi. Dengan ini kemungkinan berlakunya kebocoran dapat dikurangkan dan dapat memberikan persekitaran yang selamat kepada pekerja dalam sektor ini.

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

A	-	Area, m^2
H	-	Hours
m^2	-	Meter Square
T	-	Temperature, ºC
ºC	-	Degree Celsius
%	-	Percentage

LIST OF ABBREVIATIONS

ASME	-	American Society of Mechanical Engineers
ASTM	-	American Society for Testing Material
API	-	American Petroleum Institute
AWS	-	American Welding Society
ISO	-	International Standards Organization
UTS	-	Ultimate tensile Strength
UMP	-	Universiti Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Spiral wound gasket designs are typically used in flat faced pipe flanges. They are also often used in pump applications with recessed flanges. Spiral wound gasket is an important component in the pipe system, this is because it functions as an additional component during the installation process pipe. It works to prevent the occurrence of leakage in the pipe connection system. These gaskets also have the distinct advantages that can withstand the high temperatures and pressures because the material used for manufacturing is gasket material that can withstand the high temperatures and pressures. Spiral wound gasket special semi-metallic gasket of great resilience; therefore they are very suitable for application featuring heavy operating conditions. Spiral wound gaskets are manufactured by spirally winding a V-shaped metal strip and a strip of non-metallic filler material.

The metal strip holds the filler, providing the gasket with mechanical resistance and resilience. Features contained in this gasket is that it has three basic construction consists of a winding element, namely outer (centering ring), inner ring, spiral winding (filler), 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, functions as the sealing element. It is made up of a metallic component and a nonmetallic filler material. Spiral wound gasket should always be contact with the flange and should not protrude into pipe or project from flange. Spiral wound gaskets can be used for sealing flange joints, manhole and handhold covers, tube covers, boilers, heat exchangers, pressure vessels, pump, compressors and valves. This gasket is widely

used in industries such as petrochemical, pharmaceutical, shipbuilding, and food processing, in power industries and nuclear power stations.

A gasket is a material or combination of materials clamped between two separable members of a mechanical joint. Its function is to affect a seal between the members (flanges) and maintain the seal for a prolonged period time. The gasket must be capable of sealing the mating surfaces, impervious and resistant to the medium being sealed and able to withstand the application temperature and pressure. Figure 1.1 shows depict the nomenclature associated with a gasket joint.

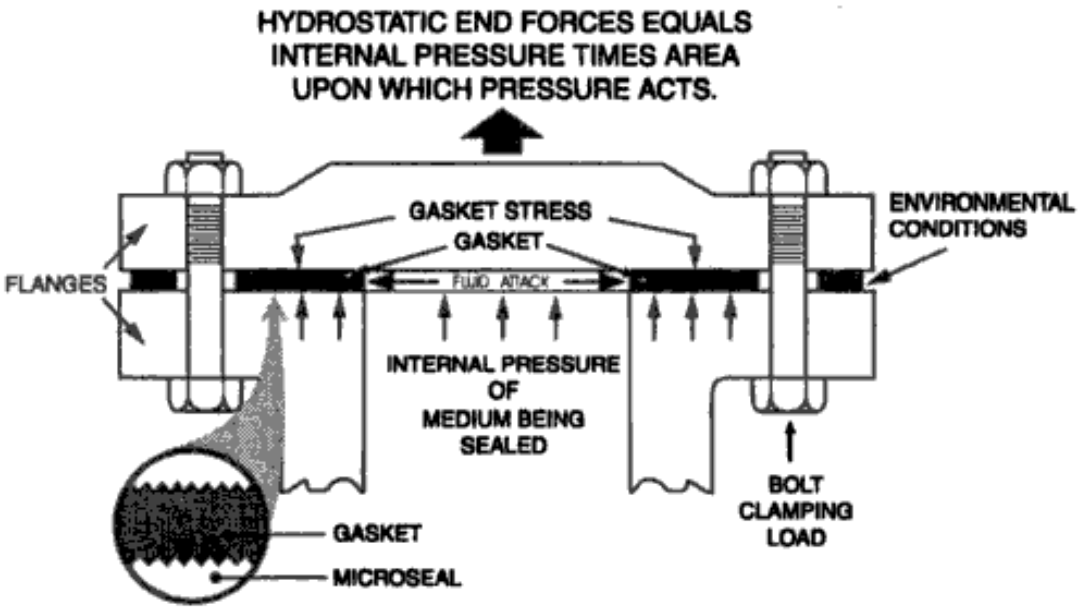

Figure 1.1: Nomenclature of gasket joint

Source: J M. Jenco (1999)

1.2 PROBLEM STATEMENT

The problems are common to the below that faces by user of spiral wound gasket:

i. Leaks often occur in the system due to connection pipe spiral wound gasket cannot withstand the pressure that high. Solution as I need to investigate the performance of spiral wound gasket in high pressure and increase the resilience of spiral wound gasket to prevent occurrence of leakage after installation gasket on the pipe system. It is very important to know the performance of spiral wound gasket that leaks can be avoided.

ii. Frequent occurrence of leakage on the spiral wound gasket when temperatures are high. This can cause contamination if a leak occurs in the pipe system. This leakage can also result in accident if the chemicals are distributed in the system and leaking pipe in the affected employees.

iii. Pipe system maintenance cost is very high because the price of each spiral wound gasket is very high. It also can not be used repeatedly and gasket will also be damaged if the way the installation gasket is wrong. This failure will also result in occurrence of leakage in the system connecting pipe.

1.3 PROJECT OBJECTIVE

1.3.1 General Project Objective

PSM project objective is to practice the knowledge and skill of the student that have been gathered before in solving problem using academic research, to born an engineer that have enough knowledge and skill. This project also important to train and increase the student capability to get know, research, data gathering, analysis making and then solve a problem by research or scientific research.

The project also will educate the student in communication like in a presentation and educate them to defend their research in the presentation. The project also will generate students that have capability to make a good research report in thesis form or

technical writing. This project also can produce and train student to capable of doing work with minimal supervisory and more independent in searching, detailing and expanding the experiences and knowledge.

1.3.2 Specific Project Objectives

i. To analysis failure of the spiral wound gasket using FEA (ALGOR) and experimental.
ii. Comparative study between both analyses.

1.4 SCOPE OF PROJECT

The scope of the project focus:-

i. Experimental result from previous study will be taken as references.
ii. Draw spiral wound gasket using solid works
iii. Analysis the spiral wound gasket using FEA software (ALGOR).
iv. Get the failure gasket from industry for experimental analysis.
v. Experimental analysis for gasket
vi. Collecting the data from both analysis
vii. Comparative study for both experiments.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide a review all the information for the spiral wound gasket, these needed to explain everything about the spiral wound gasket. These chapters explain briefly about the application of spiral wound gasket, factors affecting gasket performance**,** the important properties for gasket, factor affecting gasket performance, gasket style or type of gasket, and advantage the component in the spiral wound gasket. All information for spiral wound gasket needed to for an analysis spiral wound gasket.

These chapters also provide a review about the mechanical test like, tensile test and hardness test. This is important to gather detail information and knowledge before starting an analysis and mechanical test. Knowledge for this entire mechanical test and the spiral wound gasket required because this information could give the guideline to make sure this project follow on the right information.

2.2 SPIRAL WOUND GASKET

The spiral wound gasket is made in most metals. The performance of a spiral wound gasket depends upon the springlike action of the V-shaped metal strip. Therefore, the metal used should be on that will best maintain its resilience at the operation temperature. The maximum width of spiral wound gasket is a function of the diameter and thickness. In general, the larger the diameter is the narrower the gasket is. The spiral wound gasket requires more careful dimensioning in relation to flange facing to assure that the inner and outer layers of metal plies are under compression between the flanges facings. (Daniel E, 1996)

Nowadays leakage always happens in the industry, example leakage from bolted joints with spiral-wound gaskets has been a significant concern at many nuclear plants. In pressurized water reactor (PWR) plants, leakage from these joints has resulted in significant boric acid corrosion of flanges, low alloy steel bolting, pipes, and pressure vessel shells. Every year, this (PWR) plants experience the same problem and forced outages to deal with leaks from steam generator primary and secondary midways. (Frank P, 2005)

These outages can last 5–10 days. Although there have been fewer serious problems with spiral-wound gaskets in boiling water reactor (BWR) plants, which operate at lower pressure and temperature than the PWR primary side, these plants have not been immune to leakage and forced outages related to spiral-wound gaskets. Maintenance this two plant (PWR and BWR plant) continue to express interest in cost-effective ways to reduce leakage from bolted joints. (Jenco, 1999)

2.2.1 Application of Spiral Wound Gasket

There are many different types of gaskets including rubber gaskets, various fibrous materials held together by elastomeric binders, metal mesh with elastomeric binders, spiral-wound gaskets, metal-jacketed gaskets, corrugated metal gaskets, flat metal gaskets, and metal ring gaskets. As mentioned, gaskets are used to seal joints. However, a requirement of gaskets is depending upon the application. (Jenco, 1999)

There are characteristic very important for the gasket to make sure the gasket is functional to each condition depended on their material. This is the requirements of gaskets:

i. Heat and media resistance
ii. Zero leakage through the gasket
iii. Zero leakage over the gasket
iv. Chemical compatibility with process fluids
v. Operating pressure
vi. Operating temperature
vii. Blowout resistance
viii. Fire integrity
ix. Be environmentally safe
x. Creep and stress relaxation
xi. Available bolt force
xii. Accommodate surface finish conditions of flanges

The application of the gasket also depends on the material that use for manufacture gasket. For example, rubber gaskets are easy to seal, but they cannot withstand high pressures or high temperatures. Conversely, spiral wound gaskets can withstand high pressures and temperatures, but they are often more difficult to seal than the other gasket.

Sheet-type gaskets can be used successfully for applications involving smaller diameters, lower pressures and lower temperatures. If the diameter, pressure, and temperature increase, sheet-type gaskets become increasingly susceptible to degradation and blowout. Sheet-type gaskets are also susceptible to leakage in joints that are subject to large thermal transients. Spiral-wound, metal-jacketed, corrugated metal and solid metal ring gaskets are required for the more severe applications.(Melvin W , 2007).

2.2.2 Important of Gasket Material Properties

There are following properties of the gasket that are important for sealing performance in the application:

i. Chemical compatibility
   - To be resistant to the media being sealed.

ii. Heat resistance
   - To withstand the temperature of the environment.

iii. Sealing ability
   - To provide sealing ability both through the material and over its surface.

iv. Compressibility
   - To conform to the distortions and undulations of the mating flanges.

v. Recovery
   - To follow the motions of the flanges caused by thermal or mechanical forces.

vi. Erosion resistance
   - To accommodate fluid impingement in cases where the gasket is required to act as a metering device.

2.2.3 Factors Affecting Gasket Performance

When spiral wound gasket is clamped between the essentially stationary faces, it prevents the passage of media across the gasket connection Compressing the gasket material causes the material to flow into the imperfections of the sealing areas and affect a seal. This bond prevents the escape of the contained media. In order to maintain this seal, sufficient load must be applied to the connection to oppose the hydrostatic end force created by the internal pressure of the system. (Jenco, 1999) Gasket performance is depends on a number of factors, including;

i. Gasket metal and filler material, the materials must withstand the effect of:-

- Temperature – can adversely affect mechanical and chemical properties of the gasket, as well as physical characteristics such as oxidation and resilience.

- Pressure – the media or internal piping pressure can blow out the gasket across the flange face.

- Media – the gasket materials must be resistant to corrosive attack from the media.

ii. Joint design: the force holding the two flanges together must be sufficient to prevent flange separation caused by hydrostatic end force resulting from the pressure in the entire system.

iii. Proper bolt load: if the bolt load is insufficient to deform the gasket, or is so excessive that it crushes the gasket, a leak will occur.

iiii. Surface finish: If the surface finish is not suitable for the gasket, a seal will not be affected.

2.2.4 Gasket Styles

There are four basic designs of spiral wound gaskets that has been frequently supplied in the configurations shown in Figure 2.1. Four basic designs are plain gaskets, outer ring gaskets, inner/outer ring gaskets, and inner ring gaskets. Each design of the spiral wound gasket has specific application in the pipe flange industry. (Jenco, 1999)

i. Plain gaskets are used in tongue-and-groove applications where the groove centers the gasket and the flange dimensions define the amount of gasket compression.

ii. Inner ring gaskets are used in tongue-and-groove applications where the flange dimensions do not limit the amount of gasket compression.

iii. Outer ring gaskets are used in pipe flange applications where the outer ring acts to center the gasket within the bolt circle and the metal ring limits the amount of gasket compression.

iv. Inner/outer ring gaskets are used in pipe flange applications where the outer ring acts to center the gasket within the bolt circle, both metal rings limit the amount of gasket compression, and the inner ring acts to prevent the gasket from creeping inward as it is compressed.