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Date : 8th May 2007

RESEARCH ON MECHANICAL SYSTEM USED IN OIL AND GAS INDUSTRY
(RESEARCH AND IMPROVE MECHANICAL SEAL)

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This report is submitted to the Faculty of Mechanical Engineering
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DECLARATION

"I hereby declaration that I make this thesis myself except for statements that I verify the source that meet partial fulfillment for awarding the degree of Bachelor Mechanical Engineering (Design & Innovation)"

Signature :
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DEDICATION

To my beloved mother, father, brother and sister, and all my friends
All member of Bachelor of Mechanical Design Innovation & Engineering (BMCD)
To my PSM supervisor's, Mr Shamsul Anuar B Shamsudin
All lecturers from BMCD department
Staff of Tanjung Maintenance and Services, Kemaman
Staff of Faculty Mechanical Engineering
Staff of Universiti Teknikal Malaysia Melaka (UTeM)

Do You Have Time To Pray?
God Have Time To listen

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With the name of Allah, The Most Gracious and Most Merciful

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Not to forget also Mr. Kamal for his help regarding the the format of PSM. I had a wonderful experience working with them in completing the tasks.

ABSTRACT

The purpose of this thesis is to perform research and analysis on mechanical system used in oil and gas industry. To reduce the scope of this thesis, a research and analyses to improve mechanical seal is conducted. A mechanical seal is an important component of variety of pumps used in chemical, petrochemical and process industry. The primary function of a mechanical seal is to prevent leakage of the process fluid from the pump housing and shaft to the environment. The factors that affect the performance of a mechanical seal to leak are friction, wear and its thermal characteristics. A new design of a mechanical seal with an implanted heat exchanger in its mating ring is reported. The mating ring incorporates an internal channel in which a coolant (either a gas or a liquid) flows to remove heat from the seal face. A design was built and tested using CATIA, SOLIDWORK and ANSYS CFX.. Results are indicative of effective cooling and improved performance when compared to a conventional seal. A coating on the mating ring was successfully implemented. A simplified heat transfer analysis using the results of the finite element method is also presented for all the seal designs.

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NOTATION

NOTATION	DEFINITION
Q_g	Heat generated
P_m	Mean pressure
V	Mean velocity
A_f	Seal face area
F	Friction coefficient
ΔP	Differential pressure
B	Balance ratio
K	Pressure gradient factor
P_{sp}	Spring pressure on the seal face
D_m	Mean diameter
N	Speed, rpm
D_1	Outside diameter
D_2	Inside diameter
Q	Heat flux
V	Volume flow rate
N	number of holes
U	Velocity of the coolant into each hole
A	Area of cross section of the hole
Re	Reynolds number
Θ	Kinematic viscosity
H	Distance between the coolant entry and the coolant diversion
D	Diameter of the hole
Pr	Prandtl number

K	A Function that accounts for H/D $\geq$ 0.6 Ar $^{1/2}$
Ar	Relative nozzle area
G	Single nozzle function
F_2	A function that accounts for Reynolds number
k_t	Thermal conductivity
N_u	Average Nusselt number
h	Heat transfer convective coefficient
U_g	Velocity of the coolant in the groove
A_g	Area of cross section of the groove
D_g	Mean diameter of the groove
N_{ug}	Average Nusselt number in the groove
h_g	Heat transfer convective coefficient in the groove

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

Definition of Projek Sarjana Muda focuses on research and scientific which involving the studies in Faculty which must be prepared by student as a requirement to get the Bachelor Degree

Projek Sarjana Muda or PSM are required to fulfill the condition in order to get the Bachelor Degree, every students have to complete one of the project like research and investigation which involving one of the important title in every subjects. This project is compulsory for all final year students in Mechanical Engineering Faculty to be awarded a Bachelor Degree.

In the process of studying, students are already taught with the basic of mathematics and engineering knowledge. Students are also exposed to the application of knowledge and practical from the lab studies and also during the 20 weeks internship training .This program also helping the student to develop skills in work ethics, writing, and management towards attaining UTeM mission in producing well-rounded graduates who possess technical competence, communication and behavioral skills, lifetime learning capacity, critical thinking, business acumen, practical aptitude and solution synthesis ability.

After getting the basic of education, students are required to complete the project or thesis in order to increases more knowledge and their skill in domains especially with the problem occurred and find out the solution of the problem.

1.1 PSM Mission

The mission of PSM is to develop the knowledge and skill for every student in overcoming the problem occurred by researching and scientific in order to produce quality, competence and very professional student.

1.2 Objectives

- To analyze the function of mechanical seal.
- To improve the main problem of mechanical seal
- To identify the critical part of mechanical seal.
- To make research on new design of mechanical seal by researchers.
- To design new design of part that effected the life cycle of mechanical seal
- To be able to prove the new design have better life cycle than the conventional design.

1.3 Scope of This Project

This study identifies and to analyze and improve the weakness of current mechanical seal possible that is easily damage the cost for maintenance that was too high. The problem can be solved by using harder material so that the mechanical seal would stand longer. But the cost will rise so that is not the best solution.

In this project, a new design at face of mechanical seal will be made that could be use for all type of mechanical seal. This new design can stand higher temperature but with the same material

So by the end of this project, I aim to have designed the new design for specified part that affected the lifecycle of mechanical seal and able to prove the new design would have chance of longer life cycle than the conventional design. This will be done by using computer simulation. Firstly the design would be created into solid shape using CATIA. Then the strength of new design mechanical seal will be tested using SOLIDWORK COSMOS. Finally, an analysis using ANSYS CFX to analyze the performance of the new deign will be implemented

In designing the new part, I will look at the design coolant system as the main cause of maintenance of mechanical seal is because of the failure of face/ring of mechanical seal. A new design of face with lower temperature faced when in operation would make the life cycle of mechanical seal would stand longer.

1.4 Overview of Mechanical Seal

It is of utmost importance that two different fluids must be separated from one another if a rotating shaft passes between them in two different regions. The fluids may be at different pressures and they may be either a liquid or a gas. A shaft seal is used to separate the fluids. The seal is designed to fit around the shaft or some part connecting to the shaft in a way such that the leakage between the two regions is acceptably small under all circumstances of operation.

1.4.1 Rotating Ring Mating ring

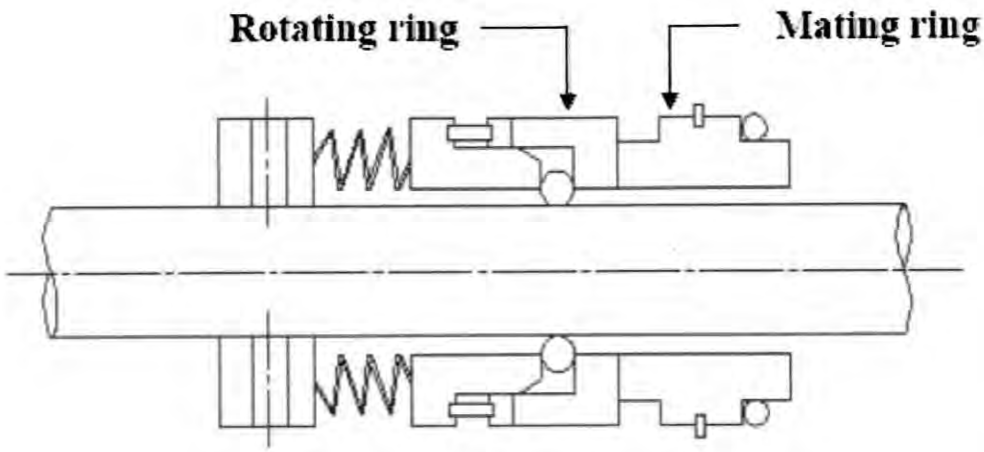

Figure 1.1 Mechanical Face Seal

Figure 1.1 shows a mechanical face seal as an example of a rotating shaft seal, since in this thesis the primary interest is on mechanical face seals. Here, the contact in between the rotating (primary) ring and the mating ring prevents the leakage or minimizes the leakage by creating a very thin gap between the surfaces. The primary ring rotates with the shaft and the mating ring remains stationary. Thus the rotating ring slides on the mating ring and this sliding is normal to the direction of the leakage of flow. Wherever the rotating shafts are used, shaft seals find their place with them. Generally rotating shafts either run into fluids where the fluid is sealed by the shaft seal or are supported by bearings, which are in turn sealed by a shaft seal. Thus almost all rotating equipment requires a shaft seal. The various types of mechanical equipment that utilize shaft seals are as follows (Lebeck, 1991):

- Aerospace industries where motors and engines in rockets and turbo jets.
- Water pumps used in irrigation, pumping of fertilizers and insecticides.
- Swimming pool pumps and garbage disposal pumps, dishwashers and washing machines use small sealed pumps.
- Water turbines, steam turbines, feed pumps, and nuclear reactor cooling pumps.
- The petroleum, chemical, textile and drug industries all use pumps extensively in their respective processes.
- All automotive engines, compressors, air conditioners.
- Ship propeller shafts as well as its auxiliary equipment in ship yards.

1.5 Types of Shaft Seals

It is important to see how mechanical face seals relate themselves to different types of seals and why mechanical face seals are an important alternative to sealing. There are two categories of shaft seals: fixed clearance types and surface guided types. The fixed clearance type seals would never touch throughout their life span. In the surface guided types, one of the seal faces is mounted onto the shaft or the housing and is entirely supported and guided by the second seal face. Thus, one face slides over another. The leakage gap is determined by the nature of the surfaces in contact. In some cases there occurs a lift off in between the surfaces and in some it does not. In the case where lift off does not occur the seals are called contacting seals and the others are called no contacting seals. The non-contacting seals are often confused with the fixed clearance seals. To get a lift off in between the faces, features such as lift pads, radial tapers, and spiral groves are used. But, the forces developed in the lift off or non-contacting seals and in that of the fixed clearance seals are decisively distinct (Lebeck, 1991).

1.5.1 Fixed Clearance Seals

The common types of fixed clearance seals are as follows (Lebeck, 1991).

- **Visco Seal**

The visco seal can seal directly against a liquid using the liquid itself or, by using a separate supply of liquid, may seal against a gas. The effectiveness of the visco seal depends primarily on the viscosity and clearance.

- **Labyrinth Seal**

This seal relies mainly on creating a high loss leakage path to minimize leakage. This seal can be used for liquids as well as gases.

• **Bushing Seal**

In this seal the flow area is the annulus created between the bushing clearance and the shaft. Resistance to flow is determined by the length and the clearance, and the clearance should be large enough to allow for all shaft motion.

• **Floating Ring Seal**

This seal is similar to the bushing seal except that the bushing is allowed to float freely in the radial direction so that shifting the bushing can accommodate large radial motions of the shaft. Thus, the floating ring can have a smaller clearance than the fixed bushing seal.

• **Ferrofluid Seal**

In this a magnetic fluid is held in place by magnets. The fluid can maintain a small pressure difference before it is pushed out of the gap. The magnetic fluid is a suspension of magnetic particles in a liquid. By staging the ferrofluid seal, significant pressure differentials can be handled. The primary advantage of the ferrofluid seal is that there is zero leakage.

1.5.2 Surface Guided Seals

The surface guided seals are classified with respect to the type of guiding surface. Nearly all the rotating shaft seals contact either on an annular surface or a cylindrical surface.

1.5.2.1 Cylindrical Surface

- **Lip Seal**

The lip seal contacts over a small axial length. This seal is generally not suitable for significant pressure differentials. Most lip seals are of the cylindrical surface guided type.

- **Circumferential Seal**

This seal contacts on a cylindrical surface over a definite axial length unlike the lip seal. It has some type of segments that allow it to clamp around the cylinder entirely, and it may be pressure loaded.

- **Packing**

Packing itself represents a cylindrical surface guided type of seal. Commonly this seal contacts or partially contacts over a large area.

1.5.2.2 Annular Surface Seals

- **Lip Seal**

A lip seal can be designed to contact on some small part of an annulus. But, the cylindrical geometry is most common.

- **Mechanical Face Seal**

The mechanical face seal contacts over a significant radial fraction of the annulus. Comparing this seal to its cylindrical surface counter part, the circumferential seal, it is somewhat simpler because the seal is not made in segments.

1.6 Mechanical Face Seals

The term face indicates that the seal contact is over an area rather than having line of contact or it may indicate that the contact is on the face of housing or a shaft. The term mechanical implies a device rather than soft packing as being the essential characteristic of the seal. Mechanical also implies touching, as well, so as to allow one to distinguish the mechanical seal from a fixed clearance seal. Often the mechanical face seal is referred to as an end face seal or a radial face seal indicating the form of the sealing surface (Lebeck, 1991).

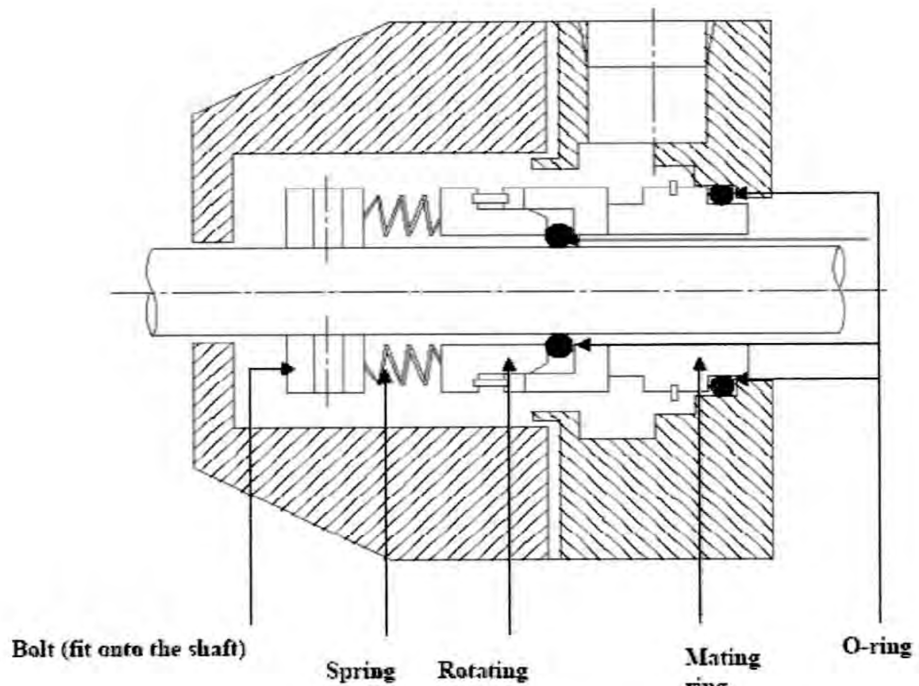

Figure 1.2 Essential Components in Mechanical Face Seal

- **Primary Ring**

The ring is mounted so as to provide flexibility to allow for small relative axial and angular motion for misalignment between the parts. The primary ring also provides one of the sealing surfaces as shown in Figure 1.2.

• Mating Ring

The ring is rigidly mounted to the shaft or to the housing but does not rotate. It provides the second sealing surface. This ring works as a surface guided ring.

• Secondary Seal

It allows the primary ring to have axial and angular freedom of motion while retaining the sealing integrity. The secondary seals are the O-rings in the case shown in Figure 1.2.

• Spring

All mechanical face seals have some type of a spring mechanism to hold the annular surfaces together in the absence of fluid pressure. The fluid pressure provides a certain force that holds the surfaces together.

• Drive Mechanism

All mechanical face seals must have some type of a drive mechanism or rely on some other features to drive the primary ring in order to make certain that relative motion occurs only at the annular interface. The drive mechanism is designed so as not to reduce the self-aligning characteristics of the primary ring.

In addition to the above terms and components, there is an additional terminology, which is worth mentioning. The rings in the mechanical face seals should possess the appropriate material properties. Generally the primary ring is made of a softer material than the mating ring. The mating ring being the guiding ring has to be made of a hard material to allow the softer primary ring to run into it. Alternatively, in some applications, the primary rings are made of the hard material and the mating ring is made of softer materials. In special applications, such as when operating in some severe environments, the design may call for a hard material to run on another hard material. As discussed earlier, in a mechanical face seal contact occurs in between the primary and the mating rings at the annulus. The essential