DESIGN/PROTOTYPE OF MECHANICAL SEAL FOR SCRAPPER HEAT EXCHANGER.

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A project report submitted in partial fulfillment of the requirement for the Award of Master of Engineering (Mechanical).

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OCTOBER 2016

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

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ABSTRACT

Ebara Pump is a stainless steel pump which is commonly used in the food industry or palm processing. Current issue that is faced by refineries for this pump design is such that product leaks through the mechanical seal during intermediate stoppage at shift change or product change over. As far as the Packaging Plant is concerned, the continuous oil leak caused by cooling process is incurring high process wastage. In this project we have fabricated a prototype of Ebara Pump mechanical seal as a prove of concept to solve an ongoing problem in transferring of palm oil or palm product in the refinery and other downstream refinery processing areas. In mechanical seal, the likelihood of failure is cause by spring failure. Using this improved pump mechanical seal, minimal waste is targeted. This measure is forecasted to save an estimate of RM 360 000.00 per annum in a factory of 16 pumps.

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CHAPTER 1

INTRODUCTION

In the palm oil industry, leakages due to improper sealing between machinery parts could cost high wastages. The properties and physical structure of the oil would change according to the process. There would be instances the oil is in a liquid and less viscous form such as in the refining and deodorization process. During the fractionation and crystallization process, oil property changes to a more viscous form. Type of sealing for process machinery parts depends on these circumstances.

There are instances in the palm industry, to transfer oil in a pipeline we require to heat the medium in order it doesn't solidify. Keeping the medium in a certain temperature can be done before transferring by heating the oil in a storage tank and during transferring having a steam tracing system along the pipe line for the oil to stay hot and not to solidify. Steam tracing is a heating system using copper tubing coiled along the pipeline with steam as a heating medium.

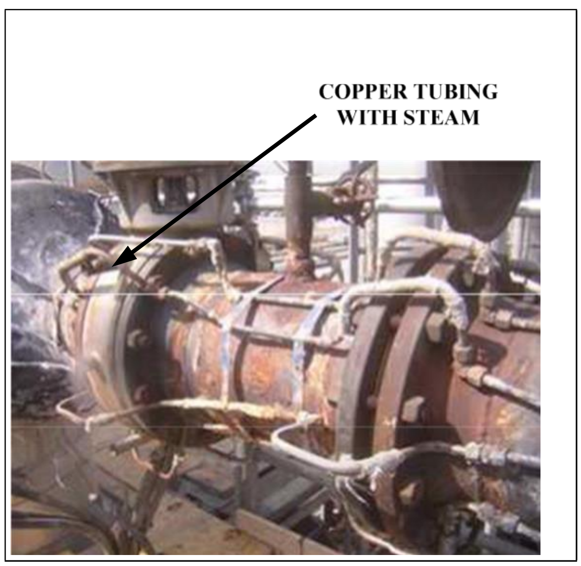

Figure 1: Steam Tracing Along Pipe Line (Wermac,2012)

It is a practice in oil transferring after any type of oil viscous or non-viscous, the operator would then blow the line with pressurize nitrogen gas to clear the pipe line

from oil. This will prevent balance oil in the pipeline from solidifying.
In process of oil transfer, a pump is always integrated into the piping system to add energy into the fluid line which adds pressure to the system for flow.
As for centrifugal pump it has to have proper sealing in rotating shaft system, the sealing prevents oil from leaking would require 2 components of seals, the stationary and rotating part. When both of this component surface are in contact ideally a good sealing is obtained. Referring to the Figure 2, the sealing area is the lapping surface for rotating and stationary. Both of these components in whole are called the mechanical seal or mech. seal in short.

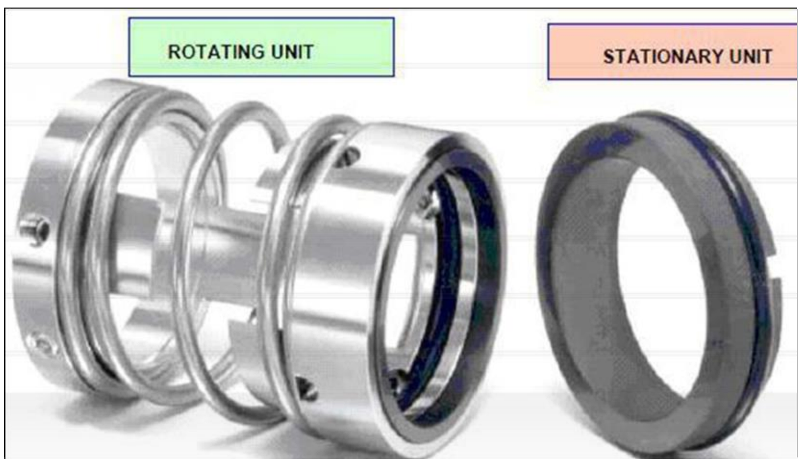

Figure 2: Mechanical Seal Component. (MacCormack,2014)

Process of transferring oil through pipe line requires pump to add energy to the fluid flow, this can only be done when palm product is in liquid form. To achieve this state, palm product has to be heated to a temperature in range of 60-75 deg C.
If heated at higher temperature it would cause the oil to oxidize causing quality issues. When pump has stop to transfer, oil remaining in the pipe line is still heated up by using the steam tracing system but oil in the pump would solidify especially at the mechanical seal area, causing the mechanical seal spring to seize. When spring is not free to move, it causes the stationary ceramic seal and rotating seal face not to have proper contact. When this happens, the transfer fluid leaks through the seal face till the solidified fats at the spring are melted when operation uses the pump again.

CHAPTER 2

PROBLEM STATEMENT.

In the crystallization plant we have rotating equipment such as the Kombinator, where palm oil is crystalized under very low temperature to form crystals in the scraper heat exchanger. The scraper is a rotating shaft which scrapes crystalized oil on the surface of heat exchanger to maintain the efficiency of heat exchange.

To prevent leakages of oil, the design of scraper shaft is fitted with a mechanical seal. There is a little heating on the shaft seal externally by hot water jacket but the temperature can’t be high because it would destroy the crystal in oil.

Due to this limitation during production, crystalized oil would leak from the mechanical seal. For the prototype mechanical seal, will be using Ebara pump as a proof of concept due to the solidifying fats in its mechanical seal, the spring tend to seize and oil would leak from the mechanical seal. Total 15 units of Ebara pumps are used in the factory and there is a waste of RM 350 000.00 a year due to oil leaking from the mechanical seal cause by this type of failure. Out of RM 350 000.00 waste only 15% can be recovered and the rest RM 297 000.00 is total loss to the company for a year.

CHAPTER 3

OBJECTIVE

The objective of this research is to develop a mechanical seal prototype which would prevent product oil from leaking through the mechanical seal due to seizing of spring. This design could be used in a rotating shaft for crystalized oil for process or harden fats in the Kombinator of the cooling cylinder. In order to have the proof of concept, I would test it on an Inoxpa brand Pump. It is a centrifugal pump which faces the same problem as the Kombinator Machine.

Objective to achieve with new design the mechanical seal:

1) Mechanical Seal should not seize during start up and operation due to contact with product. No leakages at shaft.
2) Ease in fabrication and material machining. Targeted fabrication cost below RM 3000.00.
3) Design of conical spring to change to straight spring for easy assembly and simple spring casing design.
4) Perform stimulation on conical spring and compare with straight spring design on achieving similar forces and compatibility with old ceramic seal.
5) Test the new mechanical seal and observe if any failure on functionality of mechanical seal. Total minimum of 200 hours in testing for this prototype.
   Have to observe pump functioning as good as manufactures mechanical seal design. Pump has to achieve a minimum 2 bar discharge pressure when discharge valve is fully open.
6) New design should also eliminate product leaking issue during intermediate stoppage of pump and during production change over period.

CHAPTER 4

LITERATURE REVIEW.

Design of Mechanical Seal for Scrapper Heat Exchanger

4.1 Introduction.

Yearly production and consumption of oil and fats around the globe is about 119 million tones and gradually rises at a rate of 2 to 6 million tonnes per year. Peter R.N Childs. (2014) Approximately 14% of current fat and oil production is used as preparatory material for oleo chemical industry and a6% is used as animal feed. The remaining staggering 80% is used for human food such as cooking fats, salad oils, frying oils, and spreads. Peter R.N Childs. (2014)

Spreads and cooking fats are derived from liquid oil form, example palm oil. It is then crystalized and textured to form semi solid fats which are used as spread and cooking fats. A commercial example of this product would be margarine, butter, shortening and etc. This process of transforming oil from liquid form to semi solid form is called crystalizing.

A crystalizing plant comprises blending tanks, scrapper heat exchanger and filling station. An example of a basic plant layout is in the diagram below.

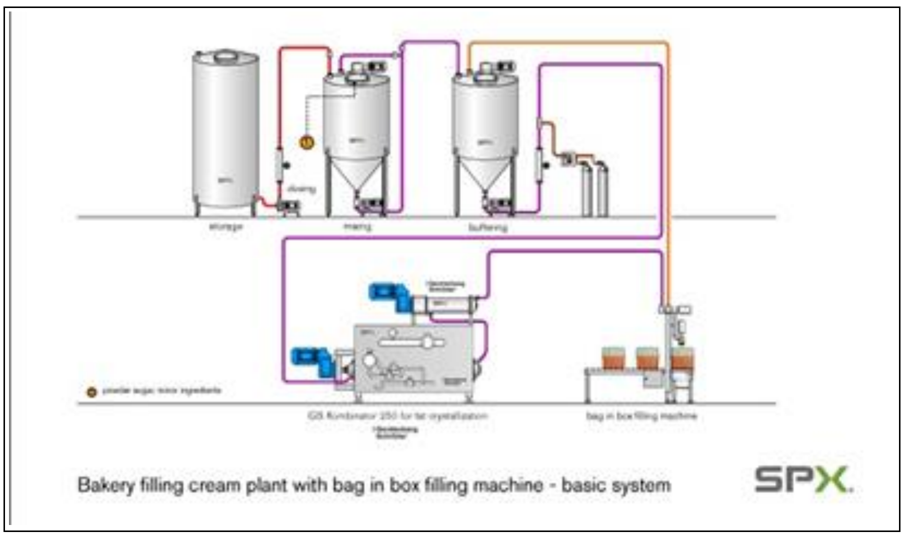

Figure 3: Crystalizing Plant (www.spx.com, 2012)

The purpose of scrapper heat exchanger in this application is to be used as cooling purpose. Fat blend from blending tank would be in the temperature of 50-55°C cooled down to a range of 24-32°C depending on the type of fat to crystallize. The idea of using a scraped heat exchanger in comparison to plate heat exchanger or shell and tube would be due to profound the nature of fats itself.

Currently, the Kombinator design uses hot water jacketing for the mechanical seal or another term called double seal. But having this design it reduces the plant output or efficiency because the purpose of the Kombinator is to perform cooling to the oil. By having external heating requires the machine to perform additional cooling or have to size the crystallizer for a bigger efficiency.

In past palm oil factory produces 2 types of product using this machine which are shortening and majerine. In recent years when Indonesia became a major player in palm oil manufacturing, manufactures in Malaysia begin to diversify their product.

In year 2014, the cost of raw material for Cocoa butter has increased which cause the cost of manufacturing chocolates also increase. Using Palm oil as raw material many found that we can produce Cocoa Butter Substitute (CBS), Cocoa Butter Equivalent and Cocoa Butter Replacement (CBR). To produce this type of product we have to crystalize palm oil with added additive which makes the oil more viscous when cooled down.

This type of product causes major leaking in mechanical seal especially during production and not only during start up.
Functionality of mechanical seal depends on the spring, by having the spring of seal in contact with the product and it tends to harden the mechanical seal fails from proper sealing which cause product leaking from machinery. To solve this problem, come up with a design of mechanical seal with enclosed spring housing.

When oil or fat blend is crystalized, it would reduce the efficiency of heat exchanger by creating high fouling and act as an insulator at the shell of heat exchanger. To counter the effect of fouling by solidified fat, the inner shell of heat exchanger is design with a shaft mounted with flexible tilting rows of scraper blades. This shaft is commonly known as the mutator shaft; it rotates and scrapes the surface of heat exchanger to remove accumulation of solid fats.

When product is pumped through the heat exchanger it flows in between the shell and mutator shaft for heat exchange to take place.

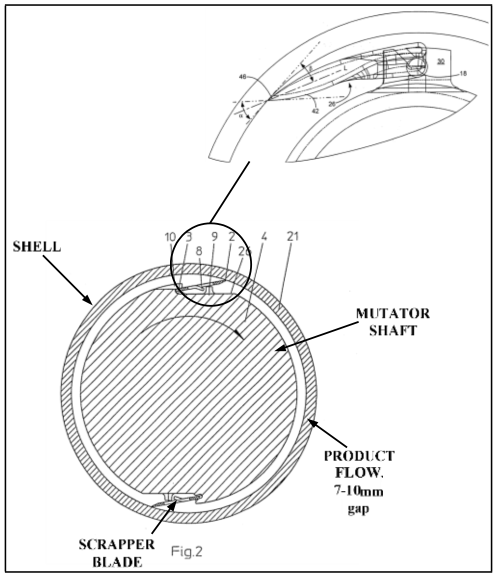

Figure 4: Blade in Scraper Heat Exchanger. (Gerstenberg Schroder,2012)

One of the leading manufacturers of scraper heat exchanger would be from Gerstenberg Schroder from Denmark. Their brand SPX GS (Gerstenberg Schroder) is globally recognized as the leading manufacturer design in food processing equipment.

Application of heat exchanger could also be used for heat sensitive products a part from the usage as crystalizing fat, where delicate product which are negatively altered by prolonged contact to heat. The scraper blade prevents product residue to be on the heat transfer surface by constantly eliminating and renewing the film.

For viscous products heat transfer between the wall and product would be low, therefore high heat transfer rates will be induced by continuous scraping of product film from heat transfer wall.

Scrapper Heat Exchanger is used to control conventional heat exchangers where particulate laden product will have a tendency to plug on them. Generally, particulates would maintain optimum product identity.

Looking into the application of cooling and crystalizing fats this equipment would be most suitable to be used but there is a drawback on the design of the mechanical seal for the rotating mutator shaft. This flaw is contributed by the property of hard fat by seizing the mechanical seal spring. This causes the rotating and stationary faces of seal being not in contact. Pressurized oil or product would then leak through this gap.

The stationary seal is always fixed to the housing of equipment while the rotating seal would be on the shaft which is in a rotating motion.

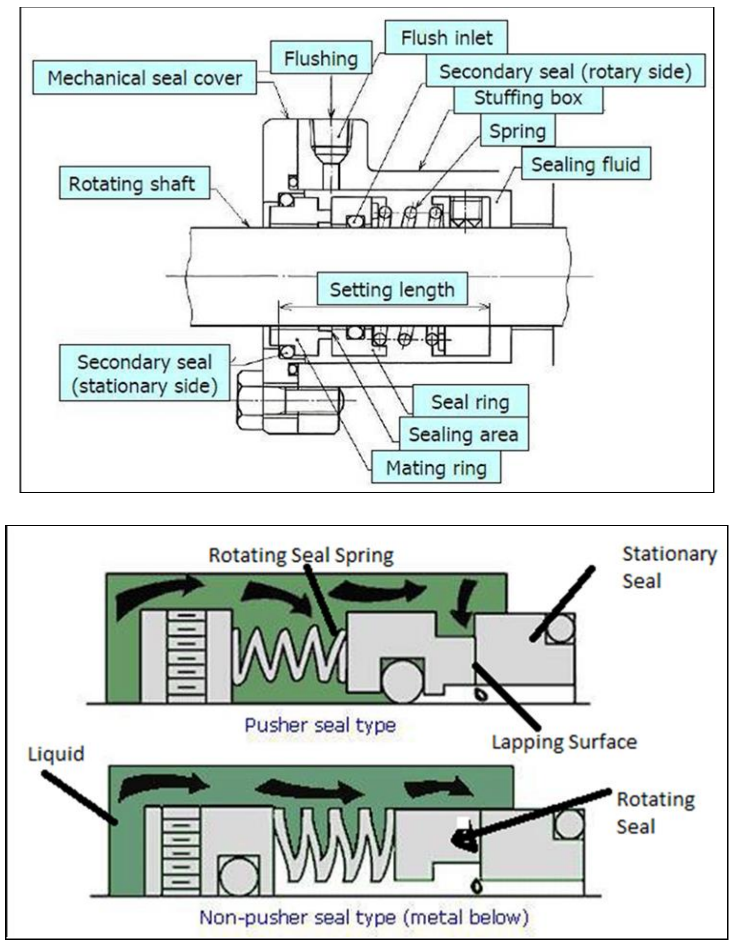

Figure 5: Rotating and Stationary Seal (Peter R.N Childs. ,2014)

In Figure 5, illustration of condition when mechanical seal installed in pump. The transferred liquid is in contact with the rotating seal in whole.

The purpose of the spring is to exert mechanical force to the rotating face of mechanical seal. This would ensure both faces are firmly in contact. If the spring fails there would be leakages through the mechanical seal. Failure of the spring can be contributed by mechanical failure such as fatigue or material deterioration due to chemical properties of liquid, this is because the spring is directly in contact with the fluid.

Another type of functional failure by spring, which is common in the palm oil industry would be the seizure of crystalized or harden oil. This effect is very common when the pump stopped at the end of transfer but balance oil still remain in the pump. This stagnant oil encapsulating the mechanical seal tends to harden and seizes the spring. So during start up, the rotating part sealing surface is not in contact with the stationary surface. This gap would cause the oil or liquid to leak out, example as in Figure 6.

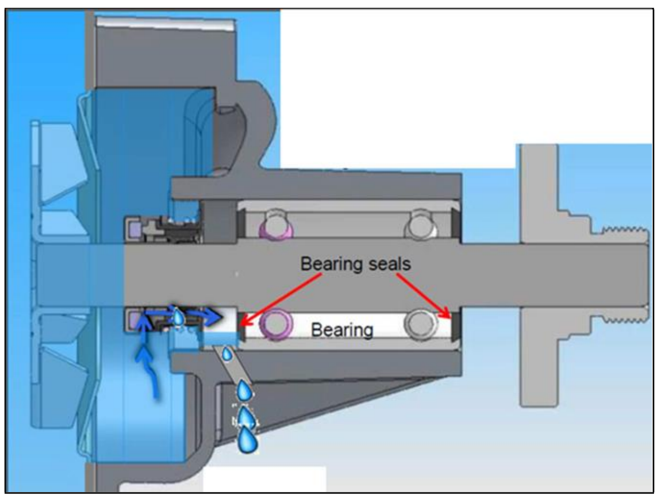

Figure 6: Leaking through Mechanical Seal (Peter R.N Childs. ,2014)

There are a few ways pump manufacture has solved this problem, by jacketing the mechanical seal housing with hot water or coiling the pump housing with steam tracing. This keeps the pump housing always warm and any solidified oil on the mechanical seal will be melted. For pumps, seizing of mechanical seal can be solved using steam tracing system but in the palm oil industry some of the quality requirement is to maintain the crystals in the oil.

4.2 Mechanical Seal in Pumps.

Mechanical seal is widely used in sealing of rotating shafts. Majority of its usage would be for pumps. A pump is a device which moves fluid and slurries by mechanical action. Figure 8 is a diagram of a pump and its construction.

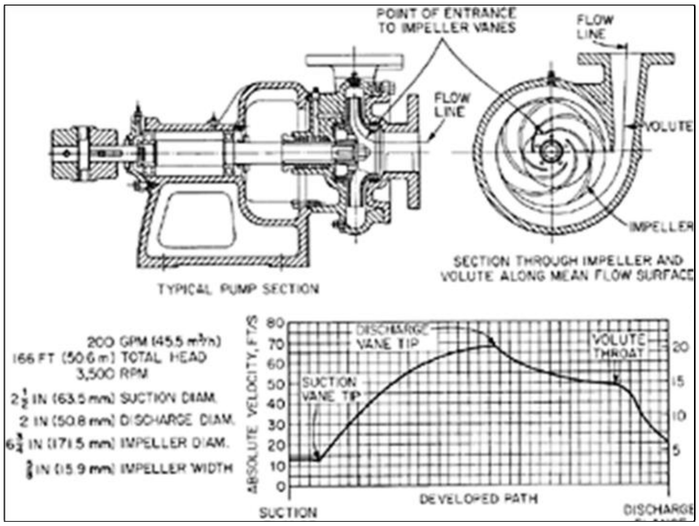

Figure 7: Single stage end suction volute pump (Wermac,2012).

Referring to the Figure 7, fluid would flow into the pump casing through the suction inlet (shown in the diagram as flow line). In the pump, fluid is force into by atmospheric or other pressure into a set of rotating vanes. This vanes which are also known as impeller would force the fluid out from the casing with higher velocity.

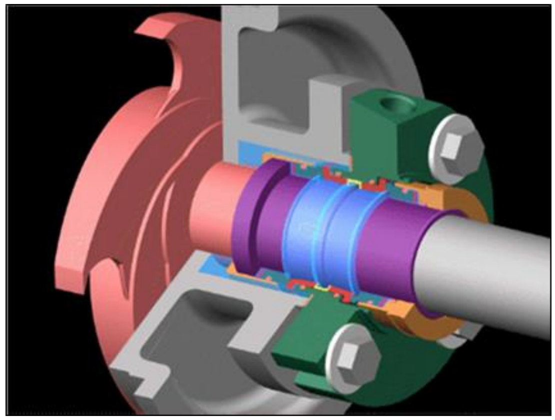

Figure 8: Installation of Mechanical/Shaft Seal in Pump (Peter R.N Childs. ,2014).

Sealing the pressurized fluid in the pump casing from leaking through impeller shaft would be the mechanical seal.

The difference between a crystallizer and pump, pump introduces kinetic energy to the fluid system while crystallizer is a processing machine. The physical characteristic of the fluid in a crystallizer would be almost same as the fluid in a slurry pump. This kind of application is considered heavy duty for a fluid system.

4.3 Mechanical Seal in General.

In this segment we would give attention on the sealing mechanism between the rotating shaft and the housing, a device called as mechanical seal. Looking into the design of a pump and an S.S.H.E we can observe similar design of its shaft seal or mechanical seal. Both equipment shaft seals has 2 components one a rotating and a stationary part. (Micheal, 2013) Both seal face touches each other creating a seal when the shaft is ideal or when rotating preventing fluid from leaking.

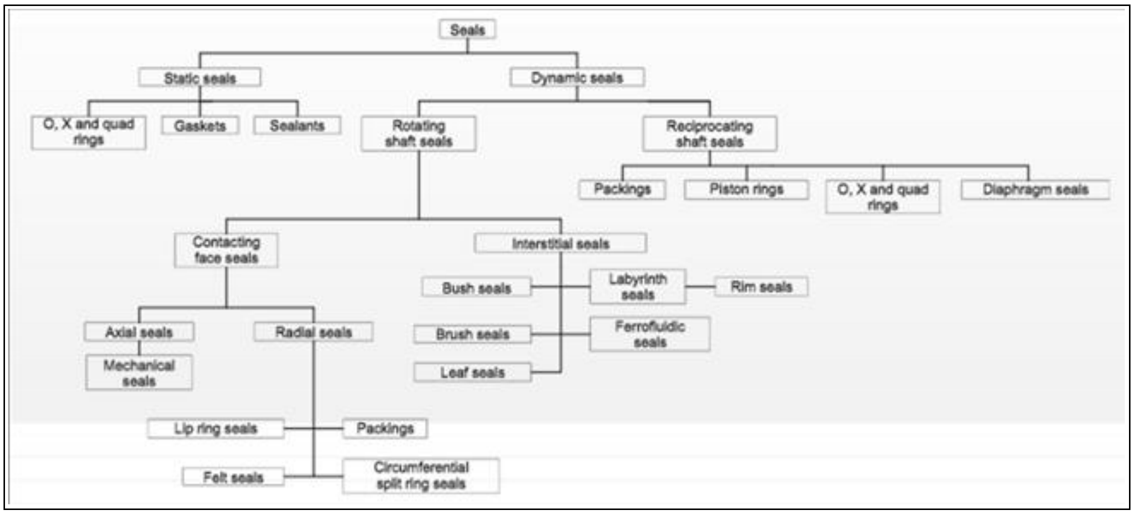

Figure 9: General Seal Classification Chart (Micheal, 2013)

In the figure above, the mechanical seal is classified as a dynamic seal, which is a device that limits the fluid flow between surfaces that moves relatively to each other. High contact pressure between the stationary and rotating part would need effective sealing to operate optimally. (Micheal, 2013)

Rotary motion seals consist of O rings, lip seals, face seals, sealing rings, compression packing, and non-contacting seal such as bush.

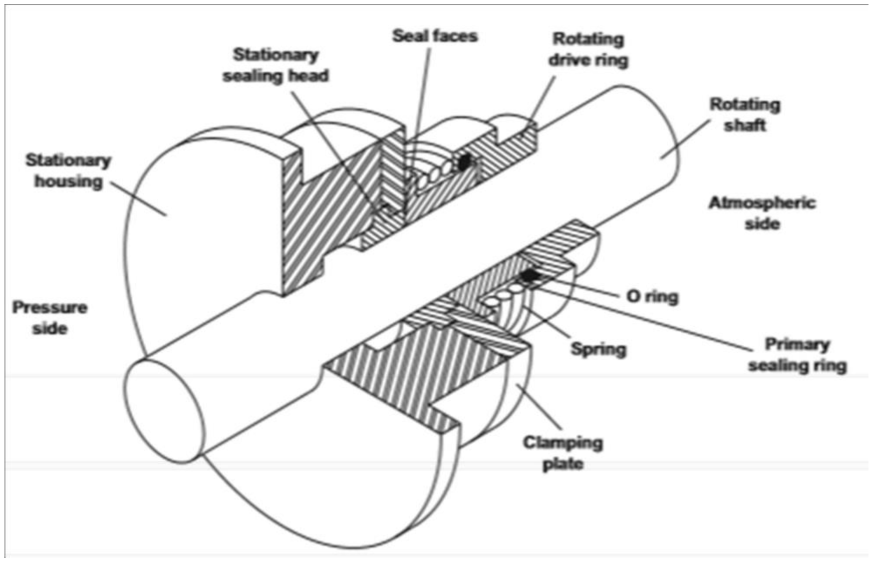

Figure 10: Typical Mechanical Seal 2

(Graeme Addie & Anders Sellgren,2014)

The overall assembly is illustrated as in Figure 10. Forces acting in the axial direction by hydraulics and mechanically maintains frictional rubbing contact between the sealing faces. As an example the seal spring forces the seal face to have contact with each other.

In Figure 11, in next page is a clear image of an installation of the mechanical seal in pump housing. Mating ring would be the rotating seal, primary ring is the stationary part with the seal spring exerting an axial force in order both of the seal faces in contact with each other.

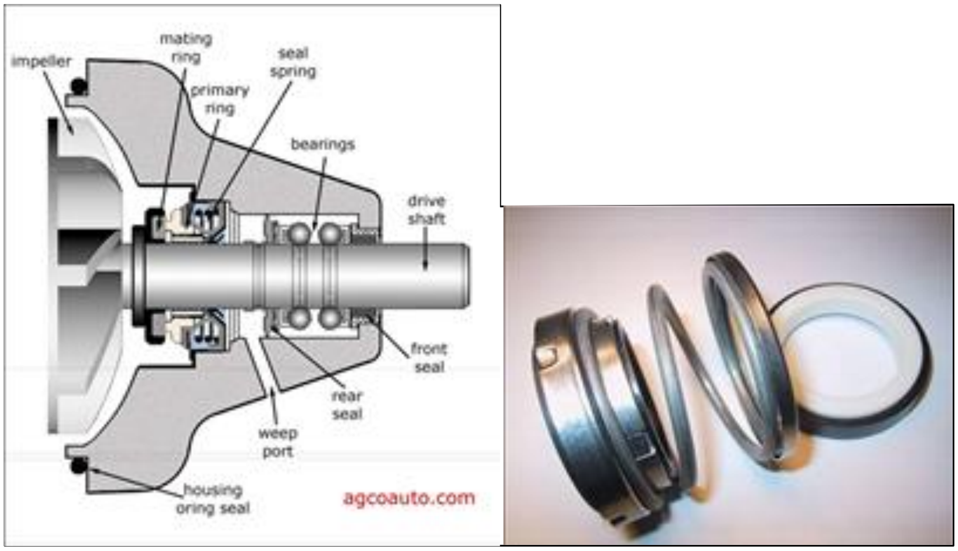

Figure 11: Mechanical seal installation in a pump and mechanical seal set (Garlock, 2010)

There are many types of mechanical seal types such as Inside Seal, Outside Seal, Rotary Seal, Pusher Seal, Stationary Seals, Non Pusher Seals, Metal Bellow Seals, Unbalance Seal, Balance Seal and Double Seal. (Garlock, 2010)

A primary seal is when two flat surface in a mechanical seal is sealed together. The critical part of mechanical seal is the flatness of the surface which is measured in helium bands. One helium band is 0.000294mm. (Garlock,2010).
The seal attached to the pump shaft is the rotary surface and the other seal which is attached at the pump casing is the stationary seal which does not rotate.
There is a secondary seal for surface or face seals for mechanical seals such as o-rings or gaskets.

The stationary component of mechanical seal closes the gap between the rotary face and shaft as well. As seal face wear off due to friction or vibration a spring or a metal bellow would be needed to insure continuous surface contact even when pump is shut off (Garlock, 2010) .
When both of the stationary and rotating face rubs and slides there would be a fluid film between this faces to cool and lubricated. Without this layer of film the seal face tends

to get hot due to friction and damages easily.

As the product is being pumped a small amount of fluid would leak between the faces and remain until vaporizing as it reaches the atmosphere. This type of leakage is not visible and all mechanical seal leak a small amount of vapor.

4.3.1 Inside Seals

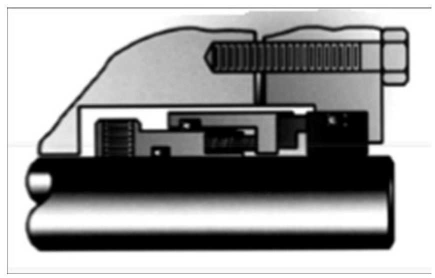

Figure 12: Inside Seal(Summers-Smith, 1992)

An inside seal (Figure 12) is designed for rotary portion of the mechanical seal, when installed, it is located inside the pump seal chamber. The fluid pressure generated by pump would create a closing force which makes this seal good to be used in high pressure application. This design uses the centrifugal force from impeller to divert solids or impurities in fluid away from seal face. This reduces failure due to impurities in between the seal faces and this type of seal is most compatible with chemical fluids (Garlock, 2010).

4.3.2 Outside Seals

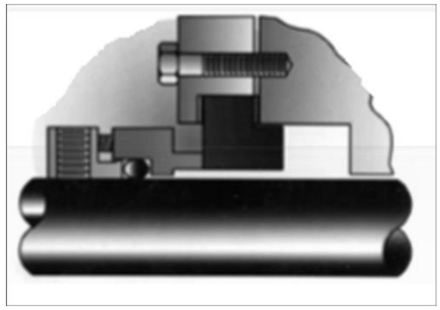

Figure13:Outside Seal(Summers-Smith, 1992)

Figure 13 is a mechanical seal where the rotary seal is located outside the pump seal chamber. If the fluid has contamination of solid it would cause clogging on the mechanical seal as the pressure of fluid acting on the seal face is in the inside diameter of the seal.

The product pressure can overcome the spring load with some outside designs.

Fluid pressure due to the centrifugal force would lubricate both the stationary and rotating seal surface. Due to product pressure overcoming spring strength this limits the working pressure of the pump to 150psi. There are some designs incorporating set screws and clamp ring to overcome the low working pressure of this type of mechanical seal.

Outside seal are commonly used in non metallic pumps for chemical service, due to the cause fluid would not come in contact with metal parts of mechanical seal (Garlock, 2010).

4.3.3 Rotary Seals

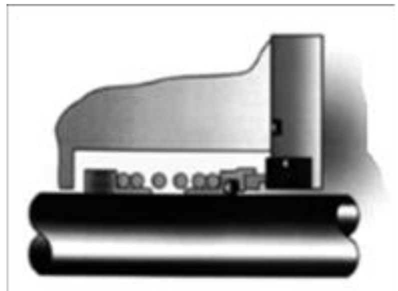

Figure 14: Rotary Seal(Summers-Smith, 1992)

Rotary seals are most commonly used in the palm oil industry it uses a spring as a mechanical loading device to ensure both the seal faces are in contact. Spring can be easily distorted at high rotating speeds and it self-aligns approximately twice per revolution. This constant movement in axial direction can cause fatigue and breakage. This type of mechanical seal would expel solids away as it spins (Garlock, 2010).

4.3.4 Pusher Seals.

Face wear or shaft movement would be compensated by a pusher seal which acts as a optimum seal design that pushes a dynamic secondary seal (O-ring, wedge, chevron, u-seal, etc.) along the shaft. As a result, a pusher seal will wear a groove in the shaft or sleeve surface. Secondary seal will create an area of wear called fret. (Garlock, 2010)

4.3.5 Stationary Seals.

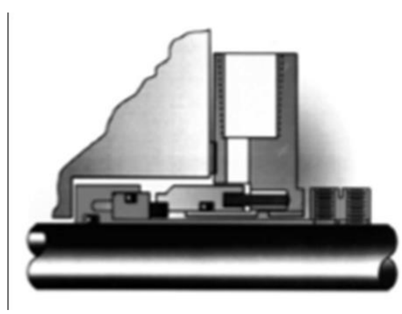

Figure 15: Stationary Seal (Garlock, 2010)

For a stationary seal the mechanical seal spring would not rotate like conventional seal it would remain stationary as in Figure 15.

Non-rotated spring, they are unaffected by the pump speed. During rotation, the springs would not correct or adjust accordingly. They adjust for misalignment only once, when installed, and are much less subject to fatigue or breaking. Stationary seals are preferred for high-speed service. (Garlock, 2010)

4.3.6 Seals Non Pusher.

Figure 16: Non Pusher Seals (Garlock, 2010)

Metal below or elastomeric below are used in non pusher seals if there is other movement other than rotational such as axial movement it would not scratch or wear the pump shaft. This is due to the movement flexes with the bellow. This design eliminates a dynamic secondary seal (Garlock, 2010).

4.3.7 Metal Bellows Seals

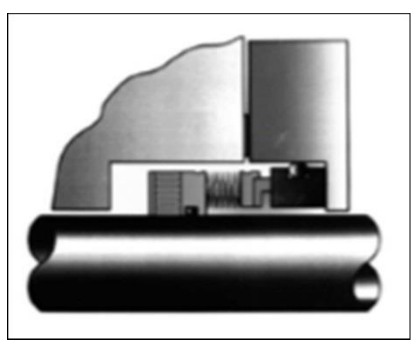

Figure 17: Metal Bellow Seals(Summers-Smith, 1992)

Instead of using a spring as a mechanical loading device a metal bellow seal is made by welding a few plates together forming a spring loading device and it also acts as a secondary seal. An o –ring is used below the metal below and it is static which does not cause damage to shaft. The main success for this seal is it is always balance in design (Summers-Smith, 1992).

4.3.8 Unbalanced Seals.

Besides using a spring design such as the Metal Bellow Seal, the unbalance seal uses the hydraulic pressure generated by the pump to close the mechanical seal together. This type of seal is only used for low pressure application which is at 3.5bar or less. The pressure acting on the seal is regulated by the geometric design of the seal (Summers-Smith, 1992, pg.4).

4.3.9 Balanced Seals

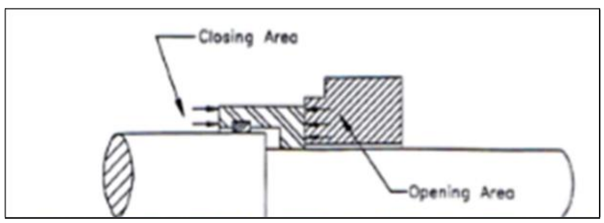

Figure 18: Balanced Seal (Summers-Smith, 1992)

Comparison with the unbalance seal, this seal can operate at higher pressure where it generates less heat by reducing pressure acting on the seal faces. This is done by reducing the hydraulic pressure with a geometrically design seal where opening or neutralized area of seal is reduced (Summers-Smith, 1992).

4.4 Mechanical Seal in Scrapper Heat Exchanger.

The new Scraper Heat Exchanger Design by SPX, Votator 2 is furnished by a mechanical seal single or double type at both ends of shafts. Type of mechanical seal is chosen by customer upon request.

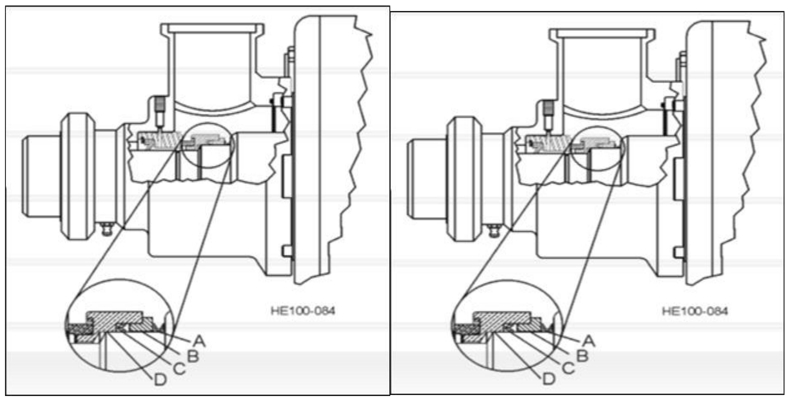

Figure 19: Single Mechanical Seal (Waukesha, 2013)

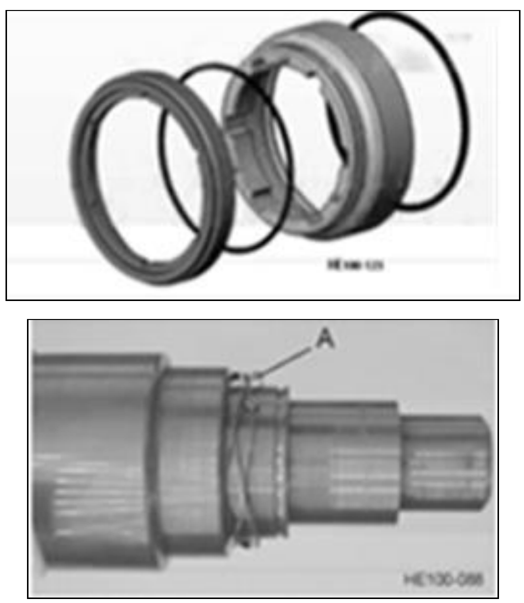

Figure 20: Primary Seal body and Spring Washer (A) (Waukesha, 2013)

Designed Single Mechanical Seal is not meant to be flushed. As Figure 20, lip seal purely designed to contain water or liquid flush. Flushing is done by removing the spring in the seal and lip reinstalled in relief position. (Waukesha, 2013, pg. 22)

When mechanical seal is rotating, permanent damage to seal assembly could be avoided by introducing product or water flow to provide cooling to rotating surface.

Item B and D are the rotating and stationary seals in Figure 20, Item A would be the spring washer which to provide mechanical force on the rotating seal. Double mechanical seal is equipped with a prime seal for product and minor seal to contain water or steam.

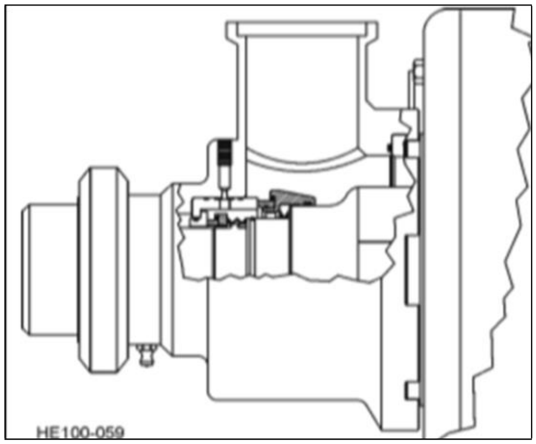

Figure 21: Double Mechanical Seal (Waukesha, 2013)

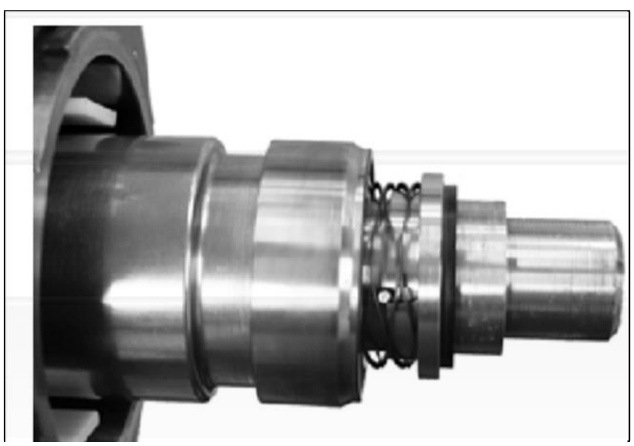

Figure 22: Installed Double Mechanical Seal (Waukesha, 2013)

Reason for water (hot) or steam designed to be contain in mechanical seal is to keep the module warm or at higher temperature then the crystalized product melting point. This will prevent the mechanical seal movement restricted by harden/crystal product (Waukesha, 2013, pg. 25).

CHAPTER 5

RESEARCH METHODOLOGY

Concept of the new design is to enclose the seal housing in order the oil does not have contact with the spring. By eliminating the fluid oil contact with the mechanical seal there would be no seizing of spring. To test on a smaller scale by using a Inoxpa Pump, this current pump design has mechanical seal spring exposed to oil which can seize the spring when harden or crystallized. Below is the existing design of the mechanical seal and pump design.

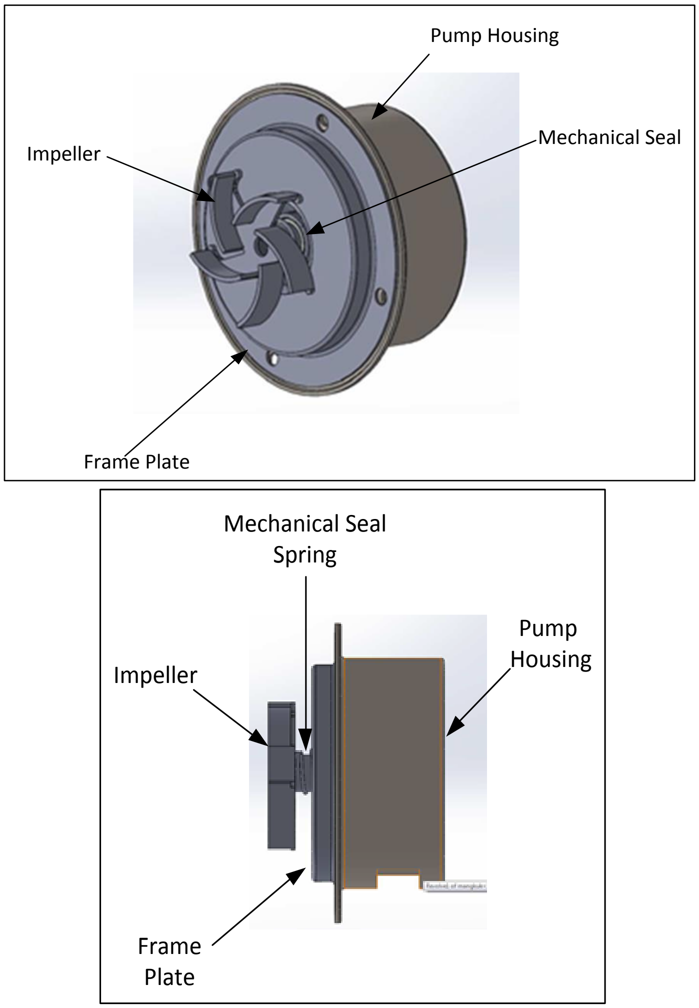

Figure 23: Existing Pump Design

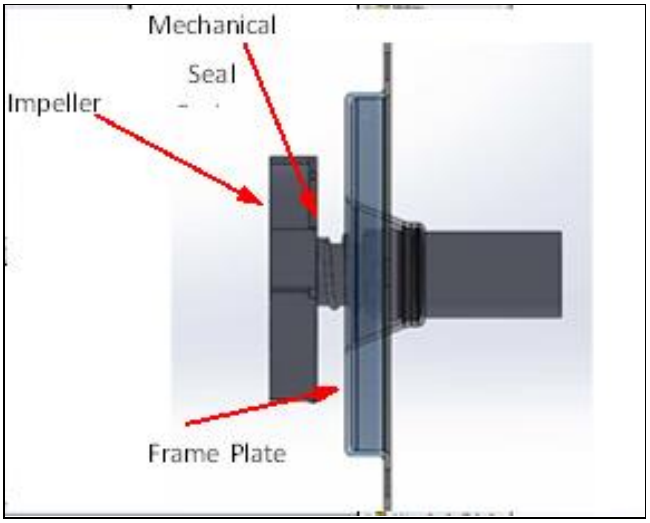

Figure 24: Installation of Mechanical Spring Assembly.

In Figure 24, can observe the spring has contact with product when running. This causes the spring to seize when product harden.

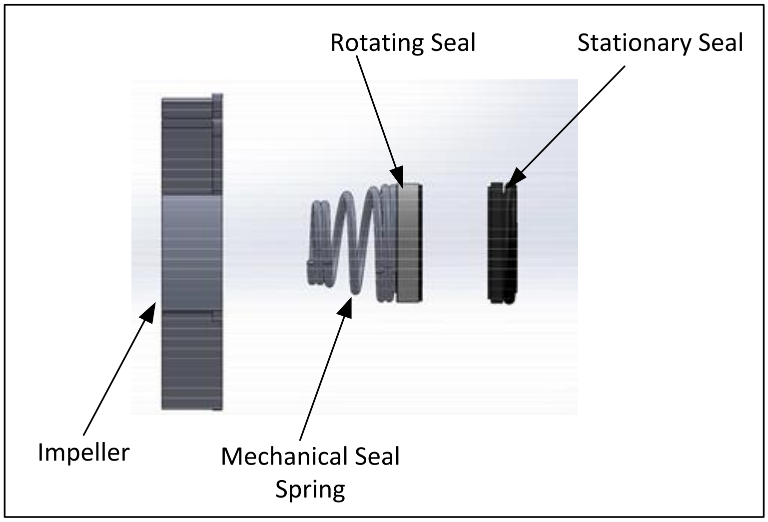

Figure 25: Existing Mechanical Seal Design

5.1 Design 1.

The new mechanical seal design as below, which has an enclosed compartment for the spring

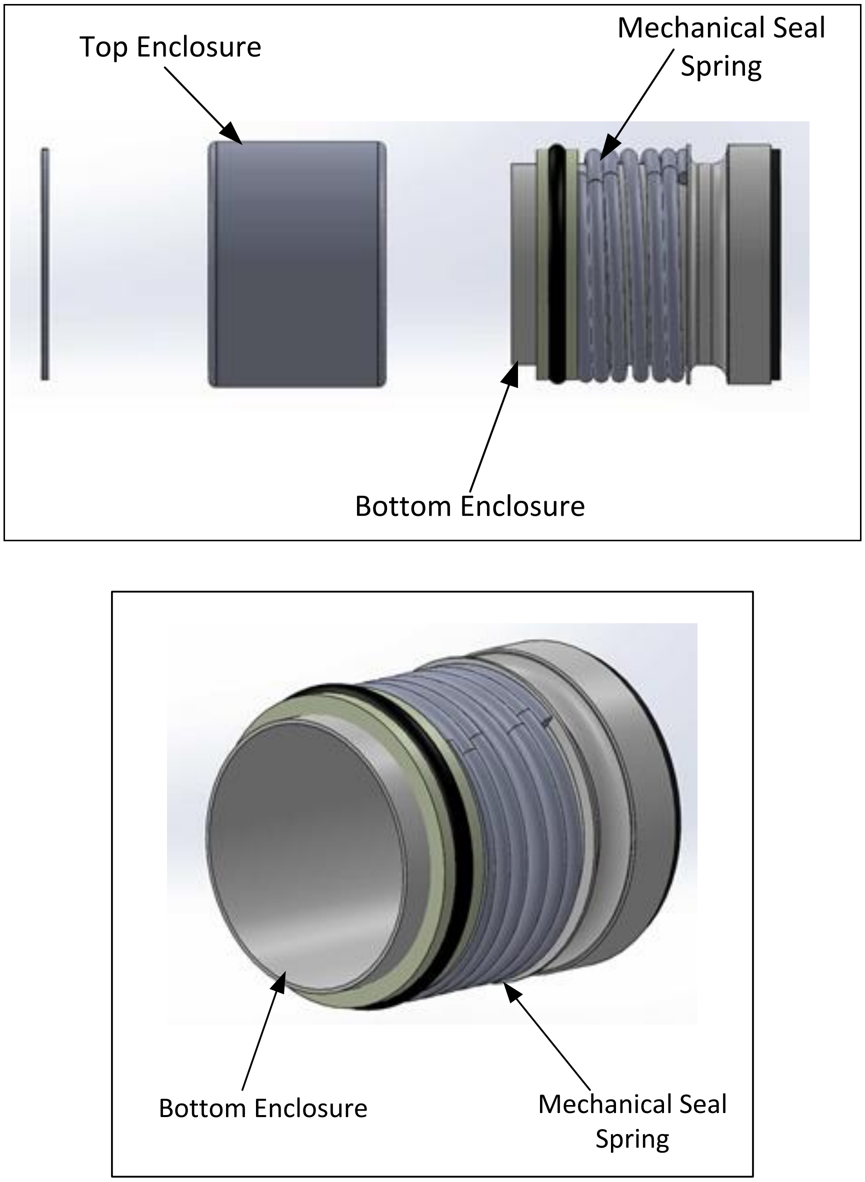

Figure 26: Enclosed Spring Design

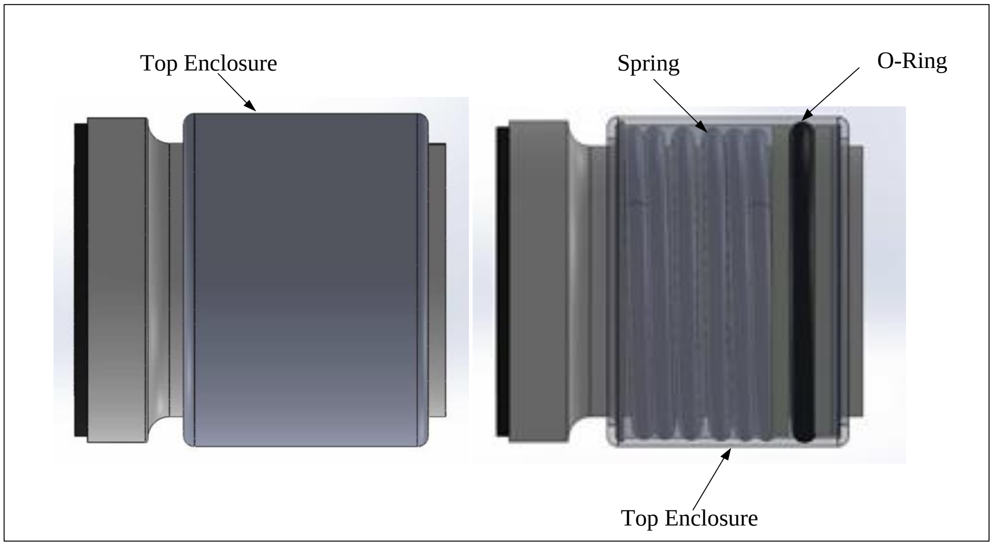

Figure 27: Assembly of Enclosed Spring

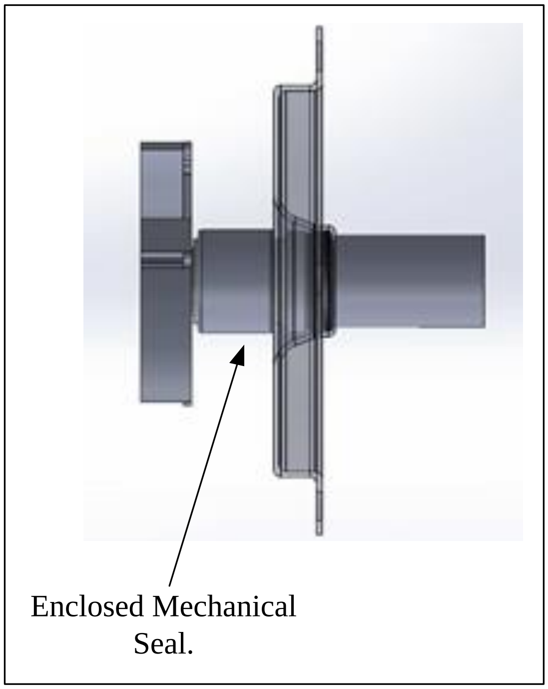

Figure 28: Installation of Mechanical Seal in Pump

This design covers the bottom of the spring using the same casing of the ceramic seal, but to cover the spring using the Top Enclosure restricts the spring from free movement. In initial installation the pump would not leak but we forecast after a few months of pump running the ceramic seal would wear off, spring would not be able to push the rotating ceramic to the stationary seal.

5.2 Design 2

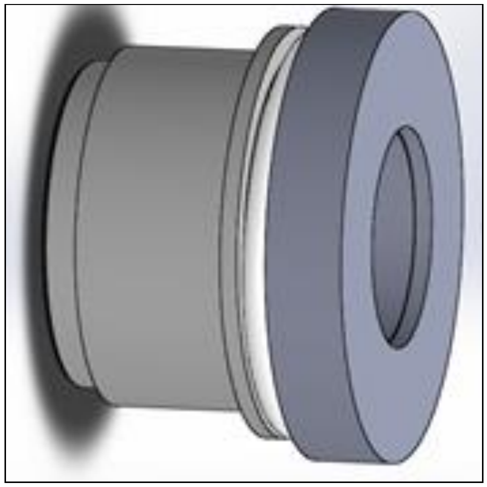

Figure29: Complete assembly of the mechanical seal

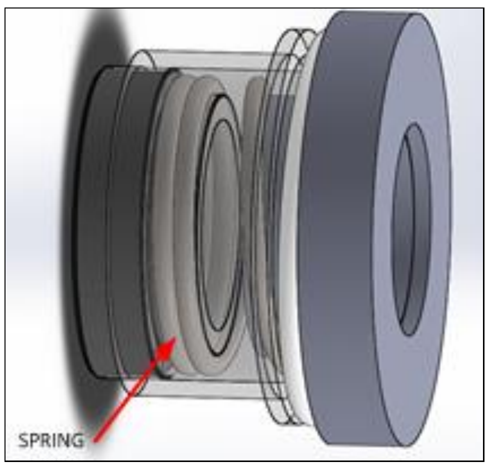

Figure30: Spring inside the Seal Enclosure

Similar with the Design 1, Design 2 has two main components sealing the spring, a housing which spring is placed in and the top enclosure provides external sealing. Both of these components provide a shell for the spring to be placed inside. Design 2 is more flexible in providing a better seal and easy to install components inside the seal housing. My prototype would be based on Design 2.

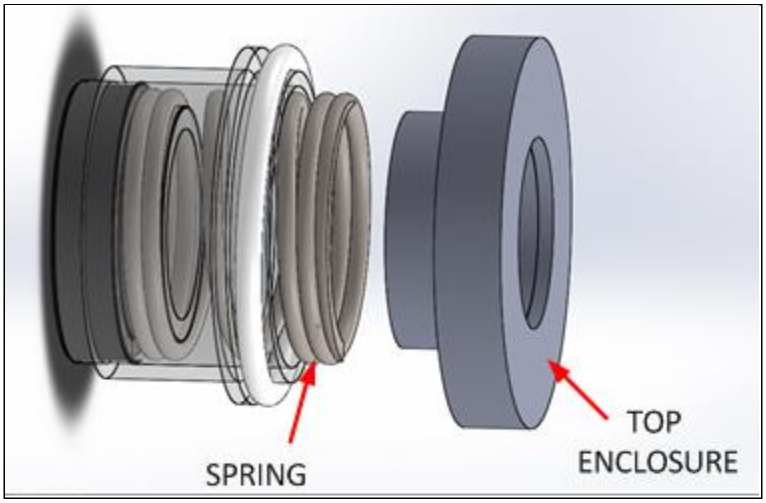

Figure 31: Top enclosure separated from the mechanical seal assembly

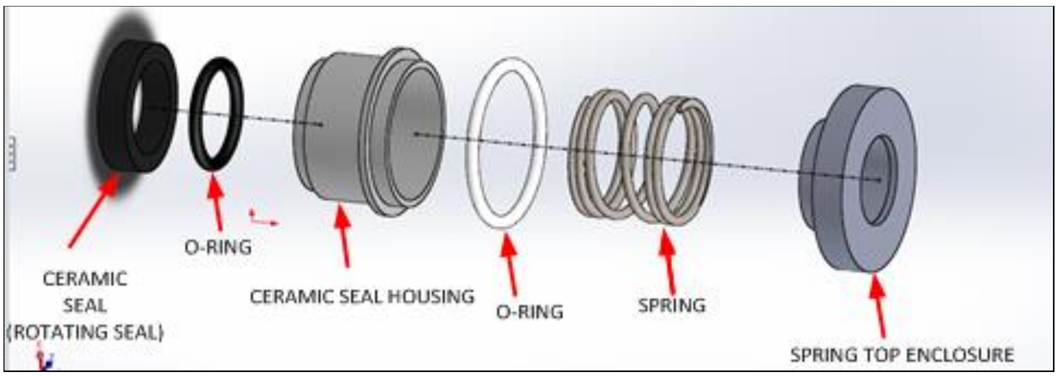

Figure 32: Exploded view of the mechanical seal assembly

Figure above demonstrates the breakdown of the mechanical seal assembly. The O-ring between the ceramic seal and housing, seals the oil from coming through the ceramic seal. The white O-ring in figure above seals the oil from coming through the Spring Top Enclosure into the spring chamber.

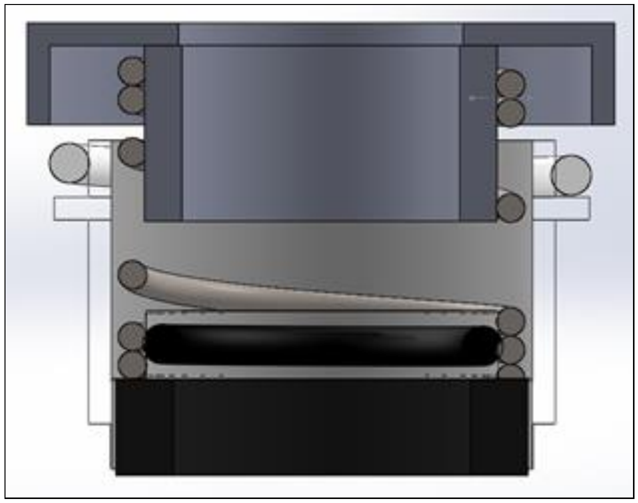

Figure 33: Sectional view of mechanical seal assembly

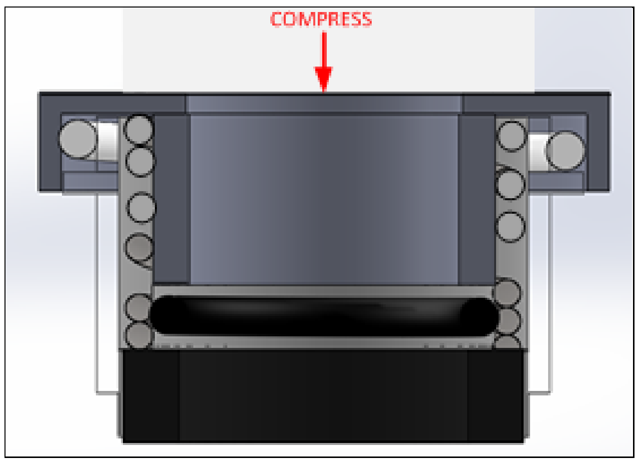

Figure 34: Sectional view of mechanical seal assembly when compressed by impeller

5.3 Spring Calculation

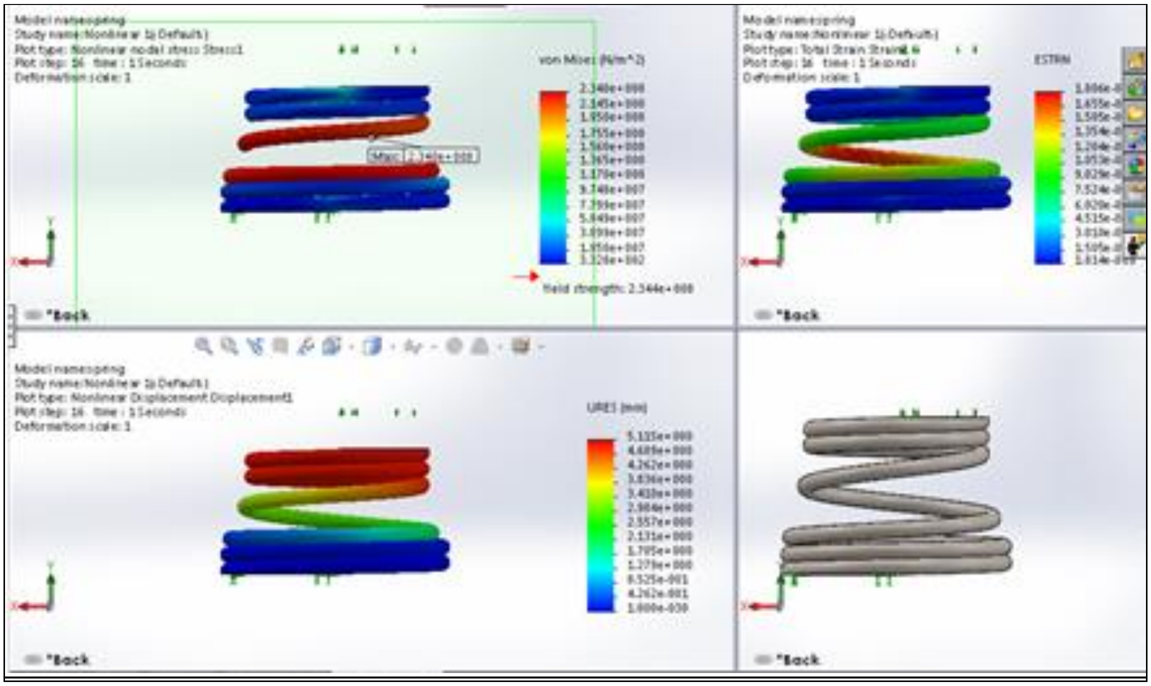

Figure 35:Stimulation result of Inoxpa Original tapered.

Stress stimulation when tapered spring is compressed, purpose of this stimulation is to compare the stresses in the tapered spring (manufactures spring) and the straight spring which we will be using for our prototype. Both of stimulated spring are Stainless Steel 304. Total displacement required for both of the spring to compress the ceramic seal together is 5mm. At a displacement/compression of 5mm the maximum stress is $2\times 10Nm^2$.

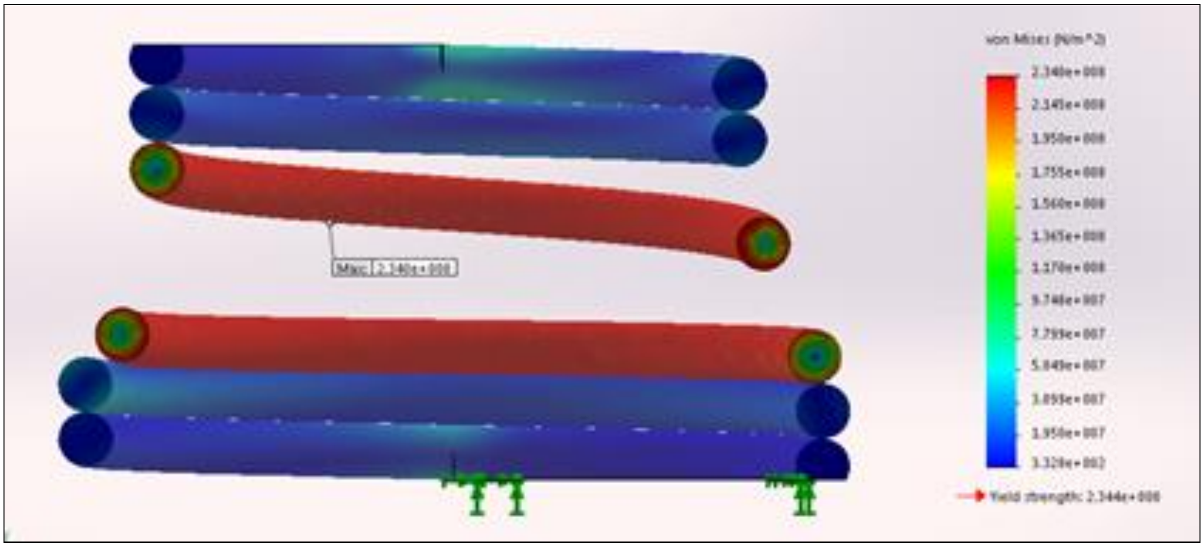

Figure 36: Cross section of the tapered spring internal stress

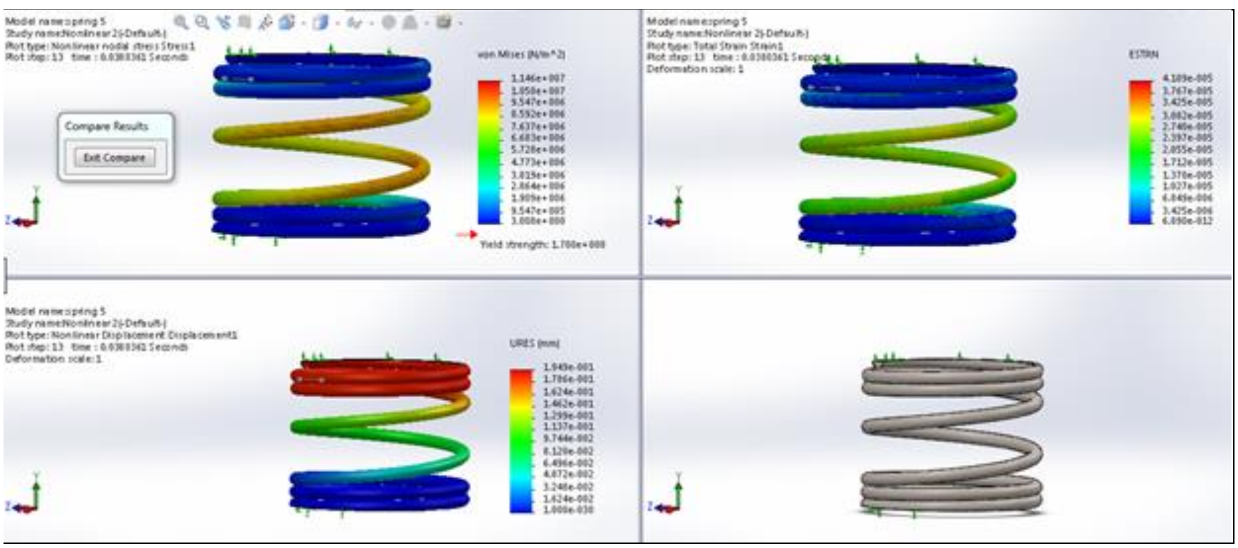

Figure 37: Stimulation Result on spring for Prototype Mechanical Seal

Maximum stress acting to the prototype spring when deformed is $1.14\times10^{8}Nm^{2}$ which is lower than the original tapered spring.

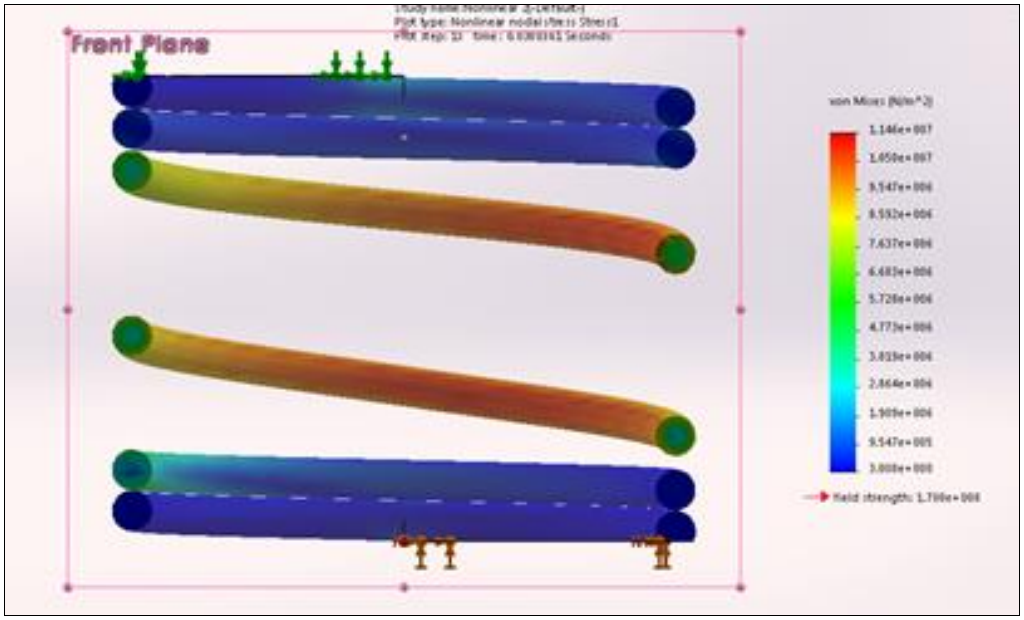

Figure 38: Cross section of the straight spring internal stress

The spring did not buckle during the stimulation process; straight spring design can be used for the prototype mechanical seal Design 2. If the forces of the spring is not even distributed or high force acting to ceramic face, it would cause loading on the pump motor overheating it and cause the coil to burnt out. One method of testing the spring tension would be rotating it by hand and feel the resistance. It should be free with less force used to turn the impeller.

5.4 Performance Monitoring.

Table1: Pump Condition Monitoring Checklist.

MEASURING PARAMETER	READING
Pump Motor Current Reading (Amp)	
Motor Temperature Reading (degC)	
Pump Discharge Pressure Reading (PG 1)	
Measurement of seal face thickness	
Vibration of pump	

After installing the pump with prototype mechanical seal in the production line, running parameter for condition above are observed. 2 sets of parameters has to be monitored, the reading of pump with original mechanical seal and reading with modified mechanical seal. Both of these different parameters are to be compared and one can evaluate the performance of the new mechanical seal.

If the reading of motor current is higher than 50% from the original installation it would be an abnormal condition for the pump motor. Motor temperature should not be higher than 50degC; this would indicate if there is any part of new mechanical seal is rubbing with the surface of the pump housing.

Pump discharge pressure indicates the functionality of the pump, whether it's working according to design performance. Pump pressure should be in the range of 1.7bar to 2.5bar for this application.

In the period of 150 hours of testing the new mechanical seal, the ceramic face should not lose more than 1mm of face thickness. This would indicate the pump is running under abnormal condition, where the wear and tear to the ceramic seal is high.

There would be two set of testing for the new mechanical seal, normal operating condition where the discharge valve of the pump is fully open and the other set of testing would be by throttling the discharge valve till it is fully closed and performance reading is collected as in Table 1.

CHAPTER 6

RESULTS AND DISCUSSION.

6.1 Installation of Mechanical Seal Prototype.

Figure 39: Steps in installing Mechanical Seal Prototype

6.2 Introduction

To test the new design of prototype mechanical seal, it requires running the pump with palm oil product in a condition stimulated as in our actual production.

I have presented the benefits and design of using encloses mechanical seal to production department and Packaging Production Head, Mr Azam for approval for this testing.

From Production Planning Schedule there is a change of product at 14 April, 2 pm at Packing Plant 3.

Currently there are 15 units of similar Inoxpa pump (EFI-2222) used in Intercontinental Specialty Fats Sdn.Bhd, 7 units in Packaging Plant and 3 units in Semi Continuous Deodorization Plant and 5 units at the Dry Fractionation Plant. All of these pumps are used for oil transfer at temperature around 50°C to 60°C, and the oil product of this plant would solidify at temperature of 40° C.

The usage of these pumps is not continuous and it's intermediate for batch processing. Purpose of this design is to eliminate the wastage of oil during the stop and start of the oil transfer for this plant.

During my presentation with the production team, I have showed them the estimate cost of losses for our production.

Measured oil during (pump stop-start) losses/day = 20kg

Cost of oil per tonne = RM 3225.00 (Not including profit only cost of process)

Cost of oil loss/day = RM 64.50

Cost of oil loss/year = RM 23 220.00

Average for 15 units of pump, losses of oil due to initial startup due to change of product

= RM 348 300.00.

6.3 Installation Setup

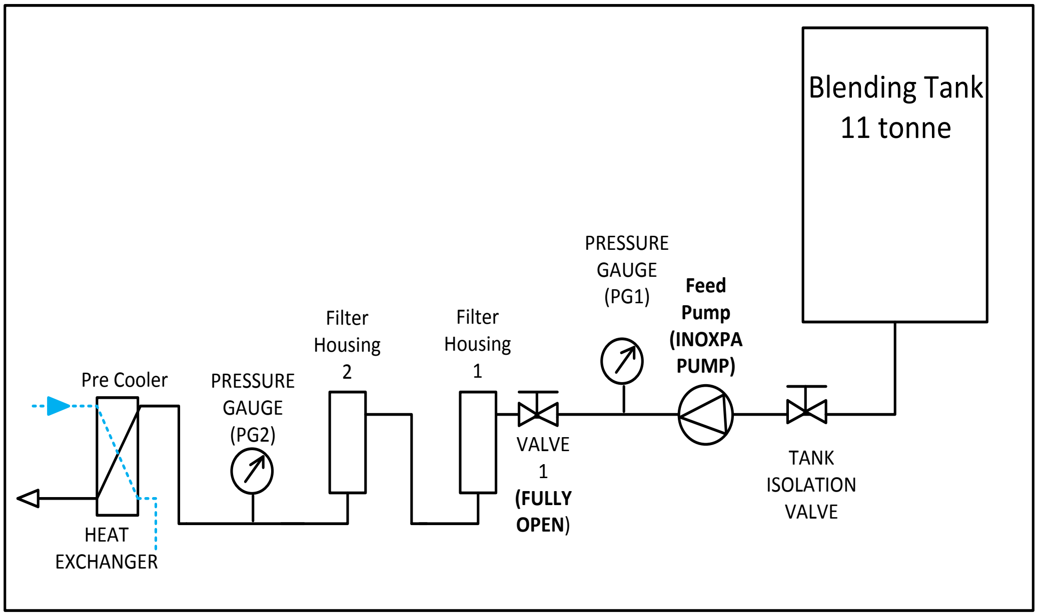

Figure 40: Feed pump installation with prototype mechanical seal

For the Packing Plant 3, the Inoxpa pump is used as a feed pump for the process. For pump performance monitoring the production has a pressure gauge after the feed pump, which the pump pressure is monitored in the range of 1.8-2.0bar this gives out a flow rate of 4m3/hr-5.2m3/hr.

Purpose of the feed pump is to transfer the production oil from Blending Tank to the Processing Equipment for Crystalizing the oil or cooling process.

During normal production Tank Isolation Valve and Valve 1 are open, and then production would start up the Feed Pump. Both of these valves has to be open before starting up the pump if Tank Isolation Valve is close, the pump would dry run and cause mechanical seal to damage if repeat continuously and if Valve 1 is close when pump is running can cause high pressure at pump discharge side.

6.4 Normal operation conditions with original manufactures mechanical seal

Table 2: Pump Operating Data taken with original Mechanical Seal

MEASURING PARAMETER	READING
Pump Motor Current Reading (Amp)	1.9amp
Motor Temperature Reading (degC)	45 degC
Pump Discharge Pressure Reading (PG 1)	2bar
Measurement of seal face thickness	9.5mm
Vibration of pump	0.3mm/s.

Figure 41: Mechanical Seal Spring with Solidify Fats

For this model of Inoxpa Pump EFI-2222, the motor is 2.2Kw the maximum current 5 amp.

If motor current is at 80% of the maximum current around 4 amp it would cause the motor to overheat and burnt out.

By taking the temperature reading and motor current we could determine the load or resistance acting on the motor. If the load for this 5kW motor is high the motor would be extremely hot around 80-100°C and motor current reading at the range of 4-5amp. At this condition the motor winding would over heat and short circuit. Making the motor unusable

At normal production mode when Valve 1 is open, the discharge pressure would be at 2 bar if at certain conditions such as by mistake if operator left the valve closed the discharge pressure can build up to 4 bar. This would be the maximum pressure the mechanical seal would be put under at this condition and have to be able to stand without failing.

A new mechanical seal would have a thickness of 9.5mm if wrong installation the thickness of this seal would reduce in matter of hours and fail.

Table 3: ISO Standard Recommendation for General Machinery

Recommended for General Machinery Turning from 600 to 12000 RPM
(Based on ISO IS 2372)

<table>
<tr><th colspan="2">RMS Overall velocity Level Measured in 1000 Hz Bandwidth</th><th colspan="4">Vibration Severity Criteria</th></tr>
<tr><th>Mm/s</th><th>In/s</th><th>Class I</th><th>Class II</th><th>Class III</th><th>Class IV</th></tr>
<tr><td>0.28</td><td>0.01</td><td rowspan="3">Good</td><td rowspan="4">Good</td><td rowspan="5">Good</td><td rowspan="6">Good</td></tr>
<tr><td>0.45</td><td>0.02</td></tr>
<tr><td>0.71</td><td>0.03</td></tr>
<tr><td>1.12</td><td>0.04</td><td rowspan="2">Satisfactory</td></tr>
<tr><td>1.8</td><td>0.07</td><td rowspan="2">Satisfactory</td></tr>
<tr><td>2.8</td><td>0.11</td><td rowspan="2">Unsatisfactory</td><td rowspan="2">Satisfactory</td></tr>
<tr><td>4.5</td><td>0.18</td><td rowspan="2">Unsatisfactory</td><td rowspan="2">Satisfactory</td></tr>
<tr><td>7.1</td><td>0.28</td><td rowspan="5">Unacceptable</td><td rowspan="2">Unsatisfactory</td></tr>
<tr><td>11.2</td><td>0.44</td><td rowspan="4">Unacceptable</td><td rowspan="2">Unsatisfactory</td></tr>
<tr><td>18</td><td>0.71</td><td rowspan="3">Unacceptable</td></tr>
<tr><td>28</td><td>1.10</td><td rowspan="2">Unacceptable</td></tr>
<tr><td>45</td><td>1.77</td></tr>
</table>

Class I. Small-sized machines (powered from 0 to 15 KW)
Class II. Medium-sized machines (powered from 15 to 75 KW)
Class III. Large-sized machines (powered > 75 KW) mounted on "Rigid Support" structures and foundations
Class IV. Large-sized machines (powered >75 KW) mounted on "Flexible Support" structures

At normal operating the pump would only vibrate at a maximum of 1.8mm/s any vibration above this value would indicate mechanical failure in the pump. With the original mechanical seal the pump vibrates at 0.3mm/s which is under Class 1 (2.2Kw) equipment.

6.5 Operating conditions with prototype mechanical seal at normal process condition

Table 4: Pump Operating Data taken with Prototype Mechanical Seal

Pump Motor Current Reading (Amp)	Immediate after installation	2.2amp
	1 hour after installation	2.0amp
	24 hours or running	2.0amp
	50 hours of running	2.0amp
	100 hours of running	2.0amp
Motor Temperature Reading (degC)	Immediate after installation	40.0degC
	1 hour after installation	46.5degC
	24 hours or running	46.5degC
	50 hours of running	46.5degC
	100 hours of running	46.5degC
Pump Discharge Pressure Reading (PG 1)	Immediate after installation	2bar
	1 hour after installation	2bar
	24 hours or running	2bar
	50 hours of running	2bar
	100 hours of running	2bar
Measurement of seal face wear surface after	50 hours or running	**9.49mm**
	100 hours of running	**9.49mm**
	150 hours of running	**9.49mm**
Vibration of pump	50 hours or running	**0.4mm/s**
	100 hours of running	**0.4mm/s**
	150 hours of running	**0.4mm/s**

Observation:-

a) Pump motor current.

This would be the most important parameter to be observed during the startup of the motor. It would indicate if the mechanical seal design is imposing higher load or resistance to the motor. Normal operating condition with original mechanical seal is 1.9amp; targeted current reading of the motor should not be more than 2.5amp. The targeted motor current at 2.5amp would ensure the motor having longer life span. In the beginning after starting up the pump we got 2.2amp, which was still acceptable and observed for 5 minutes the reading was stable at 2.2amp.
After 1 hour the current reading dropped to 2.0amp which was good.

Believe the starting current was slightly higher due to the new ceramic seal face after running for a period of time it came seasoned or smoother.

b) Motor Temperature Reading.

Motor Temperature is directly related to the motor current, when motor current increases the temperature of motor also increases. This parameter is also important to observe during the startup of the pump. If the prototype design has very high friction with the pump casing it would increase the motor temperature dramatically and melt the motor winding insulation causing the voltage of different phases to short circuit and this is considered motor has condemned.

Over startup temperature in the first 10 minutes are at 40° C, which indicated 2 reasons. The mechanical seal is not assemble is not rubbing with the pump casing which can cause the motor temperature to increase dramatically high up to 80-90°C.

The second reason the motor temperature is not high as the temperature of motor with original mechanical seal because the running hours of the motor with prototype mechanical seal is not as long as the original installation when temperature reading is taken.

c) Pump discharge pressure.

The normal discharge pressure for Inoxpa Pump Type EFI-2222 is at 2 bar. This parameter observes if there is external leaking at the mechanical seal. If the primary function of the mechanical seal has fail, it would cause the discharge pressure to drop and transfer oil will leak out vigorously from the pump. By visual observation there is no oil leaking from the pump during operation and pressure reading at PG 1 shows 2 bar up to 100hours of testing.

d) Measurement of seal faces thickness

Figure 42: Ceramic Seal Thickness Reading with a Caliper.

For this parameter reading, the pump was stopped during the product change over and dismantled. The ceramic face of mechanical seal is then removed from the assembly and measured. If there are high reduction of thickness >1mm before 3000 running hours, it indicates the transfer medium has high abrasive particles such as foreign contamination (sand, metal particles and etc.). Or the spring tension is too high causing very high friction on the seal face, this condition can also be observed by the motor current reading. There was a reduction of 0.01mm of the ceramic seal thickness at 50 hours of running and no reduction of thickness up to 150 hours of running hours.

e) Vibration of Pump

This parameter is an overall indication for the pump installation correctly done. If the pump shaft is bent or screws not properly tighten or mechanical seal not center aligned with the shaft, it would cause high unbalancing to the whole pump itself. Overall reading is at 0.4mm/s which is not over the limit of 1.8mm/s.

6.6 Operating conditions with prototype mechanical seal at unusual process condition

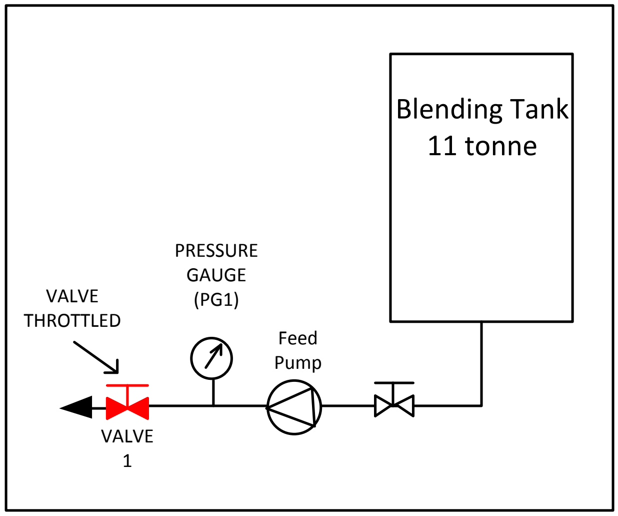

Figure 43: Pump with prototype mechanical seal tested with Valve 1 throttled

After testing the prototype mechanical seal for 150 running hours, performed unusual testing condition where the discharge valve is throttled in 4 steps till it is fully close. This type of running condition is highly not recommended by pump manufacturer as it can cause strain to mechanical seal and damage motor pump. It can also cause cavitation and damage the pump impeller if run at longer hours.

But under production, there are times operators might accidently run the pump under this unusual condition. In order not to damage the motor or mechanical seal, test period done in a short period of 10 minutes at 30 min interval between different percentage of valve closing.

Table 5: Pump Operating Data taken with Prototype Mechanical Seal

MEASURING PARAMETER	VALVE 1 25% CLOSED	VALVE 1 50% CLOSED	VALVE 1 75% CLOSED	VALVE 1 100% CLOSED
Pump Motor Current Reading (Amp)	1.8amp	1.5amp	1.2amp	3.0amp
Motor Temperature Reading (degC)	46.5degC	51degC	65degC	80.4degC
Pump Discharge Pressure Reading (PG 1)	2.4bar	3.0bar	3.8bar	4.5bar
Measurement of seal face thickness	**9.49mm**	**9.49mm**	**9.49mm**	**9.49mm**
Vibration of pump	**0.4mm/s**	**0.4mm/s**	**0.4mm/s**	**0.4mm/s**

The objective of this trial is to observe the prototype mechanical seal is able to function on extreme working conditions or fail at an unusual rate.

Observation:-

a) Pump Motor Current.

It is observed when throttle the valve to smaller opening up to 75% closed, the motor amp would reduce. This result is predicted because other pump motor current also reduces when discharge valve is throttled. By closing the discharge valve as long as there is flow would reduce the motor current but when fully closing causes the motor current raises abnormally. Motor would get overheated by long time.

b) Motor Temperature Reading.

By throttling the discharge valve it would cause the pump casing itself to be very hot. This is because the energy that doesn’t circulate process oil in the pump is retained in pump casing as heat and this heat is transferred to the motor, causing the motor to be warm or hot depending on the percentage of throttle.

This heat transferred to the motor if reaches 120°C and motor if operates in this condition for long period of time can melt the motor coil insulation and cause short circuit.

c) Pump Discharge Pressure.

Having the discharge pressure increased gradually to 4.5 bar would be the maximum pressure this pump would be operating. This test would stress the prototype mechanical seal to operating limits and there was no leakage from the mechanical seal.
At this pressure, it is not only the seal could fail but the o ring if the grove and seating is not properly placed.

6.7 Observation

The mechanical seal was able to function at this condition of higher pressure (unusual operating condition) without failing. After testing each condition by throttling the valve, for 10 minutes the pump is then observe for next 30 min for any failure at normal running condition. Result from this test is the seal is working as good as the original mechanical seal and during the plant/pump stoppage and start up there was no product oil leaking from the mechanical seal due to temporary spring failure in the mechanical seal.

CHAPTER 7

CONCLUSION AND RECOMMENDATION.

7.1 Cost of Product Lost due to Mechanical Spring Failure

Table 6: Process Manufacturing Cost and Raw Material.

ITEM	COST
1) CPO Raw Material Cost.	RM 2 400/tonne
2) Refining Process Cost	RM 320/tonne
3) Dry Fractionation Process Cost	RM 150/tonne
4) SCD Process Cost	RM 320/tonne
Total Raw Material Cost	**RM 3 190.00/tonne =RM 3.19/kg**

CPO is the Crude Palm Oil, the current market price is RM 2400/tonne and CPO is feed into the Refinery for the refining process before passing down to the Dry Fractionation Process Plant and to SCD Process Plant for further processing. The cost for all the process going through these plants includes the man power cost, utility cost and maintenance cost. Table above summaries the total cost of processing the oil before going to the Packaging Plant.

The cost of manufacturing 1 kg of raw material for the Packaging Plant is RM 3.19/kg. If there are losses of oil in the Packaging Plant it would cost RM 3.19 for each 1 kg of oil. We have collected the oil losses during the pump stop-start and during the duration of process. Collected the oil by using a tray located under the pump, if the mechanical seal fails during the operation product oil will leak into this tray.

The oil collected in the tray is then measured in weight daily.

Average oil collected is 20kg per day.

1)Weight of Oil/day lost due to stop and start for 1 pump = 20kg/day

<u>Total losses by factory</u>

Cost oil lost per kg. RM 3 190.00/tonne = RM 3.19/kg

Total losses for 1 pump = RM 63.80/day

Total losses for 1 pump in a year = RM 22 330.00

Total losses for factory for 15 pumps = RM 334 950.00 in a year.

Figure 44: Cost of oil losses for a year due to mechanical seal leaking during start up.

Calculated losses of oil in a year totals up to RM 334 950.00. Out of these losses 20% can be recovered in the Effluent Plant by removing the moisture content and filtering the oil. It would then be downgraded to CPO at Refinery. By reducing or eliminating the oil losses when spring fails the company would be able to save this money an estimate of RM 267 960 of product oil.

7.2 Cost of fabricating prototype mechanical seal

The cost of an original mechanical seal = RM 680.00

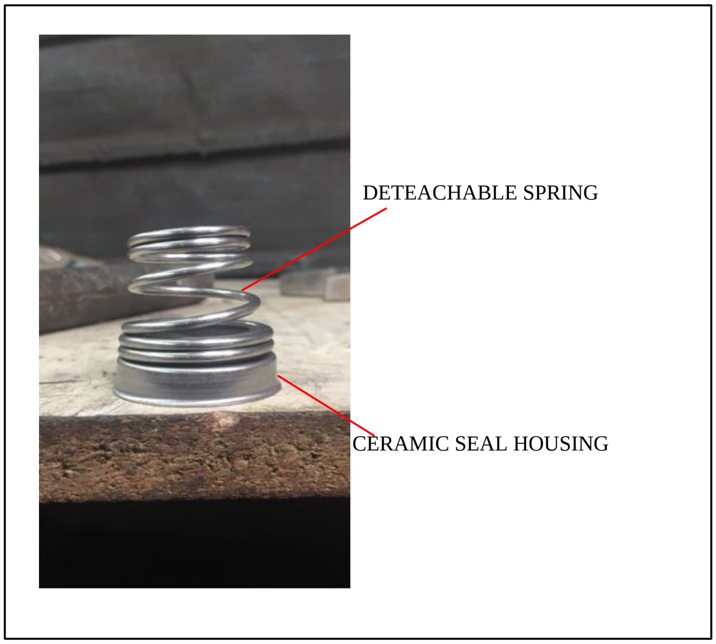

Figure 44: Original Mechanical Spring Assembly

The original Inoxpa Pump Mechanical seal is sold as 1 set as spare part or consumable item for maintenance purpose. This set includes 2 unit of O-ring, conical spring, stainless steel housing for the ceramic seal and the ceramic seal itself. Figure above is the complete set of mechanical seal.

The cost of prototype mechanical seal for 1 unit = RM 1450.00

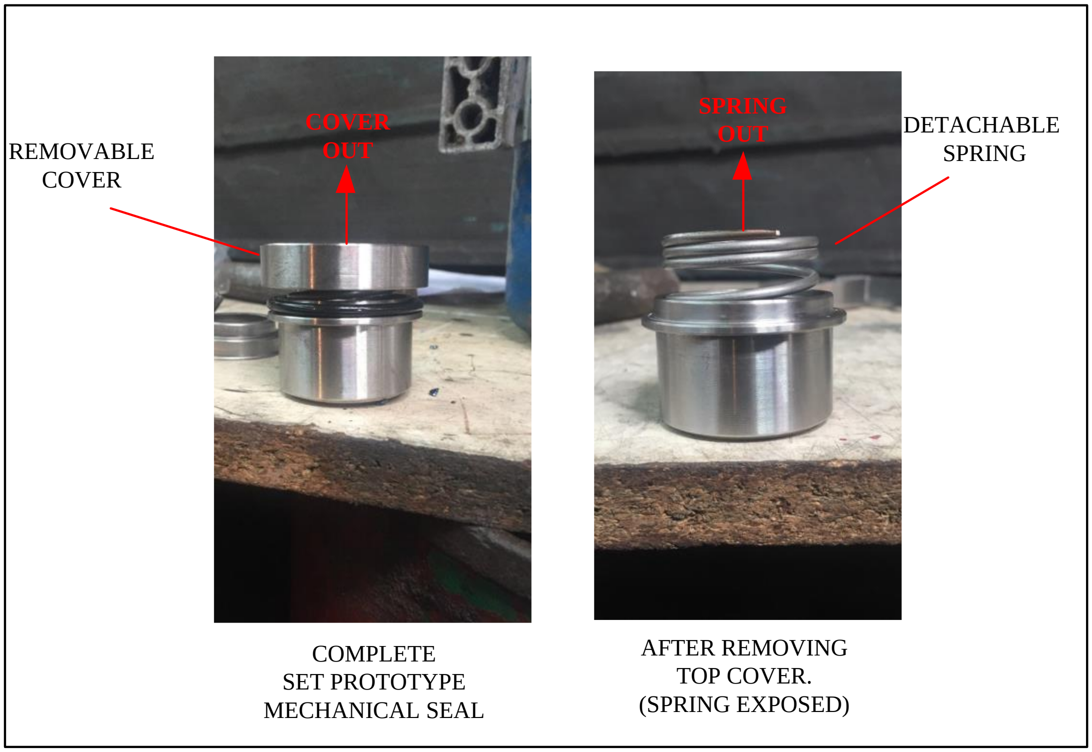

Figure 45: Prototype of Mechanical Spring Assembly

For this design, the fabrication cost is RM 1450.00, if pump facing mechanical seal failure due to damage O-ring, spring or ceramic seal the maintenance person does not need to replace the whole assembly but can replace the failing components such as the ceramic seal, which is detachable from the seal housing, O-rings and spring.

This 3 set of item can sold as a repair kit for this mechanical seal assembly.
The repair kit cost for this prototype is RM 450.00.

The cost of spring is RM 250.00 from the RM 450.00 of the repair kit cost. The fabricator informed me he would be able to reduce the price for the spring to RM 180.00 if the quantity of order is 20pcs. 3 units of O-ring which was purchased from the hardware for this prototype cost RM 2.00. There was a RM 198.00 of mark up by the fabricator for profit. This cost can be reduced if the prototype was mass manufactured by a local manufacturer.

Estimate cost of repair kit with a minimum order of 20 set would be at RM 182.00 not including profit compare to original mechanical seal price per unit is at RM 680.00. This design offers a cheaper spare part cost.

7.3 Summary of objective achieved:

1) Mechanical Seal did not seize during start up and operation due to contact with product. No leakages at shaft.

2) Ease in fabrication and material machining. Targeted fabrication cost was below RM 3000.00 and manage to create prototype at RM 1450.00

3) Came up with a straight spring design for easy assembly and simple spring casing design which was reflected on the fabrication cost.

4) Performed stimulation on conical spring and compared with straight spring design, maximum force for tapered spring is $2 \times 10 Nm^2$ and straight spring is $1.14 \times 10^8 Nm^2$ which gives less stress on the rotating ceramic seal.

5) Have test pump with new mechanical seal for 150 hours of normal working condition and 50 hours of abnormal working condition. Total 200 hours in testing for this prototype. Pump able to achieve 2 bar discharge pressure when discharge valve is fully open.

6)New design should has eliminate product leaking issue during intermediate stoppage of pump and during production change over period as no oil was leaking through the mechanical seal during startups.

7.4 Other Application of New Design Mechanical Seal

Other than solving the problem of harden fats failing the mechanical seal of this pump. The enclosed seal can be used in other pharmaceutical and food industry.

Pharmaceutical Process

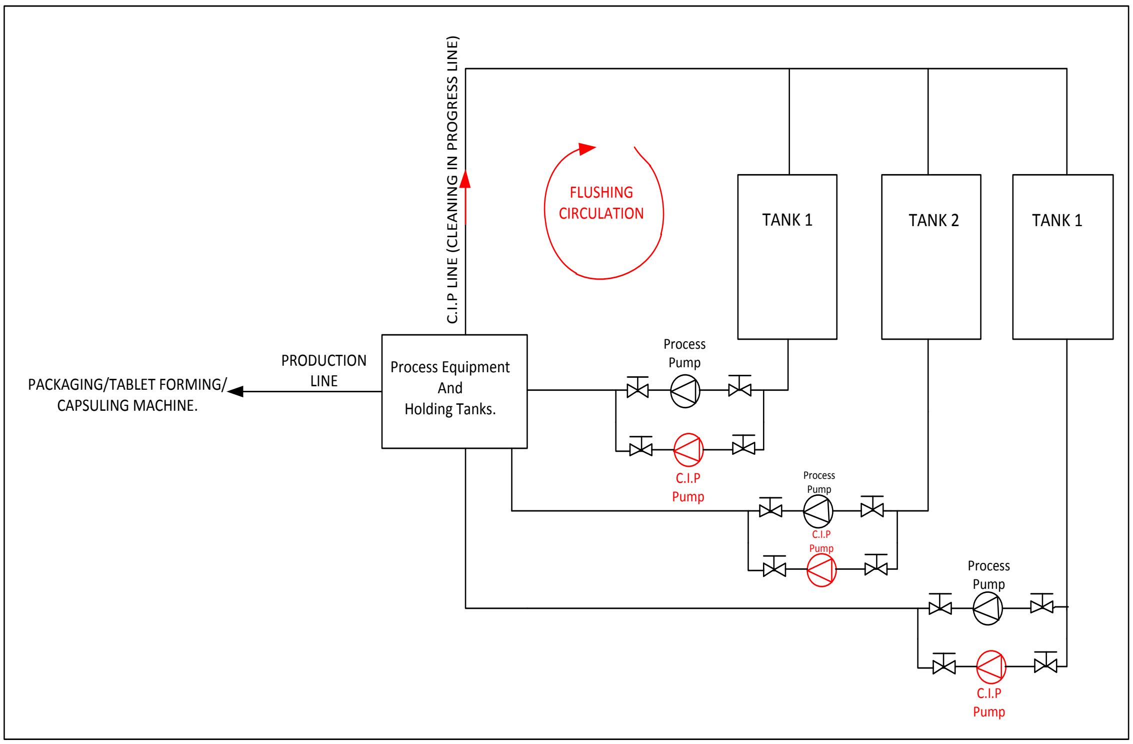

Figure 46: Processing and CIP Line in a Pharmaceutical Processing Line

For the pharmaceutical line the C.I.P process can be shorten by eliminating the process of uninstalling their process pump to perform cleaning. Usually for this process, the method of cleaning their production line is by flushing continuously similar in the food industry where their cleaning fluid would circulate into the tank and production equipment.

Big capacity pumps will be malfunction when residual get caught in the mechanical spring which can't be cleared by flushing. The operations would actually dismantle the pump for soaking and cleaning, using hot water or caustic. When dismantling the process plant the C.I.P Pump would be used for circulating the cleaning fluid.

By having a covered mechanical seal, there would be no contamination after CIP process is completed. Process design would not need to install a CIP pump for cleaning process and the cleaning fluid can pump using the process pump for cleaning.

7.5 Conclusion

New design mechanical seal has proved its concept, preventing product leaking due to spring failure cause by seizing of fats. For batching plant in palm oil it is commonly used for crystalizing the oil by cooling. Even we have find major problem of oil leaking during the stop and start of pump, when production face problem at the filling process the product oil will circulate in processing plant where cooling is still "ON" causing formation of fats in the oil. These fats by time would seize the spring causing minor leak at the mechanical seal. Eliminating the contact of process oil with the spring has solved this problem.

As for the cost of manufacturing the mechanical seal cost of fabrication is RM 1,450.00. This cost represent the prototype cost but if mass produced by a manufacture, cost of material and process can be reduce to match the existing mechanical seal cost.

Since this Inoxpa Centrifugal Stainless Steel pump is commonly used for palm oil production in many refineries, oil packaging plant, pharmaceutical and food and beverage processing plant such as F&N and Pepsi. This product has potential in saving for plant design where C.I.P pump can be eliminated and on the maintenance cost due to low cost of spare part.

Supplier can offer the customer two types of spare part the whole mechanical seal or mechanical seal repair kit for the housing of the ceramic seal and spring if it is not damage by bent shaft due to other reasons.

REFERRENCES

1) Peter R.N Childs. (2014) Mechanical Design Handbook. Chapter 14 Seal.
2) GRAEME ADDIE & ANDERS SELLGREN. (2014).Pump Handbook. Application and Handling of Solid Centrifugal Pumps.
3) Sellgren, A., and Vappling, L. (1986). Effects of Highly Concentrated Slurries on the Performance of Centrifugal Pumps. Proc. International Symposium on Slurry Flows, FED Vol. 38, ASME, USA, pp. 143–148.
4) Micheal B Huber. (2013) Pump Handbook, Centrifugal Pump and Mechanical Seal. Chapter 5.
5) Summers-Smith, J. D. (1992) “Mechanical Seal Practice for Improved Performance.” The Institution of Mechanical Engineers, Suffolk, UK.
6) Philip Kiameh. (2003) Power Generation Handbook: Selection, Applications, Operation, and Maintenance. GAS TURBINE BEARINGS AND SEALS, Chapter (McGraw-Hill Professional), Access Engineering
7) Garlock Sealing Technology. (2010) Mechanical Seal Technical Manual. Chapter 1&2.
8) Waukesha & Cherry-Burrell. (2013) Votator II Scrapper Heat Exchanger. Instruction Manual. Chapter 1, 2, 3 & 4.
9) James B. Rishel: HVAC Pump Handbook, Second Edition. Physical Description of HVAC Pumps, Chapter (McGraw-Hill Professional, 2006 1996), Access Engineering
10) Pascual, M.R., et al. (2009). Flow and particle motion in scraped heat exchanger crystallizers. Chemical Engineering Science
11) Bob Flitney. (2004) Sealing Technology. Mechanical seal housing design – are there real benefits, and do we want them?
12) Joseph E. Shigley; Charles R. Mischke; Thomas Hunter Brown, Jr.: Standard Handbook of Machine Design, Third Edition. SEALS, Chapter (McGraw-Hill Professional, 2004 1996), Access Engineering
13) Grant (1996) Patent US 5485880 A. Blade system for a scraped surface heat exchanger.

14) Requerimento. (2004) Patent US 20040099405 A1. Scraper blade and method for scraped-surface heat exchanger.
15) L. I. Ezekoye and J.A. George,(1977)"Valve Packings that Don't Leak," Machine Design, pp. 142, 143.
16) "Trouble shooting Process Operations", 3rd Edition 1991, Norman P.Lieberman, PennWell Books
17) "Centrifugal pumps operation at off-design conditions", Chemical Processing April, May, June 1987, Igor J. Karassik
18) "Understanding NPSH for Pumps", Technical Publishing Co. 1975, Travis F. Glover
19) "Centrifugal Pumps for General Refinery Services", Refining Department, API Standard 610, 6th Edition, January 1981
20) "Controlling Centrifugal Pumps", Hydrocarbon Processing, July 1995, Walter Driedger
21) "Don't Run Centrifugal Pumps Off The Right Side of the Curve", Mike Sondalini
22) "Pump Handbook" , Third Edition , Igor j. Karassik , Joseph P.Messina Paul cooper Charles C.Heald