Online Purification of Contaminated Lubricant

By

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Dissertation submitted in partial fulfillment of
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(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
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January 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

LAU CHUNG TECK

ABSTRACT

The objective of this FYP is to develop improved model of the centrifugal separator for online purification of contaminated lubricant. The scope of study covers mathematical modeling and modeling of simulation using FLUENT software. The experimentation study is excluded from the scope of study. The mathematical model is developed to understand the mixture behavior. Then, possible improvement method in terms of purification rate and/or quality is tested out using FLUENT simulation software. After that, current lubricant purification methods are established and better separation system is studied. Validation of the results from the mathematical model and FLUENT software are done through journals. It is found that the velocity profile of the mixture of water and oil is du = 338467238.3 dy. The rotational speed of cones at 800 rpm produce better separation compared to rotational speed of cones at 1400 rpm. A new separation system is studied to boost purification rate and oil quality.

ACKNOWLEDGEMENT

It is a pleasure to thank those who made this project possible especially my supervisor, Ir. Idris, who is always there when I needed any advice regarding the project. The supervision and support that he gave truly help in the progression and smoothness of the project.

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Abbreviations and Nomenclatures

FYP I	Final Year Project 1
FYP II	Final Year Project II
2 – D	2 dimensional
3 – D	3 dimensional
F	Force (N)
μ	Dynamic viscosity (kg/m.s)
A	Area (m^2)
N	Rotational speed (rpm)
τ	Shear stress (pascal)

CHAPTER 1
INTRODUCTION

1.1 Background of Lubricant

A lubricant is a substance that is introduced between two moving surfaces to reduce friction between them. This will improve the efficiency and reduce wear. It is also used in distributing heat. A lubricant usually contains 90% base oil and less than 10 percent of additives. The uses of additives are reducing friction and wear, increase viscosity of oil, improve viscosity index, resistance to corrosion and oxidation, aging and contamination. Most lubricant face problem of aging and oxidation before expected life cycle. This will cause massive problem to the machine as the oxidation will produce sludge that is hard to filter out from the machine and causes instability performance of the machine.

1.2 Background of Centrifugal Separator

Centrifugal separator is used to separate two different particles with two different densities for example water and oil. The centrifugal separator is used in the petro-chemical industry to separate oil and water, oil and sludge, and others. There are two main categories of centrifugal separators – batch and continuous. The batch centrifuge processes the solid / liquid mixture in discrete batches whereas the continuous centrifuges operate on a continuous flow or feed.

The project covers online purification which is using continuous centrifuge. An example of a continuous centrifugal separator is shown in Figure 1.1 .

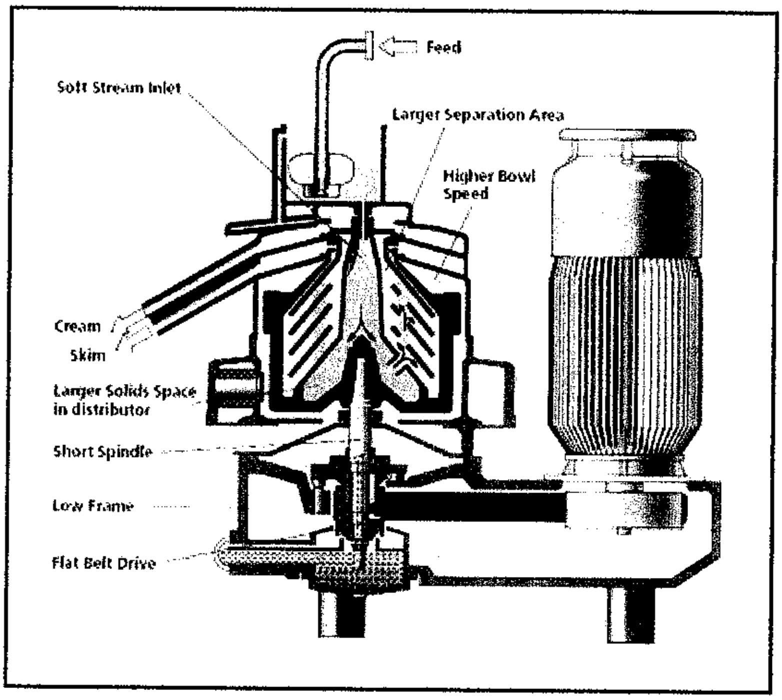


Figure 1.1: Continuous centrifugal separator [1]

The way the separator works is using the principle of centrifugal force. The fluid (orange colour) is continuously pumped from the feed to a high-speed disc-bowl separating centrifuge where subjected to high G forces (up to 7,500 times the force of gravity) the fluid typically separates into a heavy phase (water in yellow colour) and a light phase (oil in milky yellow colour). The two liquid phases separate and the liquids exit the centrifuge through separate liquid discharge connections. Any residual solids are separated and removed manually from manual clean units or discharged automatically with an automatic self-cleaning style unit.

1.3 Problem Statement

A fertilizer plant had high water content in one of the lubricant tank. Seal leak in the turbine has caused the steam to leak into the lubrication system that lead to high water content in the lubricant. The water is emulsified with the oil. Oxidation is accelerated causing formation of sludge. Sludge caused the control system of the turbine to "hunt" and act unstable. This causes reduction in production rate and downtime due to several trips.

In order to reduce the water content in the lubricant, they used industrial separator to extract the water and sludge from the oil. Contamination in the lubricant has to be purified online in order to ensure the longer and stable life cycle of the components in the machine. However the removal rate of water from the oil cannot keep up with the steam leakage rate.

1.4 Objective

The objectives of the project are:

1. Development of velocity profile of the fluid in centrifugal separator.
2. Development of simulation model of the centrifugal separator cones and suggest improvement in purification rate.
3. Study for better separation system.

1.5 Scope of Study

The scope of study covers from searching for relevant journals and information to find out the relevant parameters that influence the purification rate and / or quality of the lubricant for centrifugal separator. Disc bowl centrifugal separator is studied in detail. Improvement methods are suggested. Fabrication and testing of centrifugal separator is not included in the scope of this project. 2-D design of the centrifugal cones is used in the simulation.

Centrifugal separator type MAB103B – 20 is used in the fertilizer plant as shown in Figure 1.2 and Figure 1.3 .

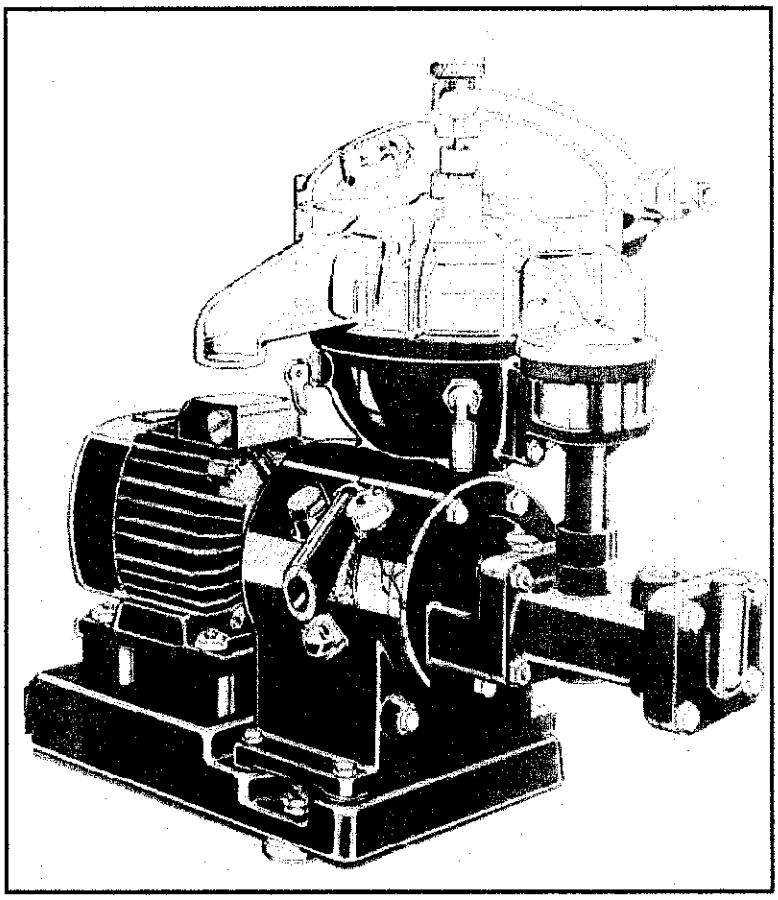


Figure 1.2: Centrifugal separator type MAB103B – 20

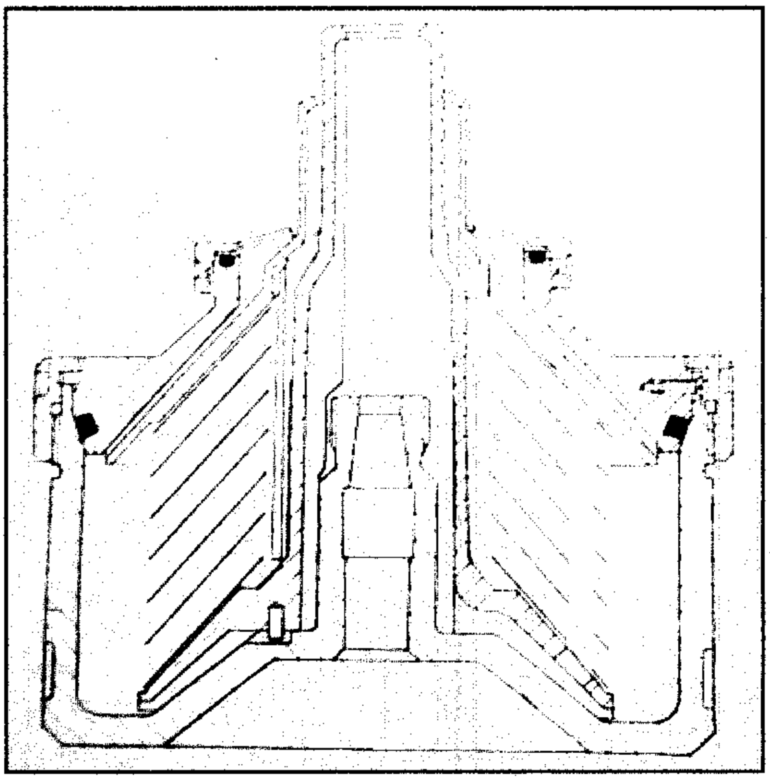


Figure 1.3: Casing and cone cross section

CHAPTER 2

LITERATURE REVIEW

In this chapter, some recent journals and books related to the project will be mentioned. The information gathered will help in finding relevant parameters that affect purification rate and quality of the lubricant.

The dimension of separator can be obtained in De Laval instruction book and also taken from the plant [2]. A journal written by Xiaojian and Xuehui [3] mentioned about 4 main faults of the centrifugal separator. They are rotating drum's unbalance, rolling bearing's fault, helical gear's fault, buffering spring's fault and centrifugal clutch's fault. These information are useful to find out the methods that can be adopted to improve the performance of the separator itself which will lead to its optimum performance.

A group of students from Northeastern University [4] has done a simulation of particle motion by using numerical integration of Runge-Kutta to determine the size, configuration, rotating speed and other parameters of centrifuge separator. They found some relations among the length of drum, particle diameter and the revolution of drum.

Another research [5] of a 2 - D computational fluid dynamics (CFD) model of flow through a tubular bowl centrifuge was developed with FLUENT software. A volume-of-fluid (VOF) approach was used for most of the simulations to track motion of the liquid and gas phases, because the location of the gas/liquid interface depends on the centrifuge operating conditions.

Dave Meikrantz, Charles Schardin, Lawrence Macaluso, Alfred Federici and H. William Sams [6] had successfully invented a separator with efficiencies of greater than 99% have been achieved over a wide range of oil viscosity and oil-water ratios. Operational equilibrium is rapid and is maintained during changes of oil-water ratios, flow rates, and flow interruptions. The separator appears unaffected by normal shipboard motion from waves.

X. Romaní Fernández and H. Nirschl from Universität Karlsruhe [7] has published a paper about the study that presents some initial results from the numerical simulation of the flow in a solid bowl centrifuge used for the particle separation in the industrial fluid processing. Fluent, Computational Fluid Dynamics (CFD) software was used to simulate this multiphase flow. Simplified two dimensional and three dimensional geometries were built and meshed from the real centrifuge geometry. The CFD results showed a boundary layer of axially fast moving fluid at the gas-liquid interface. Below this layer there was a thin recirculation. The obtained tangential velocity values are lower than the ones for the rigid-body motion. Also, the trajectories of solid particles were also evaluated. Figure 2.1 shows that the tangential velocity is linear to the radial position as calculated.

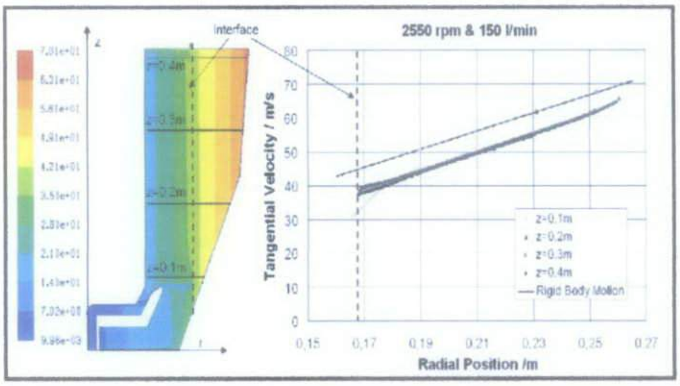


Figure 2.1: Tangential velocity of fluid in the centrifugal separator [7]

Figure 2.2 shows the distribution of the heavier particles at the bottom of the casing while lightest particles are forced to the top of the casing.

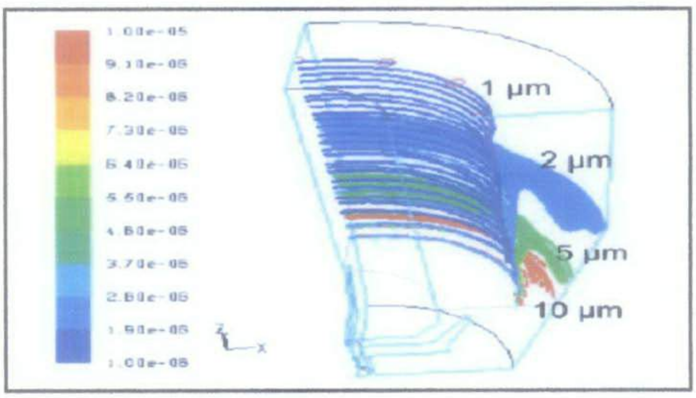


Figure 2.2: Particle trajectories in the casing [7]

Figure 2.3 shows clarification, purification and concentration processes. Clarification process is the separation of suspended particles from a liquid. Purification process separate heavy liquid from a main light liquid. While concentration process concentrate separate out mixture with more heavy liquid. Noticed that the angle of the con differs for different purposes. This shows that the angle of the con will affect the flow stream and the centrifugal force created.

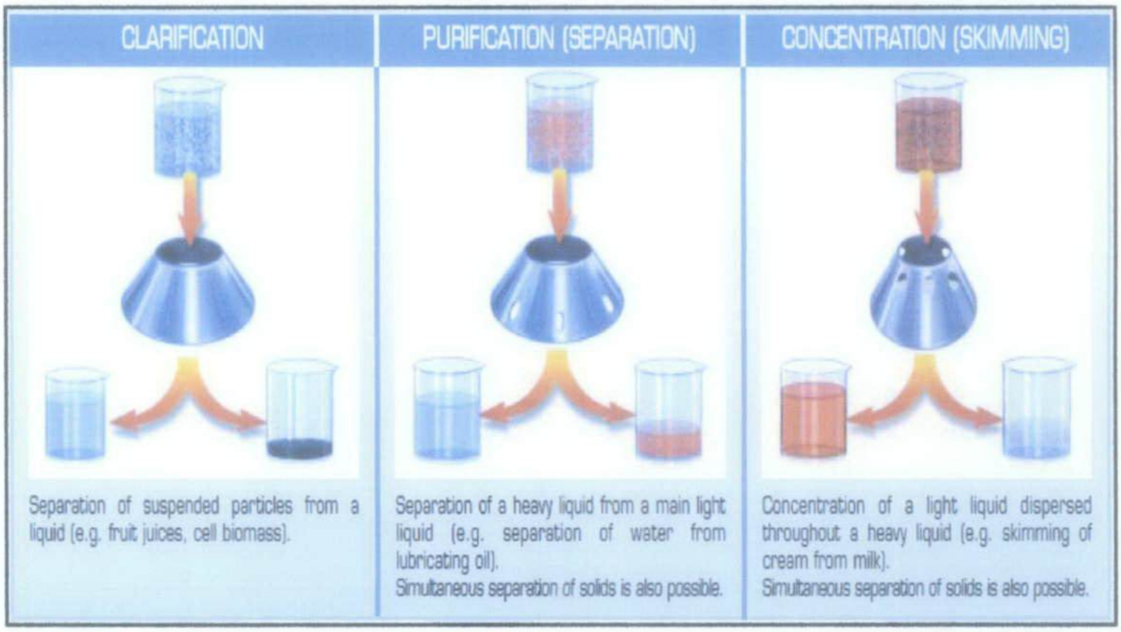


Figure 2.3: Clarification, purification and concentration [8]

Table 2.1 shows data of different separator bowl volume with 2 set up for different purposes. The separators with solid retaining bowl will retain solid particles in the bowl after separation. The waste has to be cleaned up manually therefore is suitable for mixture with little solid particle. The separator with automatic discharge will discharge out the solid particles automatically. This application is useful for separation of mixture with high solid particle percentage.

Table 2.1: Specification of separators with solid retaining bowl and automatic discharge[8]

	SEPARATORS WITH SOLIDS RETAINING BOWL				SEPARATORS WITH AUTOMATIC DISCHARGE			
Type	S200	S250	S300	S400	FPC 6	FPC 12	FPC 18	FPC 24
Bowl Volume (L)	5	11	25	40	9	14	24	38
Sludge Space Volume (L)	2	6	8	12	4	7	12	16
Bowl Speed (rpm), max.	7600	6400	6400	5800	7100	6500	6400	5800
Hydraulic Capacity (L/h)	5000	8000	30000	50000	8000	16000	30000	50000
Dimension L x W x H (m)	1,0 x 0,7 x 1,2	1,2 x 0,8 x 1,4	1,5 x 0,8 x 1,7	1,7 x 1,0 x 2,0	1,3 x 0,9 x 1,4	1,6 x 1,2 x 1,4	1,7 x 1,3 x 1,7	1,8 x 1,4 x 1,9
Weight (kg)	300	500	950	1600	1100	1400	2000	2600

CHAPTER 3
METHODOLOGY

3.1 Develop Mathematical Model of Fluid Velocity Field in Centrifugal Separator

A mathematical model of fluid velocity field in centrifugal separator is established using fluid mechanics fundamentals. The fluid running in the centrifugal separator is PETRONAS JENTERAM SYN XV 32 high performance turbines & turbo compressor lubricant. Detail of the lubricant oil is attached in the appendix.

Simplified model is being used to find out the velocity field. The rotating cone is assumed to be a long cylinder. Other assumptions are made in order to simplify the development of fluid velocity field model.

Assumptions :

Newtonian fluid, incompressible flow, negligible temperature variation, steady flow, 2 – D, line – vortex flow, earth gravity does not act on x or y direction, axisymmetric flow, flow always stays at 1400rpm.

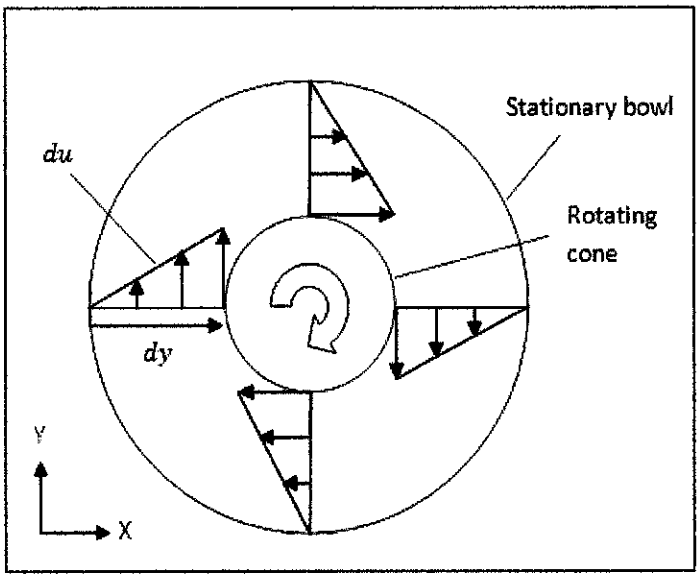


Figure 3.1: Description of centrifugal force of fluid as rotating cone spin at 1400rpm

Cross section area of the cone is used in order to study the velocity flow of the fluid inside the stationary bowl while rotating cone spins at 1400rpm. Figure 3.2 shows the dimension of the cross section of stationary bowl and rotating cone. Velocity flow of the fluid is also shown. The arrows of the velocity field is pointing to x axis (out of this page). Area A_1 represents the velocity profile of the whole fluid body across x axis.

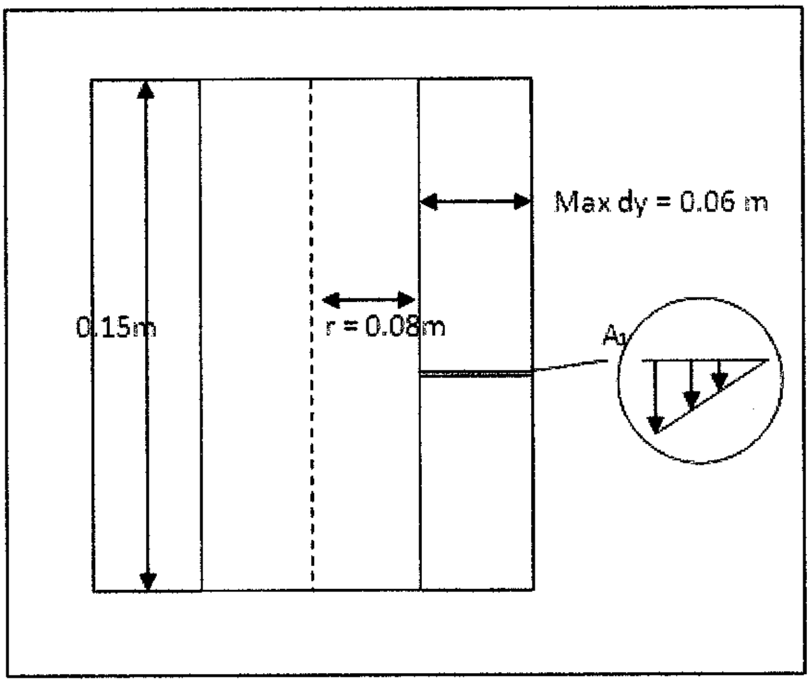


Figure 3.2: Cross section of stationary bowl and rotating cone

The velocity field of the fluid in the centrifugal separator is established based on the basis of shear stress where [9],

$$\text{Shear stress}, \tau = \frac{F}{A_1} = \mu \frac{du}{dy}$$

$$F = \mu A_1 \frac{du}{dy}$$

Where, F = force needed to turn cone at desired speed (1400rpm)

From the catalogue of centrifugal separator type MAB 103B - 20, motor power consumption = 0.75kW = 750W

Speed of the rotating cone, N = 1400rpm

Table 3.1 shows the data for water content, kinematic viscosity and dynamic viscosity. The data of the water content and kinematic viscosity is obtained from fertilizer plant. The lubricant density is obtained from the oil spec as attached at the appendix. The dynamic viscosity is a product of kinetic viscosity and lubricant density.

Table 3.1: Table of water content, kinematic viscosity and dynamic viscosity

Month	Water content (ppm)	Kinematic Viscosity, υ (cSt)	Kinematic Viscosity, υ (m^2/sec)	Dynamic Viscosity, μ (kg/m.s)
Jan	208	30.9	0.0000309	0.003147227
Feb	145	30.8	0.0000308	0.003137042
Mar	137	31.3	0.0000313	0.003187968
Apr	147	30.8	0.0000308	0.003137042
May	126	30.9	0.0000309	0.003147227
Jun	129	30.9	0.0000309	0.003147227
Jul	220	30.9	0.0000309	0.003147227
Aug	375	31	0.0000310	0.003157412
Sep	168	30.7	0.0000307	0.003126856
Oct	126	30.8	0.0000308	0.003137042
Nov	202	30.7	0.0000307	0.003126856
Dec	109	31.3	0.0000313	0.003187968
average		30.91666667	0.0000309	0.003148924

lubricant density = 101.852 kg/m^3

Motor power consumption = F x velocity

$$750W = F \times 1400\frac{rev}{min} \times \frac{1min}{60sec} \times \frac{0.502655m}{1rev}$$

F = 63.95N

Area A, = 0.001 m x 0.06 m

= 0.00006 m^2

From table 3.1, average dynamic viscosity, μ = 0.003148924 kg/m . s

Velocity profile is calculated out after replacing F, A and μ in equation

$$F = \mu A, \frac{du}{dy}$$

3.2 Analysis Method

The analysis is conducted numerically. The results gain from numerical analysis is validated with the journal.

3.2.1 Numerical Analysis

A CFD simulation is carried out using both GAMBIT and FLUENT software. The software is obtained and run through laptop. Simulations are done to prove the improvement in terms of the purification rate. The quality of the lubricant is proved theoretically.

GAMBIT (Design Software)

- A preprocessor for engineering analysis
- Easy to use interface with advanced geometry and meshing tools in a powerful, flexible, tightly integrated with any major CAD / CAE system.
- Used to specify and build the design of the centrifugal separator.

Figure 3.3 and Figure 3.4 shows the detail dimension of the cone in centrifugal separator.

Figure 3.3: Top view of one of the cone in the centrifugal separator

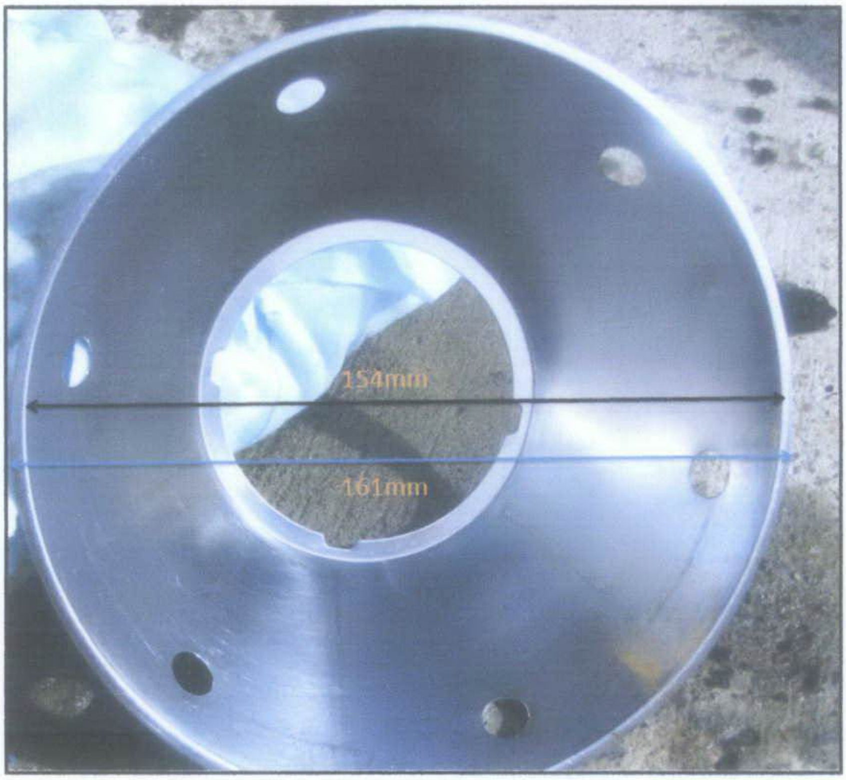


Figure 3.4: Back view of one of the cone in the centrifugal separator

Due to the complexity of design, 2-D design is chosen. Below are the steps taken from start till export of mesh:

1. Specify the vertex (points)
2. Join vertices to form edges
3. Complete the edges to form the design
4. Create face
5. Group the edges created into different groups
6. Specify the boundary types
7. Mesh one edge on double sides
8. Create sizing function by picking source as the
meshed edge and attach to face created
9. Create face mesh with interval size of 0.25
10. Export the mesh to FLUENT software and save the export

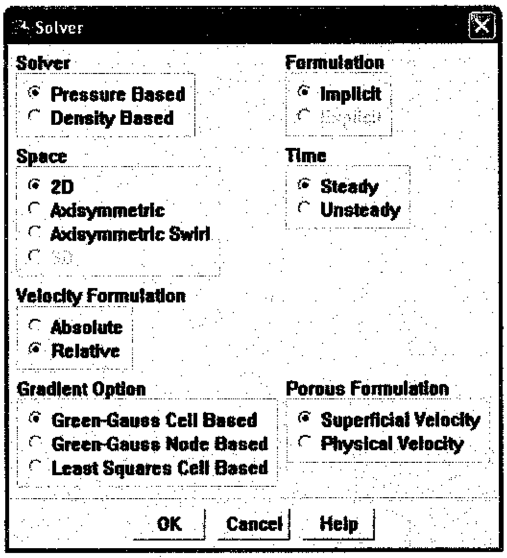
FLUENT (Modeling Software)

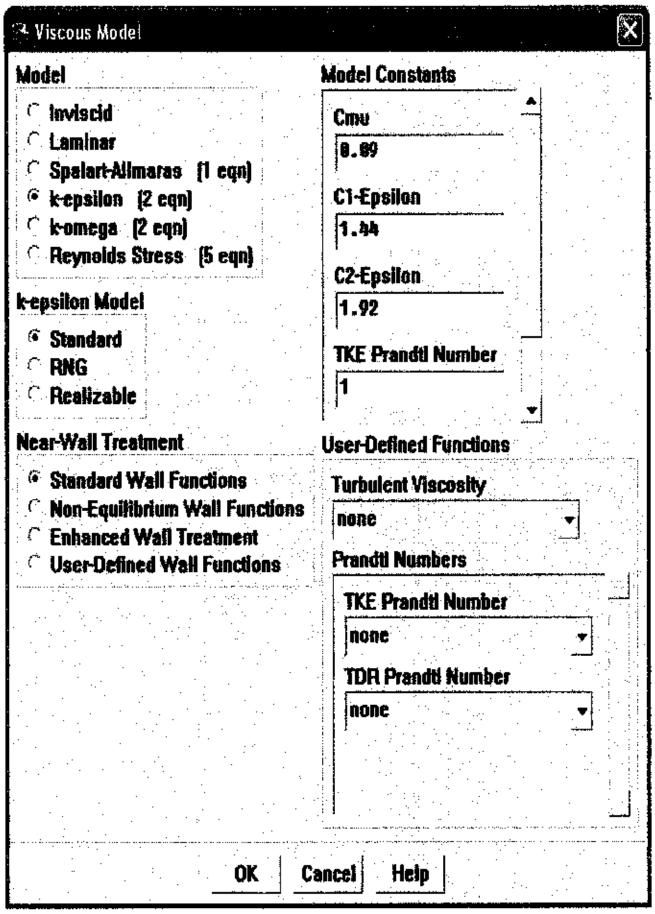
- Broad physical modeling capabilities needed to model flow, turbulence, and heat transfer.
- Advanced solver technology provides fast, accurate CFD results, flexible moving and deforming meshes, and superior parallel scalability

The exported design is being read at FLUENT software. Below are steps taken from start till display of results:

1. Run fluent using 2ddp version to gain best accuracy for 2-D design
2. Read data
3. Check grid

4. Define model





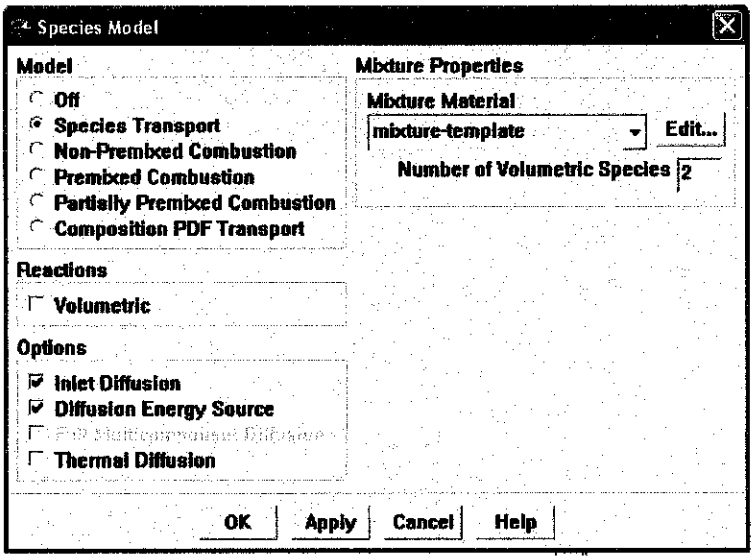


Figure 3.5: Fluent define model print screen

5. Define material
   - H2O(l) taken from fluent database
   - Oil is defined in user defined database:

     Density = 101.852 kg/m^3

     Cp = 1857.7 j/kg-k

     Thermal conductivity = 0.138 w/m-k

     Viscosity = 0.0036025 kg/m-s

     Molecular weight = 417.1143 kg/kgmol

   - Stainless steel is defined in user defined database:

     Density = 8060 kg/m^3

     Cp = 503 j/kg-k

     Thermal conductivity = 9.4 w/m-k

   - Mixture is defined as:

     Thermal conductivity = 0.1 w/m-k

     Viscosity = 0.003147 kg/m-s

     Mass diffusivity = 0.0000288 m^2/s

6. Define boundary condition
    - Mass_flow_inlet

      Mass flow rate = 0.000040278 kg/s

      Total temperature = 313k

      Species mass fraction h2o(l) = 0.02

      Y- Component of flow direction = 1

    - Mixture template

      Rotation-axis origin Y (m) = 1

      Motion type = Moving Reference Frame

      Speed = 1400 rpm

    - Outflow remain the same as set
    - Wall

      Wall motion = moving wall

      Motion = Relative to Adjacent ; Rotational

      Speed = 1400 rpm

      Rotation-Axis Origin Y (m) = 1

      Wall roughness constant = 0.002

      Temperature = 313k

      Wall thickness = 0.001m

      Material name = stainless steel

7. Solve
    - Initialize

      Compute from = all zones

      Reference frame = relative to cell zone

8. Iterate until convergence has been achieved
9. Display result

3.3 Execution Flow Chart

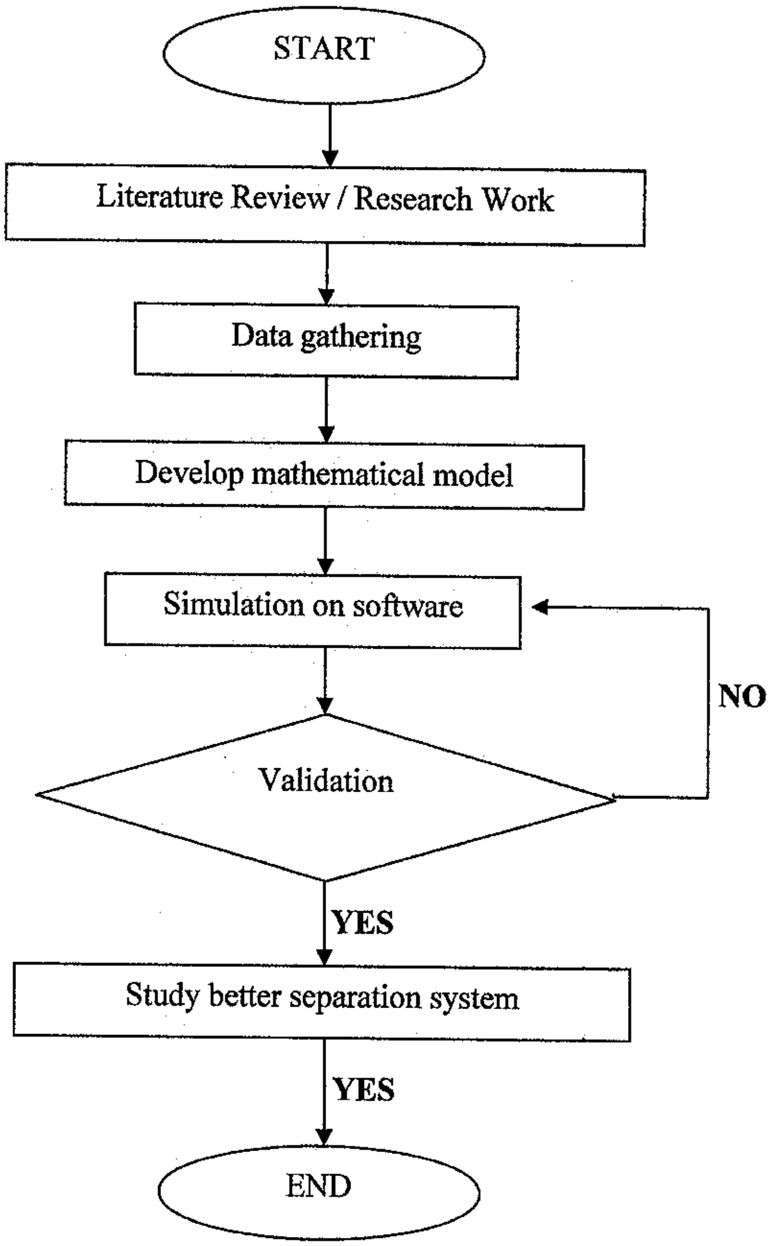


Figure 3.6: Execution flow chart of the project

More details can be found in the Gantt chart at the appendix.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Mathematical Modeling

As mentioned in Chapter 3.1,

F = 63.95N

$\mu = 0.003149 \frac{kg}{m.s}$

$A = 0.00006 m^2$

$F = \mu A \frac{du}{dy}$

$63.95\, N = 0.003149 \frac{kg}{m.s} \times 0.00006 m^2 \times \frac{du}{dy}$

Velocity field of the fluid inside the centrifugal separator is therefore,

$du = 338467238.3\, dy$

Replacing dy with value, we get:

Table 4.2 Distance from stationary bowl and velocity calculated

dy (m)	du (m/s)
0	0
0.01	3384672.383
0.02	6769344.766
0.03	10154017.150
0.04	13538689.530
0.05	16923361.920
0.06	20308034.300

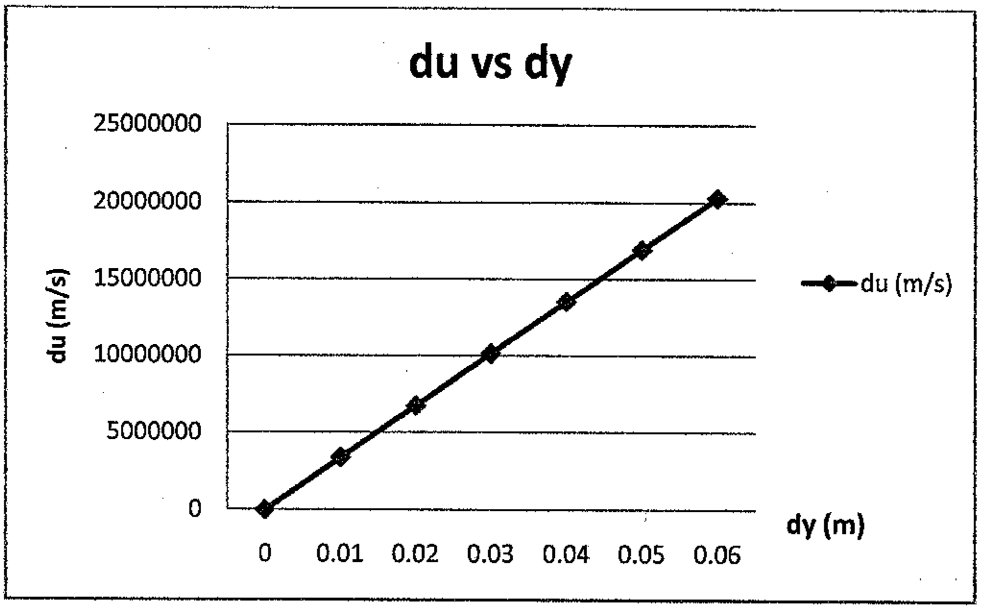


Figure 4.1: du vs dy

The pattern of the velocity field shown on Figure 4.1 is as predicted, a straight line where the velocity of the fluid gets faster linearly as distance from stationary bowl gets nearer to rotating cone.

From the velocity field mathematical model, huge velocity was obtained. This is due to the small area A and also the low viscosity of the lubricant oil. The linear line showed is identical with the literature review result in Figure 4.2 as below:

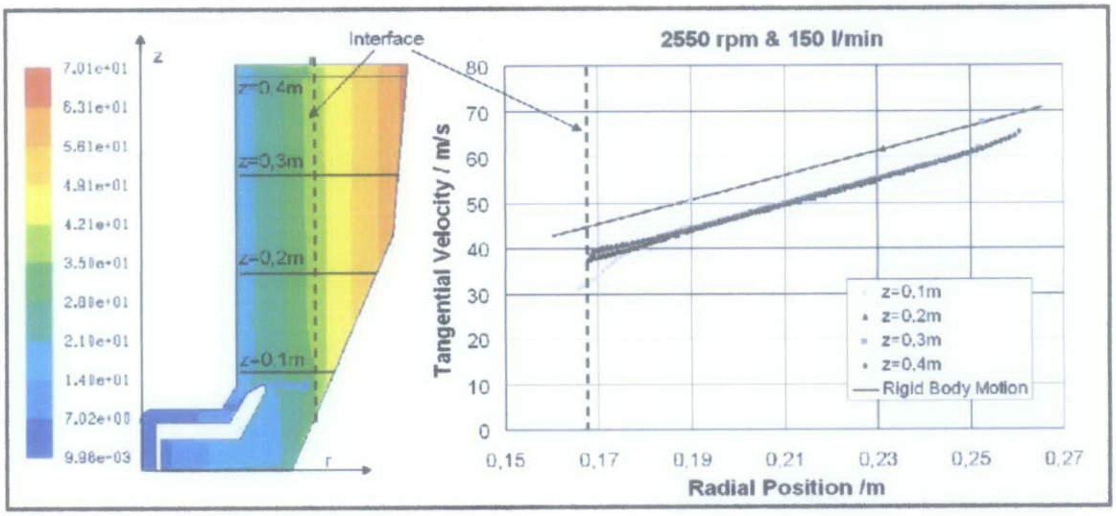


Figure 4.2: Tangential velocity of fluid in the centrifugal separator

This shows that the calculated result is in a way validated as the pattern of the velocity flow is identical with the research done by X. Romaní Fernández and Prof. H. Nirschl from Universität Karlsruhe [7].

4.2 GAMBIT and FLUENT Simulations

By the end of step 10 in GAMBIT software, the exported result is shown in Figure 4.3 .

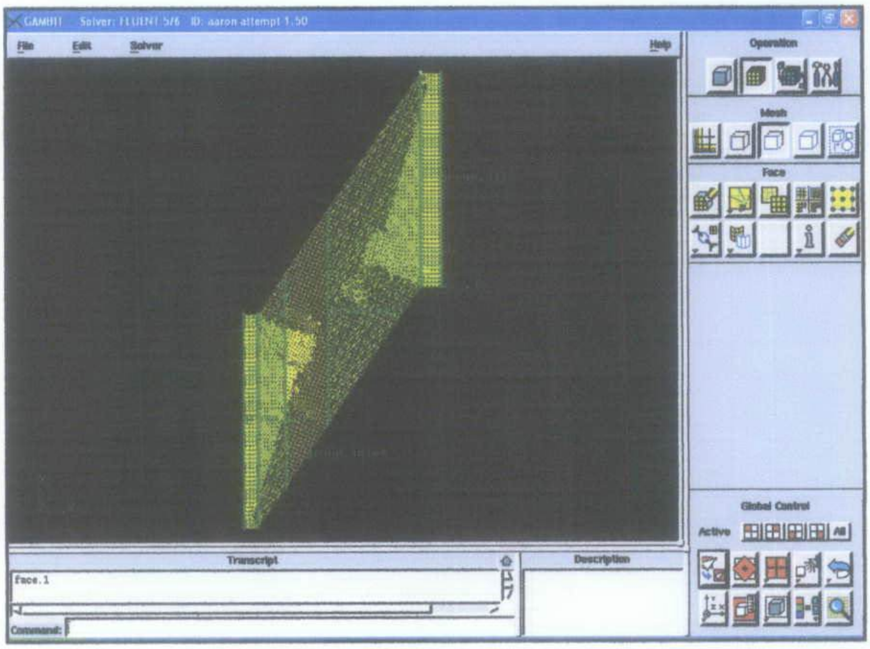


Figure 4.3: Design by the end of step 10

Figure 4.3 shows the half of cone successfully meshed and exported. This data created is ready to be brought to FLUENT software for further simulation stage.

The exported mesh is opened in FLUENT software. By the end of step 9 in FLUENT software, the result is displayed in Figure 4.4:

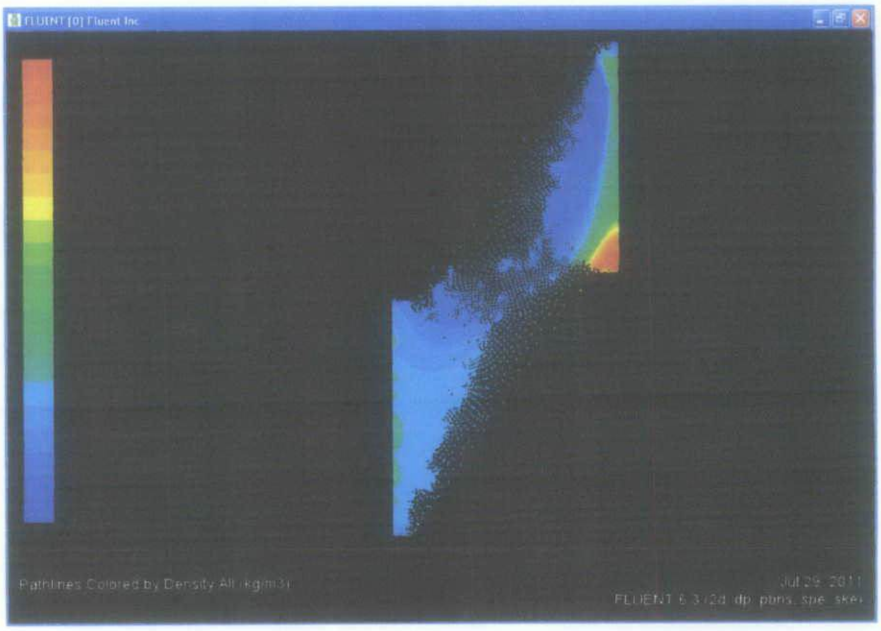


Figure 4.4: Distribution of water, oil and mixture at 1400 rpm

Figure 4.4 shows the result of the simulation using rotational speed of 1400 rpm. The steps in FLUENT software are repeated but changing the rotational speed into 800 rpm. After the simulation is done, the result is displayed in Figure 4.5 .

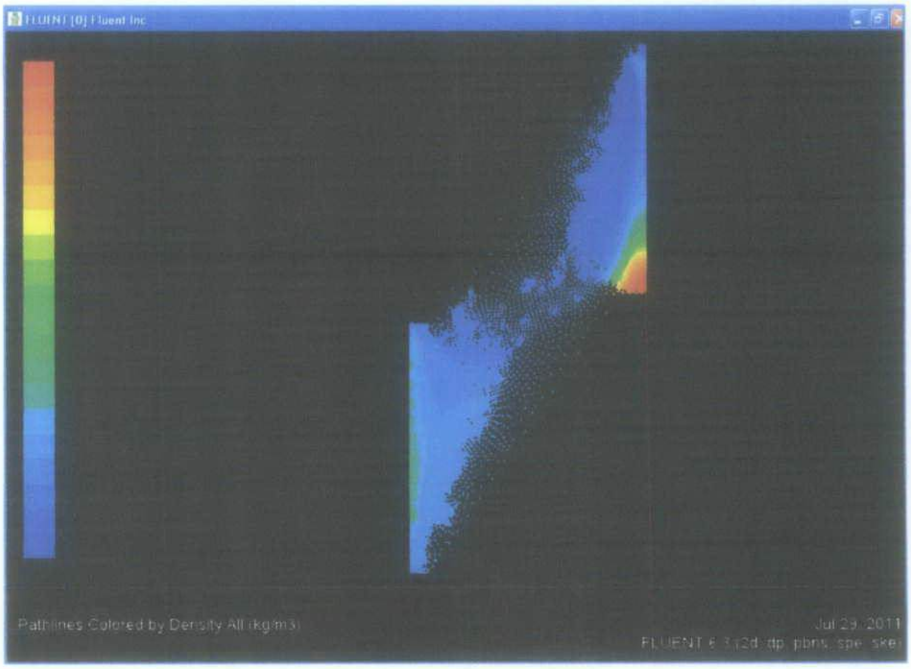


Figure 4.5: Distribution of water, oil and mixture at 800 rpm

The colours indicate the density of particles from lightest (blue) to heaviest (red). It is known that water is most dense (101.8520 kg/m^3) followed by mixture (101.8515 kg/m^3) and oil (992.2500 kg/m^3). As shown in Figure 4.4 and Figure 4.5, it can be seen that the separation of water is in light blue and oil is in dark blue. The density of water, oil, and mixture are near to each other causing the mixture colour hard to be identified. But from the amount of oil separated in both figures, it can be said that figure 4.5 has most oil separated out when rotating at 800 rpm compared to 1400 rpm. It is concluded that 800 rpm gives better separation effect compared to rotating at 1400 rpm.

Different types of oil and mixture properties will give different separation effect on the same rotational speed. What is best is to run the oil and mixture properties on the simulation to find out the optimum operating rotational speed as different rotating speed gives significant difference in separation rate.

Similar particle distribution on the cones and casing is found in the journal written by X. Romaní Fernández and H.Nirschl from Universität Karlsruhe. Figure 4.6 shows the particles size distributions result gain by them.

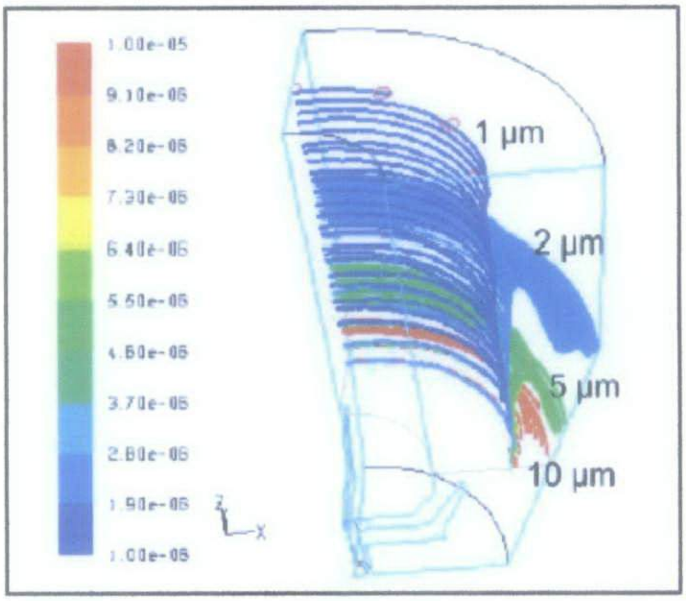


Figure 4.6: Particle size distribution on the casing of centrifugal separator [7]

The oil has the smallest size followed by mixture, then water.

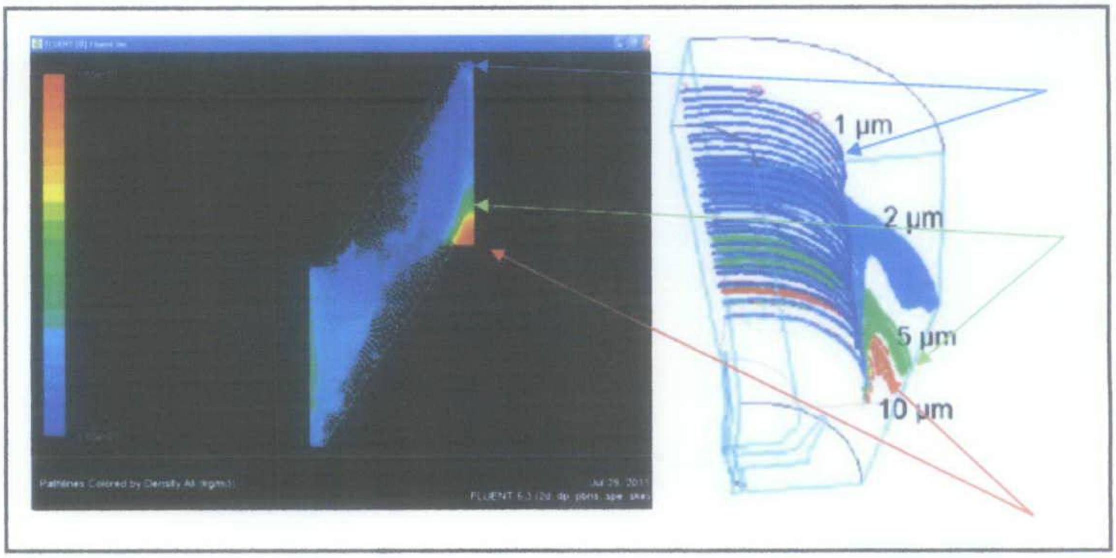


Figure 4.7: Validation of result gained on Fluent simulation

The arrows in Figure 4.7 show the similarities in trend for both results. It can be said that the results gained from the simulation are supported by the results gained from the journal.

4.3 Study for Better Separation System

4.3.1 Oxidation

Oxidation is the chemical combination of a substance with oxygen. All petroleum products are subject to oxidation, with resultant degradation of their composition and performance. The process is accelerated by heat, light, metal catalyze (e.g., copper, iron), and the presence of water, acids, or solid contaminants. The first reaction products of oxidation are organic peroxides. Continued oxidation catalyzed by peroxides, forms alcohols, aldehydes, ketones, and organic acids, which can be further oxidized to form high-molecular-weight, oil-insoluble polymers; these settle out as sludge, varnishes, and gums that can impair equipment operation. The organic acids formed from oxidation are corrosive to metals.

Most performance lubricants are a blend of base stocks and additives. The base stock is the oily portion of the lubricant, chosen for the physical and chemical properties needed in the final blend. Base stocks, are selected based on the requirements for viscosity, oxidation stability, fire-resistance, biodegradability and water miscibility in the final product.

Oxidation stability is one of the very important factors that the author would like to discuss here. Oxidation stability is the resistance of a petroleum product to oxidation; hence, a measure of its potential service or storage life. There are a number of ASTM tests to determine the oxidation stability of a lubricant. Oil companies have some additives that contain powerful oxidation inhibitors. These additives break down the oxidation cycle. Oxidation inhibitor is the substance added in small quantities to a petroleum product to increase its oxidation resistance, thereby lengthening its service or storage life; also called anti-oxidant.

An oxidation inhibitor may work in one of three ways:

1. By combining with and modifying peroxides (initial oxidation products) to render them harmless
2. By decomposing the peroxides
3. By rendering an oxidation catalyst (metal or metal ions) inert.

As long as these inhibitors are present, no significant oxidation will occur. However, these additives are consumed with time. After their depletion, oil oxidation proceeds rapidly. Typical oxidation rate doubles for every 15° F to 18° F increase in oil operating temperature. Oxidation thickens the oil and produces corrosive sulfuric, hydrochloric, organic acids and sludge. Sulfur-based acids are undesirable because they attack the oil, reducing its detergency. Organic acids react with impurities to promote sludge and varnish. In addition, acids can cause additive settling, or dropout.

The formation of sludge is not only caused by these chemical reactions. It is formed by a very complex interaction of components which include mechanical and thermal stress and multitude of chemical reactions. Once lubrication oil reaches the engineering specifications for which it was designed, it will then breakdown into a gel that sticks to all moving parts in lieu of circulating and keeping the moving parts cool. As the gel settles in the compartment, it actually stores heat instead of providing the cooling necessary for the parts. Sludge is the thickening and breakdown of the oil as it deteriorates, and as moisture and contaminants build up. This is what causes the oil to gel, resulting in excess wear as friction increases or, in extreme cases, a catastrophic failure of the moving parts due to lack of lubrication between them.

4.3.2 Types of Separators

4.3.2.1Coalescer

Coalescer utilies gravity to separate oil and water. The density of water is higher than oil. Therefore the oil tend to float above the water. Figure 4.8 shows the schematic diagram of the coalescer. The water can be extracted out as shown at the water arrow in Figure 4.8.

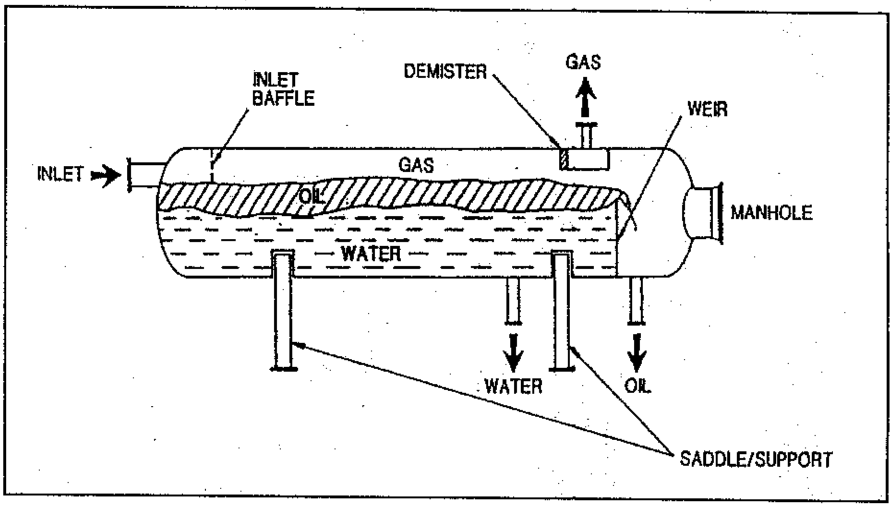


Figure 4.8 : Schematic diagram of the coalescer

Advantages:

- Less maintenance
- Works best on huge contaminant particle size and density

Disadvantages:

- Slow separation rate, low efficiency compared other methods
- High pressure drop
- Narrow operation flow range to achieve higher efficiency
- Huge in size

4.3.2.2 Vacuum Dehydration Oil Purification System

This system uses the principle where the evaporation point of water is lowered when low pressure is achieved. By using vacuum condition, water can evaporate easily without heating up the mixture of oil and water. Figure 4.9 shows an example of the vacuum dehydration oil purificator system.

Figure 4.9: Vacuum dehydration oil purificator

Advantages:

- Extract out the water without affecting oil properties
- Medium size machine

Disadvantages:

- Expensive equipment
- Advance equipment. Maintenance is expensive
- Pressure drop
- Cannot be used on high contaminant mixture, block filters

4.3.2.3 Centrifuge Separator

Centrifugal separator utilizes the centrifuge force to separate heavier fluid from lighter fluid. Water having higher density will be forced out from the mixture of oil and water. Centrifugal separator is widely used in many industries. Figure 4.10 shows an example of centrifugal separator used in oil & gas industry.

Figure 4.10: Centrifugal separator

Advantages:

- Extract out the water without affecting oil properties
- Small size machine
- More common used therefore cheaper compared to other machines

Disadvantages:

- Need different operational settings to optimize the separation
- Have to compromise between purification and clarification rate using different setting.

4.3.2.4 Thermojet

Thermojet introduces heat (energy) onto the mixture fluid to enhance water evaporation. Figure 4.11 shows one of the example of thermojet used in oil & gas industry.

Figure 4.11: Thermojet structure

Advantages:

- High purification rate
- Small size machine
- No rotary parts except pump making it very simple and reliable

Disadvantages:

- Heat up oil accelerating oxidation
- Cannot be used on high contaminant mixture, block filters

4.3.2.5 Filtration

Filtration uses material with different hole size to stop the particles from passing through. Different hole size can be selected to filter out different particles size. Figure 4.12 shows the exterior and internal structure of the filtration system.

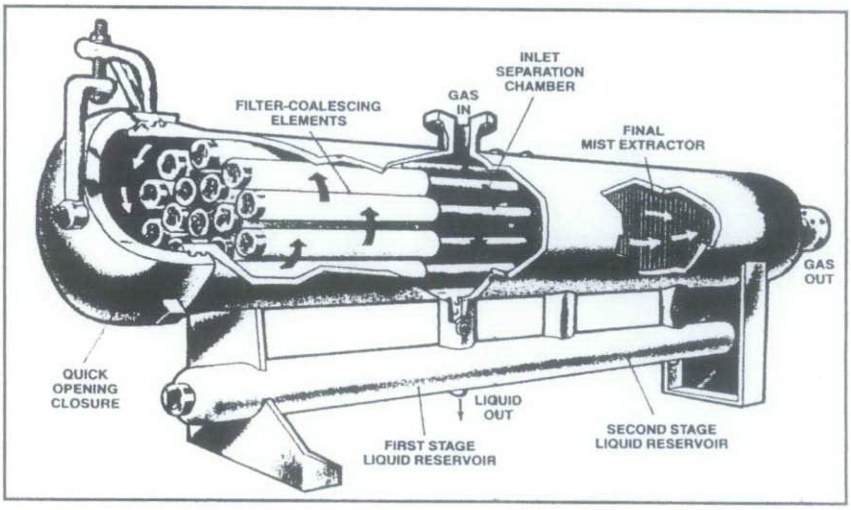


Figure 4.12: Filtration exterior and internal structure

Advantages:

- Can filter out any particle size by choosing the appropriate size
- Space saving for vertical filtration

Disadvantages:

- Regular periodic replacement causing downtime
- Wastage of filter as some filters are non recyclable

4.3.3 Better Combination of Separation System

Separation of water and oil mixture with sludge is a complicated job. The different particle size and stringent requirement made the separation even harder. In order to reduce oxidation of oil, heat introduction into the mixture has to be reduced. However, mixture with higher temperature allows better separation of oil and water as the molecules has more energy to move. Therefore, introduction of heat to a certain temperature will actually increase the separation of water and oil. The author suggests a series of different separator types to be installed to achieve best separation rate as shown in Figure 4.13:

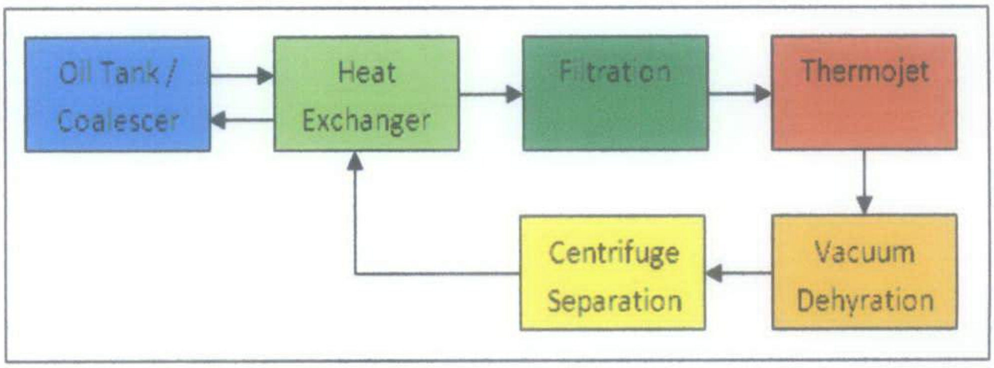


Figure 4.13: Suggested separation system arrangement

The oil coming back from the compressor is stored at the oil tank or a coalescer. The water will tend to sink to the bottom as they have higher density. The valve at the bottom of the coalesce can be opened to drip out the water. A pump will pump oil from the middle level of the oil tank or coalesce and channel it through a heat exchanger and to the filtration station. The filters are arranged in parallel formation. The idea is to change the blocked filters without shutting down the whole system. The filters are used to filter out the sludge mainly in order to protect the thermojet and vacuum dehydration machines from piping blockage.

Next, the mixture is flowed to the thermojet to be heated up. The heating temperature is depended on the type of oil used. Different oils have different oxidation temperature. This information can be gained by asking the manufacturer or through lab testing. The reason heat is introduced is to excite water evaporation rate in both the thermojet and also the vacuum dehydrator.

After that, the heated oil is flowed to the vacuum dehydration machine. The pressure inside the machine is lowered by creating a vacuum environment. Doing so will decrease evaporation and boiling point allowing more separation of water from the mixture. This method of purification is best among all as oil oxidation and emulsification does not occur through this stage.

Then, the mixture is flowed to a tank before flowing into the centrifuge separator. The tank acts as a makeup tank because the author needs to ensure the input flow rate of the centrifugal separator is stable. Instability of input flow rate will cause the centrifuge separator to loss suction pressure. The filtration stage would have filtered out most of the sludge. Therefore, the centrifugal separator is tuned to purify the mixture without having to clean the bowl of centrifugal separator after a period of time. This will help decrease downtime and increase efficiency.

The oil separated out is then flowed back to the heat exchanger. The temperature of the oil is cooled down by the mixture from the oil tank or coalescer. The heat transfer allows the oil from the oil tank or coalescer to be preheated before passing through filtration and thermojet.

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

Centrifugal separator is considerably a more economic and simpler way to purify the contaminated lubricants. The velocity field mathematical model of the separator is $du = 338467238.3\ dy$. Rotational speed of 800 rpm produces most separation for the mixture used in project case. A combination series of separators is used to achieve best separation efficiency. The mixture is directed from oil tank or coalesce followed by heat exchanger, filtration, thermojet, vacuum dehydration, centrifuge separation and back to the heat exchanger and then back to oil tank or coalescer.

5.2 Recommendations

It is recommended that further study can be done on the effects of mixture temperature to the separation rate and quality of the oil. Temperature effects can be tested using simulations. The effects on quality have to be done experimentally in order to the most precise results. Besides, different types and amount of cones design can also be simulated to see the effect on separation rate. The series of separator discussed in results and discussion chapter is discussed theoretically. It will need to be tested experimentally to see the exact increase in separation effect and quality of oil.

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PETRONAS JENTERAM SYN XV 32

High Performance Turbines & Turbo Compressor Lubricant

JENTERAM SYN XV 32 is a custom-formulated lubricant specifically designed for long life under the severe, demanding conditions normally encountered in gas turbines and centrifugal compressors.

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- Steam Turbines
- Gas Turbines
- Water Turbine
- Associated Geared Units

Specifications

- Cincinnati-Milacron P38
- Denison HF-1, GE GEK-32568
- MIL-H-17672D
- ASTM D4304
- Althom-Atlantique NBA P50001
- DIN 51524 Part 1
- DEF 2008
- BS 489(1983),
- OM-100

OEM Certifications

Certified by the following manufacturers:

- Cooper (Compressors)
- Fiat Aviazione
- GEC Alstom
- General Electric (GE)
- Siemens
- Solar
- Westinghouse

Customer Benefits

JENTERAM SYN XV 32 combines the advantages of semi-synthetic oil, which results in performance improvements beyond conventional mineral oils, and many synthetic oils. Among these are:

- Royce, and most others.
- Exceptional Oxidative Stability
- Long Life
- Low Sludge Formation Tendency
- Low Evaporation Loss
- Thermal & Hydrolytic Stability
- Improved Performance
- Rust And Corrosion Inhibited
- Viscosity Stability
- Lower Equipment Maintenance

Packaging

- 209 Liters Drum.

Product Typicals

Characteristics	Typical Values
Viscosity, cSt	
@ 40°C	35.37
@ 100°C	5.98
Viscosity Index ASTM D2270	114
Density, lb/gal, 20°C	0.850
Flash Point, C.O.C., °F	405°F
Fire Point, C.O.C., °F	430°F
TAN	0.255
RBOT(ASTM D-2272), minutes	850
Oxidation Control (ASTM D-943), Hrs	+10,000

Customer Advice

For further assistance on product MSDS, recommendation or technical queries, please liaise with the regional technical services engineer or contact HO technical engineers.

Gantt Chart FYP I

No.	Detail / Week	1	2	3	4	5	6		7	8	9	10	11	12	13	14
1.	Selection of Project Topic							Mid Semester Break								
2.	Preliminary Research Work															
3.	Submission of Preliminary Report				√											
4.	Identify related parameters and equations needed															
5.	Submission of Progress Report									√						
6.	Seminar									√						
7.	Develop mathematical model of fluid velocity field															
8.	Submission of Interim Report Final Draft															√
9.	Oral Presentation															

Gantt Chart FYP II

No.	Detail / Week	W1 (22-28) May	W2 (29-04) June	W3 (05-11) June	W4 (12-18) June	W5 (19-25) June	W6 (26-02) July	W7 (03-06) July	(07-09) July
1.	Project refreshment								Mid Semester Break
2.	Start simulation of centrifugal separator: i. Build model using GAMBIT ii. Merge GAMBIT model and set up environment conditions and boundary		√	√	√				
3.	Mesh and export GAMBIT drawing into FLUENT. Set up simulation parameters on FLUENT: i. Identify suitable models to use ii. Set material used iii. Define boundary and operating conditions					√	√	√	

No.	Detail / Week	W8 (10-16) July	W9 (17-23) July	W10 (24-30) July	W11 (07-13) Aug	W12 (14-20) Aug	W13 (21-27) Aug	W14 (28-03) Sep
4.	Run simulations on the design and discuss results gained. i. Change rotation speed to see effects on separation ii. Choose best operation rotational speed	√						
5.	Submission of Progress Report							
6.	Validation of results gained in simulation. Suggest new separation system and conclude the improvements found.							
7.	Pre EDX & Poster Exhibition				√			
8.	Submission of Dissertation Final Draft					√		
9.	Technical Paper & Soft bound						√	
10.	Oral Presentation							√
11.	Submission of Dissertation (hard bound)	7 days after Oral Presentation						