Rheological Study of Light Waxy Crude Oil

By

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Dissertation submitted in partial fulfillment of

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A project dissertation submitted to the
Petroleum Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
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May 2015

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.

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(MOHAMAD NIZAR BIN MAZENAN)

ABSTRACT

The study of rheological of light waxy crude oil is very important in understanding the flow and performance of the oil from the reservoir to the surface. In oil and gas industries over the world, most of the crude oils will contains wax and asphaltene which effect viscosity of the crude oil and the flow of the oil from reservoir. The objective of this study is to investigate the rheological behavior of crude oil with different composition of wax on the yield stress and viscosity. In this study, the amount of wax was measured by using wax analyzer. Fann viscometer also has been used in this study to measure the viscosity of the crude oil. The viscosity for all samples was measured at 40°C and the samples were prepared by mixing Dulang crude oil with Tapis crude oil. When amount of Dulang is reducing, the viscosity and yield point also reduce. The result shown that amount of wax contains effect the viscosity and the yield point of the samples.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 Background study

Deposition of wax in crude oil is not a new issue in oil and gas industries. Most of oil and gas companies spent a lot of money to solve this problem and commonly crude oils contain wax and paraffin. Viscosity of the crude oils is one of the most important properties that needs to be understood as deposition of wax in crude oil changes the rheology of the fluids. Most journals and research paper stated that crude oils from reservoir behave like Newtonian fluid. According to Sadeghazad (2000), at certain time when the crude oils were situated at low temperature environment, deposition of wax starts to form and the flow of the crude oils acts like non-Newtonian fluid (Bingham Plastics).

In this project, the crude oil that was used for experimentation is crude oils which contain of wax and without wax. Both crude oils are from various oilfields. From these crude oils, investigation was conducted to study the effect of the wax toward the rheology behavior of the crude oils.

1.2 Problem Statement

In natural hydrocarbon reservoir, crude oil exists in the liquid phase. Generally, at high temperature, crude oil behaves like Newtonian fluids. Below certain temperature, wax starts to form and when the temperature is reduced further, the wax will be precipitated from the solution. Precipitation and deposition of wax can occur in the tubings, pipelines and storage tanks. The deposition of wax from the crude oil will lead to non-Newtonian flow characteristics which the yield stress is depending on composition and temperature. This phenomenon may cause some problems which are:

- The viscosity of crude oil becomes high which leads to flow resistance.
- Need more pressure for restarting the flow.
- Wax's deposition on surface and other equipment.

1.3 Objectives

The objective of this project is:

- To investigate the rheological behavior of crude oil with different composition of wax on the yield stress and viscosity.

1.4 Scope of Study

This project is to study rheological behavior of crude oil of different composition of wax content. In rheological models, the fluid type like Newtonian fluids and Non-Newtonian fluid (Bingham Plastic) were used to characterize the fluid behavior. The light oil of different wax content are mixed which will lead to controlled wax content and composition. Different composition of wax contains in the oil sample was done by laboratory analysis. The composition of wax also effect to the yield point and viscosity.

CHAPTER 2
LITERATURE REVIEW

2.1 Crude oil sample

The crude oil samples that use for this study contains wax. According to Wardhaugh (1988) presence of wax in crude oil can lead to non-Newtonian characteristics including yields stress, time dependency, pseudoplasticity (shear thinning), and the flow properties of the crude oils. Ruben (2005) stated that while crude oils are extracted as a single organic phase from the reservoir, low temperatures encountered at the surface or during transport in subsea pipelines can lead to the separation of higher molecular weight paraffins. Under flow conditions, wax deposits can form upon the pipe wall at certain temperature. In this study, crude oils that used are Dulang oil, Miri oil and Arab oil. Dulang oil is waxy crude oil which taken from Dulang oilfield, situated in the South China Sea, 130km offshore of Kuala Terengganu, on the east coast of Peninsular Malaysia. Miri and Arab oil is the light and intermediate crude oil. These two crude oils will be mixed together with Dulang oil so that the wax content in the crude oil will be varies according to the sample preparation.

2.2 Shear stress

Shear stress can be defined as the force that causes the fluid to deform by slippage. Slippage can occur along a plane or planes parallel to the imposed stress. In other words, the shear stress is the force that exists in the fluid that opposes the flow when the fluid is flowing. This statement can be illustrated better in the equation below:

$$\tau = \frac{F}{A} \quad \text{(Eq. 1)}$$

Where, τ = Shear stress, N/m^2 or Pa

F = Applied force, N

A = Cross-sectional area of the fluid parallel to the applied force, m^2

2.3 Shear rate

Shear rate is the rate at which a progressive shearing deformation is applied to some material. Shear rate is the derivative of the shear strain with respect to time and shear strain, denoted as γ (Dealy and Wang, 2013). Shear rate will directly proportional to the flow rate for Newtonian fluids. Shear rate can be illustrated as below:

$$\gamma = \frac{\Delta x}{h} \quad \text{(Eq. 2a)}$$

$$\frac{d\gamma}{dt} = \frac{1}{h}\frac{dx}{dt} = \frac{V}{h} \quad \text{(Eq.2b)}$$

Where, V = velocity of the upper plate, m/s

v_1 = velocity of the fluid in the x_1 direction

h = gap between two plates, m

2.4 Viscosity

Generally viscosity can be described as the resistance of the flow. From other views, viscosity also can be defined as the internal resistance of the fluid and for Newtonian fluids the symbol for viscosity is η which independent from the shear rate and for non-Newtonian fluids the symbol for viscosity are known as η_a also depending on the shear rate. Viscosity is one of the most important characteristics in fluid behavior and units that are being always use in industries are mPa⁻s or cp. Below is the equation for the viscosity:

$$\eta_a = \frac{\text{shear stress}}{\text{shear rate}} = \frac{\sigma}{\gamma} \quad \text{(Eq. 3)}$$

2.5 Type of fluid behavior

Fluid can be defined as a substance that continually deforms when shear stress was applied. Fluids can be in phase liquids or gases. Fluid can flow when the deformation of the fluid is continuous with the influence of the shear stress.

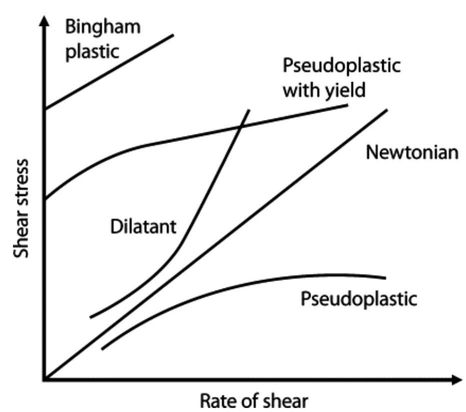

Figure 1:Graph of shear stress vs shear rate (M. Benidir and R. Chaib, n.d)

2.6 Newtonian fluid

Newtonian fluid is the simplest class of fluids and most of drilling fluids are Newtonian like freshwater, seawater, diesel oil and mineral oils. For Newtonian fluids, the shear stress is directly proportional to the shear rate and the slope of this line can be known as viscosity. The value of the yield stress for Newtonian fluids always be zero and shear stress will be doubled when the shear rate is double.

$$\eta = \frac{\sigma}{\gamma} \quad \text{(Eq. 4)}$$

Where, η = viscosity, Pa s or cp

σ = shear stress, Pa

γ = shear rate, s^{-1}

2.7 Non-Newtonian fluid

The definition of non-Newtonian fluid is the properties of the fluid differ from the fluid's properties of Newtonian fluids. Commonly viscosity of non-Newtonian fluids is depend on the shear rate or shear rate history. When plot in the graph of shear stress versus shear rate, the plot is not linear and not begin at the origin as Newtonian fluid. To describe the flow behavior for non-Newtonian fluids, several models have been developed such as Bingham Plastic and Power Law. Most of the crude oils behave like Bingham Plastic when its contain wax. For Bingham Plastic, it has linear shear stress-shear strain relationship by requiring yield stress before it starts to flow according to Rao (1999). The equation of Bingham Plastic is shown below:

$$\sigma - \sigma_0 = \eta' \gamma \qquad \text{(Eq. 5)}$$

Where, σ = measured shear stress, Pa

σ_0 = shear stress when shear rate is 0

η' = Bingham plastic viscosity, cp

γ = shear rate, s^{-1}

2.8 Cloud point (CP) and pour point (PP)

The definition of cloud point is the temperature which wax or paraffin from crude oil begins to precipitate. From another point of view, CP also described as the temperature which the fluid is no longer completely soluble and begins to be cloudy. For pour point (PP), it can be defined as the temperature which the fluids becomes semi solid from its original state and the character of the flow also may change from its original condition. Commonly, high pour point of crude oil will be related to high contents of paraffin. Normally in the case of wax deposition, temperature which the first precipitation of wax was formed from the crude oil called the cloud point and temperature which the crude oil not flow when tilted will be labeled as pour point (Sadeghazad, 1998).

2.9 Laboratory investigation

For laboratory investigation, it followed the procedure that prepare by American Society for Testing and Materials (ASTM) so that the result that obtains were reliable. Four standard procedures that prepare by ASTM were used in this study which is ASTM D2500, ASTM D5853, ASTM D5442 and ASTM D7042. ASTM D2500 is standard procedure for crude oil to test cloud point. This standard procedure test for crude oil that has cloud point below 49°C only. Another standard procedure is ASTM D5853 which is for testing pour point and specifically designed for crude oils. For ASTM D5442, this procedure is to determine the number of carbon that distribute in the petroleum waxes.

Data that obtain from this test are usually used to evaluate petroleum waxes for use in rubber formulations. The last standard procedure that will be used is D7042 which is procedure to measure the viscosity and the density of crude oil.

CHAPTER 3
METHODOLOGY

3.1 Preliminary study

For Final Year Project 1 (FYP 1), the project started with finding the research paper, journal and other references that relate to the topic which understanding of the rheological behavior of light waxy crude oil. Getting information from the research papers and journals on the rheological behavior and effect of wax is very important as experiment will be conducted to understand more about this topic. Research paper and journals usually obtain from the website and also from the Information Resource Centre (IRC) in UTP.

3.2 Pre-experimental work

Before the experiment was started, all parameters and type of crude oils that used in experiment were listed. **Table 1** is the lists of crude oils and all parameters that used in this experiment:

Table 1: List of parameters and crude oils

Type of crude oils	1. Dulang crude oil 2. Tapis crude oil 3. Masila crude oil 4. Castilla crude oil
Parameters	1. Temperature : 40°C 2. Viscosity (cp) 3. Shear stress (dynes/cm^2) 4. Shear rate (s^{-1}) 5. Dial reading 6. Rotation per minute (RPM) 7. Wax content (%) 8. Water content (%)

3.3 Experimental work

Before begin the experiment, the samples were prepared according to the experimental design. Basically this experiment was divided into two sections: samples preparation and experimental designs.

3.3.1 Sample preparation

In this section, two types of crude oils were used in samples preparation. In order to study about the wax content, Dulang crude oil was used. Another crude oil that used in this experiment was Tapis crude oil. Dulang crude oil was obtained from the Petronas Penapisan Melaka. Dulang crude oil is a type of waxy crude oil and the value of API is 37.6° while Tapis crude oil less waxy than Dulang crude oil with API value of 45.2°. Another crude oils that obtained for this experiment was Masila crude oil and Castilla crude oil. These two crude oils were not from Malay Basin. In order to avoid contaminated, the beaker that contain crude oil had to close tightly by using aluminum foil. **Table 2** is list crude oils that obtained for this experiment:

Table 2: Characteristic of crude oils

Product name	API gravity	Sulphur content	Location of field
Dulang	37.6°	0.05%	Malaysia
Tapis	45.2°	0.03%	Malaysia
Masila	31.4°	0.54%	Yemen
Castilla	18.8°	1.97%	Columbia

Samples preparation in this experiment was prepared by mixing the Dulang crude oil and Tapis crude oil. The volume for each samples was prepared by using ratio method and divided into two types: D1:TX and DX:T1. D and T represented as Dulang and Tapis respectively. 1 is ratio and X is any number. For this experiment, the number of X was chosen from two until six. **Table 3** is the list of samples that had been prepared:

Table 3: List of crude oil's samples

Sample	Dulang ratio	Tapis ratio
D1T4	1	4
D1T5	1	5
D1T6	1	6
D3T1	3	1
D4T1	4	1
D5T1	5	1
D6T1	6	1

3.3.2 Experimental Designs

Before the experiment started, some parameters of crude oils were measured. The parameters are water content and wax content and these parameters were measured in percentage (%). The wax content in the crude oils were measured by using Wax Content Analyzer while the water content in crude oils were measured using Karl Fischer Titration. After obtained these two parameters, the viscosity was measured using Viscometer.

Wax Content Analyzer

Wax Content Analyzer is located in the Core Analysis Lab. This equipment consists of three parts: water bath, power supply and UPS system. Below are the steps that need to be followed when using this equipment:

1. Switch on the power supply and the UPS system.
2. Switch on the water bath and temperature was set at -28°C.
3. Water bath need at least 4 hours to stable the magnetic temperature.
4. Open software PI analysis for run sample measurement.
5. 1.5ml of crude oil was inserted into the test tube and put in oven for 30 minutes at 90°C. After 30 minutes, the sample was mixed with 0.5ml chloroform.
6. The test tube that contained sample was inserted into water bath for 40 minutes.
7. After 40 minutes, the test tube was inserted in the UPS system and the wax content was measured.

Figure 2: Wax analyzer

Karl Fischer Titration

Below are the steps when used this equipment:

1. Samples were prepared with weight below than 0.6gram and were inserted into the tube.
2. Start the titration by click RUN.
3. Samples were added to the titration vessel.
4. The weights of samples were entered in the weight flash.
5. Close the weight entry.
6. Start actual titration.
7. The results were displayed in the desired unit. The results were recorded.

Viscometer

This equipment is located at Mud Lab. The model of this equipment is 35A and from the FANN manufacturer. The steps that need to be followed when using this equipment are shown below:

1. The sample was placed in the cup until it reached the mark line.
2. The cup was placed on the stage and was adjusted until the sample reached the scribed line.
3. The sample was stirred around 10 seconds at 600rpm before the desired RPM was selected.
4. The dial reading RPM were recorded when the dial reading was stabled.
5. Step 1-5 was repeated by using different crude oil samples.

Figure 3: FANN Viscometer

3.4 Project activities flowchart

Figure 4 is the project activities flowchart that represented for samples preparation and experimental designs:

Figure 4: Project flowchart

3.5 Project timeline

Table 4: Gantt chart for FYP 1

No.	Activities	Weeks													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	FYP 1 briefing and selection of topic	■	■												
2.	Finding journals and research papers			■	■	■	■	■	■	■	■	■	■	■	■
3.	Prepare the Extended Proposal				■	■									
4.	Submission of Extended Proposal						●								
5.	Preparation for Proposal Defence							■	■						
6.	Proposal Defence									■					
8.	Project continuation										■	■	■		
9.	Submission of Interim Draft Report													●	
10.	Submission of Interim Report														●

Table 5: Gantt chart for FYP 2

No.	Activities	Weeks														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	**Project work continues**	■	■	■	■	■	■	■								
1a.	Sample preparation	□	□													
1b.	Laboratory analysis for viscosity of wax			□												
1c.	Laboratory analysis for CP & PP				□	□										
1d.	Laboratory analysis for composition of wax					□	□									
2.	Submission of progress report							●								
3.	**Project work continues**								■	■						
3a.	Critical analysis the result								□							
3b.	Correlation with existing model									□						
4.	Pre-SEDEX										●					
5.	Submission of draft final report											●				
6.	Correction for Draft final report												■			
6.	Submission of Dissertation (soft bound)												●			
7.	Submission of technical report												●			
8.	Viva													●		
9.	Submission of Dissertation (hard bound)															●

Milestone ● Progress ■ Experiment progress □

CHAPTER 4

RESULT AND DISCUSSION

4.1 Crude oils parameters

Wax content and water content of each crude oil were measured in this experiment. These two parameters were important during measured the viscosity of the crude oils.

4.1.1 Wax content

In order to study the rheology of the wax, wax content was measured for each crude oil. Four readings of wax content were taken for each crude oil. The proposed of taking 4 reading was to make sure the results of wax content was stable and the value of wax content will be in average. The result of wax content for four types of crude oil was shown in the **Table 6**:

Table 6: Wax content for all crude oils

Crude oil	**Wax content**				
	1	**2**	**3**	**4**	**average**
Dulang	24.79%	26.22%	26.75%	25.83%	25.90%
Tapis	13.28%	13.47%	13.33%	13.77%	13.46%
Masila	6.77%	7.13%	7.02%	6.89%	6.95%
Castilla	31.24%	34.95%	32.13%	31.01%	32.33%

From the table above, Dulang crude oil and Castilla crude oil content high percentage of wax. The different between these two crude oils is Dulang is a light waxy crude oil while Castilla is a heavy waxy crude oil. Masila and Tapis crude oil can be categorized as less waxy crude oil.

4.1.2 Water content

In this experiment, water content in crude oil is the most important parameters need to be measured. Water content in crude oils need to be below 5% to make sure the result of viscosity is reliable and follow the standard of ASTM. If above 5%, the crude oil had to reduce the water content before measure the viscosity as the viscosity will be affected by the high water content. The equipment that will be used to reduce the water content is centrifuged at the speed of 7500RPM until 2 hours and 30 minutes. Result of water content for two types of crude oil was shown in the **Table 7**:

Table 7: Water content for Dulang crudeo oil and Tapis crude oil

Crude oil	Water content
Dulang	0.007%
Tapis	0.020%

From **Table 7**, water content for Dulang crude oil is 0.007% while for Tapis crude oil is 0.020%. It was shown that the water content for these two types of crude oil were less than 5%. With this amount of water, any measurement of viscosity is representative.

4.2 Viscosity of crude oils

In this section, the viscosity and yield point of Dulang crude oil and Tapis crude oil were taken and compared. The viscosity for all samples was shown in **Figure 5**, **Figure 6** and **Figure 7**. The slope of the graph represented as viscosity while the y-intercept of the graph represented as yield point. The comparison of crude oils was divided into 3 parts: Dulang crude oil with Tapis crude oil, Tapis crude oil with Tapis mixture and Dulang crude oil with Dulang mixture. The viscosity and yield point of Dulang crude oil and Tapis crude oil were determined by using FANN viscometer. The crude oils were tested at 3 RPM, 6 RPM, 100 RPM, 200 RPM, 300 RPM and 600 RPM

4.2.1 Viscosity of Dulang crude oil and Tapis crude oil

Tapis crude oil has low viscosity with the value of 5 cp at 40°C. This can be observed **Figure 5** where the gradient was low compared to Dulang crude oil. **Figure 5** also can be observed that the yield point is almost intersecting at origin of the graph where the value of yield point is 2 Pa at 40°C. This result also can be related with the characteristic of Tapis crude oil where the API value is 45.2° and the wax content is 13.46%. With the high value of API and low amount in wax content, Tapis crude oil can be categorized as less waxy and light crude oil. These criteria had shown that Tapis crude oil is almost behaves like Newtonian fluid where low in viscosity and almost intersecting at the origin of the graph. For Dulang crude oil, the viscosity is 39 cp. This value was determined from the slope of the straight line in the graph. Besides, Dulang crude oil has higher yield point. At 40°C, the yield point can come to 78 Pa. From this particular result, Dulang crude oil is behaves like Bingham Plastic where the viscosity and yield point is high. To compare the Dulang crude oil and Tapis crude oil, Dulang crude oil is more viscous than Tapis crude oil. At 40°C the viscosity of Dulang crude oil is higher than Tapis crude oil.

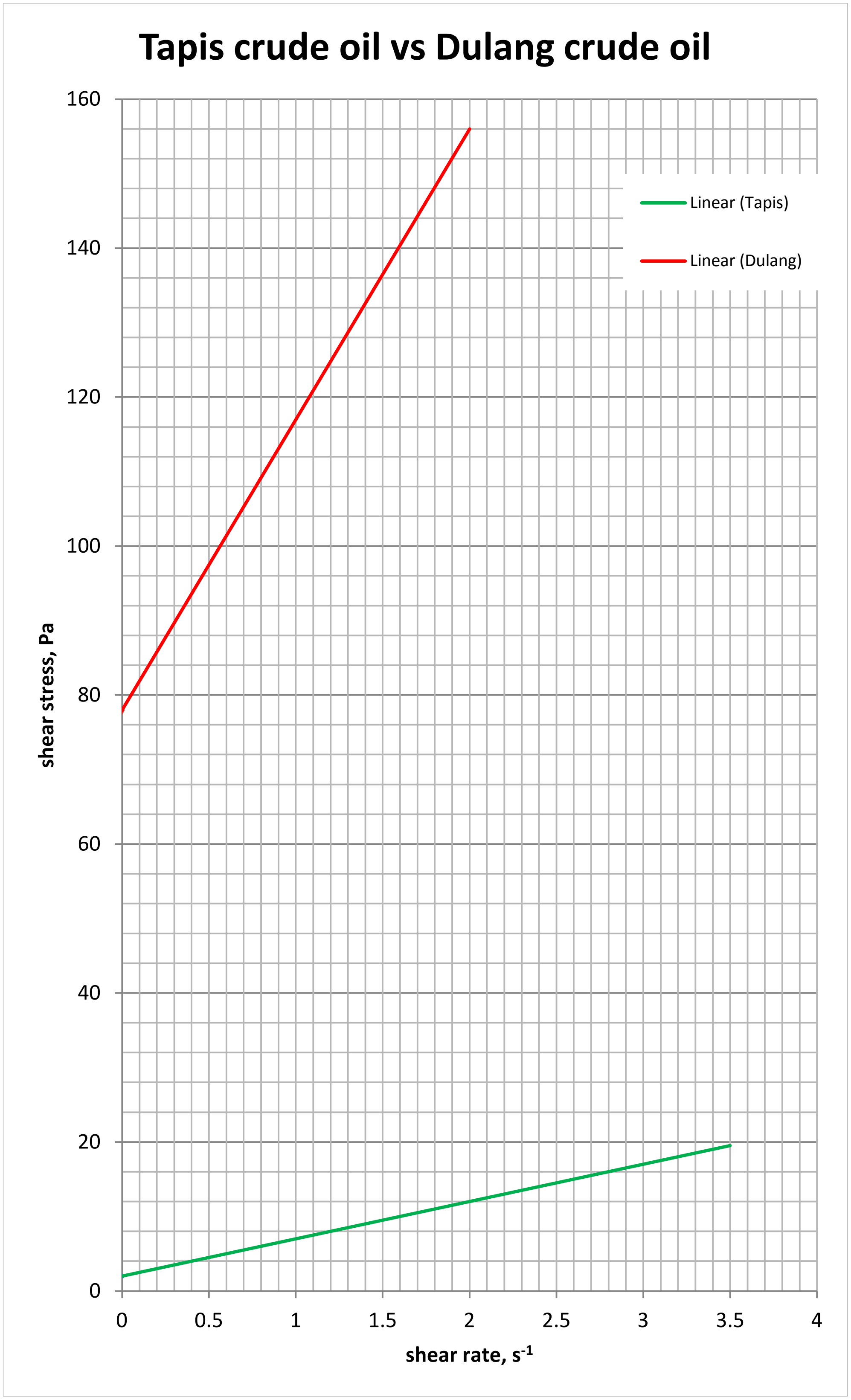

Figure 5: Graph of Tapis crude oil vs Dulang crude oil

4.2.2 Tapis crude oil and Tapis mixture

In order to study the relationship of the wax composition between yield point and viscosity, these two crude oils were mixed at specific ratio of volume. Originally, viscosity of Tapis crude oil is 5 cp. When mixed with Dulang crude oil at specific ratio of volume, the viscosity and yield point increase at 40°C. This can be explained by the increase of gradient in the graph of Tapis crude oil versus Tapis mixture in **Figure 6**. In **Figure 6** also have been observed that the yield point increase by 2 Pa and the viscosity was increase by 2 cp and 3 cp. This can be explained by the composition of wax where initial composition of wax for Dulang crude oil is 25.9% and for Tapis crude oil is 13.46%. However, since the Tapis crude oil was mixed in small amount Dulang crude oil with respective ratio of volume, the increment of yield point also increase in small. This result can be shown in the graph where the samples of D1T4, D1T5 and D1T6 had high yield point and viscosity compared to the Tapis crude oil. When Dulang crude oil was mixed with Tapis crude oil, the amount of wax content in Tapis crude oil will increase. In the increasing amount of wax content means the force need to breakdown the wax also increase. This statement already proved that in the graph where the yield point was increased compared to Tapis crude oil. The graph also shows that the viscosity of crude oils changed according to the mixing of Dulang crude oil.

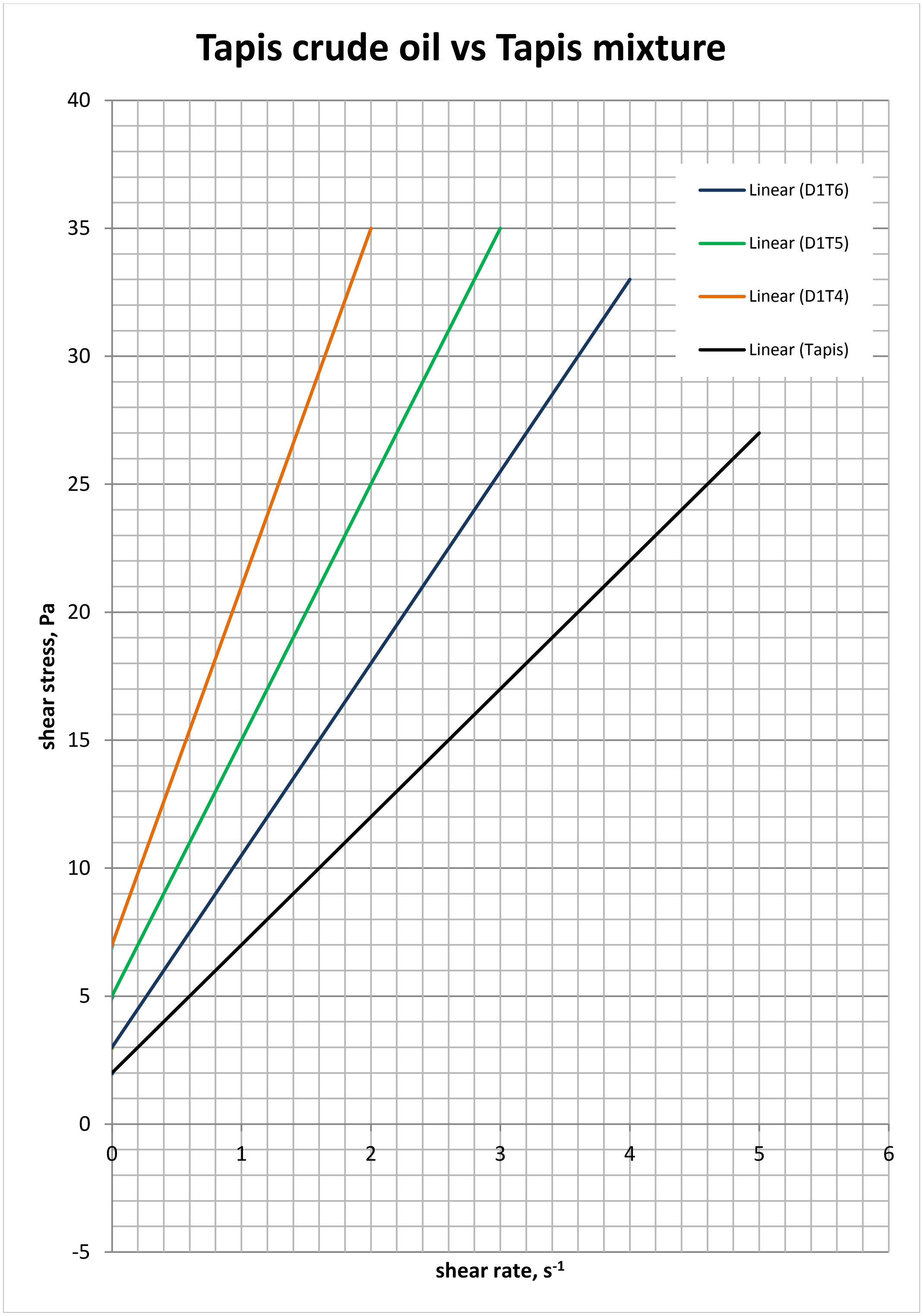

Figure 6: Graph of Tapis crude oil vs Tapis mixture

4.2.3 Dulang crude oil and Dulang mixture

When Dulang crude oil was added with small amount of volatile less waxy crude oil such as Tapis crude oil, the viscosity was reduced at 40°C. This can be observed from the graph of Dulang crude oil versus Dulang mixture in **Figure 7**. The decreasing of viscosity can be explained by the wax composition of Dulang crude oil and Tapis crude oil. Initially the wax content for Dulang crude oil was 25.9% and after the crude oil was added at small amount of Tapis crude oil, the viscosity was reduced as the wax content of Tapis crude oil is less than Dulang crude oil which is the value is 13.46%. The graph shows that the viscosity decrease as the increment in amount of Tapis crude oil and most significantly, the yield point also reduce as well. Yield point of Dulang crude oil is 78 Pa and was measured at 40°C. After adding small amount of Tapis crude oil, the yield point was reduce to 55Pa, 47Pa, 42Pa, and 35Pa respectively. From this result, it shows that the yield point of Dulang reduce significantly when Tapis was mixed. This result also can be observed from the graph where the y-intercept of Dulang was decreased significantly. This can be explained by the wax composition of Dulang crude oil. Wax composition for Dulang crude oil is higher than Tapis crude oil and when the wax composition of Dulang crude oil was reduced by mixing with Tapis crude oil, the yield point was decrease as well. The reason for the yield point to decrease is when the wax composition is decrease, the amount of force to breakdown the wax also decreases. Thus, this will make the crude oil easy to flow when a small amount of force was applied.

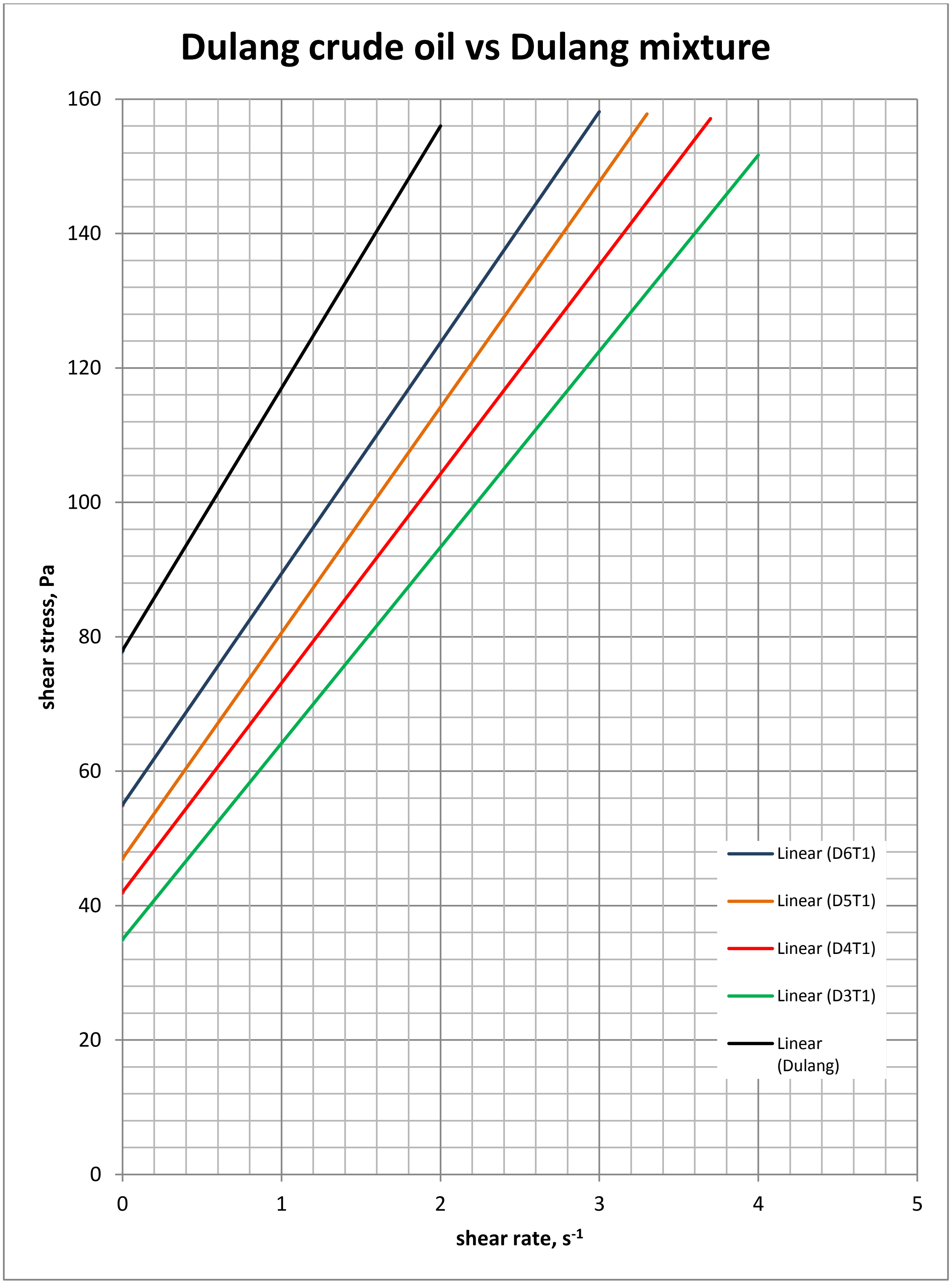

Figure 7: Graph of Dulang crude oil vs Dulang mixture

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the viscosity and yield point of crude oil are affected by wax composition. Tapis crude oil behaves almost like Newtonian fluid as the yield point is almost intersecting at the origin of the graph. However, when Tapis crude oil was mixed with small amount of Dulang crude oil, the viscosity and yield point changed. From this result, can be concluded that by increasing the wax composition, the viscosity and yield point also increases. This experiment also shows that when the wax composition decreases, the viscosity and yield point also decreases. When Dulang was mixed with small amount of Tapis crude oil, the graph shows that the viscosity and yield point were reduce. This can be concluded that when the wax composition was decrease, the force that need to breakdown the wax also reduce, therefore the yield point will be reduced. The analysis in this experiment will help the engineers during restart the flow when the production is shutdown in long period and make better flow inside the pipe according to the crude oil behavior. According to the objectives of this project, the objectives were achieved successfully.

5.2 Recommendation

Due to the time limitation, two types of crude oil were unable to test and some parameters have not been covered during the project. Below are the lists of recommendation that can be followed for the experiment:

5.2.1 Number of temperature data

Due to time constraint, the viscosity for samples was tested at 40°C only. The experiment can be tested at variety of temperature and the most important is at the reservoir temperature. By testing at variety of temperature, the real fluid behavior of crude oil at reservoir condition can be found.

5.2.2 Pressure parameter

Although the pressure can give small influence to the viscosity of the crude oil, the viscosity of crude oil still increase when pressure increase. When crude oil at higher pressure like reservoir pressure, the molecular will be less freely to move and make the force among molecular will be increase. Due to the higher intermolecular forces, the flow resistance also increases.

5.2.3 Conduct simulation

Some software can be used for pipeline simulator with presence of wax deposition like FloWax. When conducting simulation, the outcome can be compare with the outcome from the experiment. The data from the comparison of simulation and experiment will be more reliable and can be used as references for engineers.

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Appendices

Table 8: Dial reading for Tapis crude oil

RPM	DIAL READING
3	1
6	2
100	5
200	5
300	7
600	12

Table 9: Dial reading for Dulang crude oil

RPM	DIAL READING
3	14
6	17
100	64
200	79
300	117
600	156

Table 10: Dial reading for D1T6

RPM	DIAL READING
3	2
6	3
100	5
200	7
300	10
600	17

Table 11: Dial reading for D1T5

RPM	DIAL READING
3	3
6	4
100	8
200	12
300	15
600	25

Table 12: Dial reading for D1T4

RPM	DIAL READING
3	3
6	4
100	8
200	13
300	16
600	27

Table 13: Dial reading for D6T1

RPM	DIAL READING
3	6
6	8
100	20
200	30
300	89
600	123

Table 14: Dial reading for D5T1

RPM	DIAL READING
3	10
6	5
100	17
200	25
300	80
600	113

Table 15: Dial reading for D4T1

RPM	DIAL READING
3	7
6	9
100	20
200	30
300	73
600	104

Table 16: Dial reading for D3T1

RPM	DIAL READING
3	20
6	15
100	35
200	45
300	64
600	93

Table 17: Yield point and viscosity value for samples

Samples	Yield point	Viscosity
Tapis	2	5
Dulang	78	39
D1T6	3	7
D1T5	5	10
D1T4	7	11
D5T1	47	33
D4T1	42	31
D3T1	35	29