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Flow pattern, pressure drop and inclination analysis on liquid-liquid two phase flow of waxy crude oil in pipelines using PIPESIM

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Flow pattern, pressure drop and inclination analysis on liquid-liquid two phase flow of waxy crude oil in pipelines using PIPESIM

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Abstract. Produced water is a water that comes out with the crude oil during the production of the well. It contains non-soluble and soluble oil or organics, dissolved and suspended solids with different chemicals used during production process. Thus, it must be properly accounted as it affects the economical productivity of crude oil and separation efficiency as a result of stubborn emulsions between crude oil and water. Thus, a simulation study was conducted using PIPESIM to predict the flow pattern and pressure drop of waxy crude oil and water flow in horizontal and inclined pipelines (i.e., -15º from horizontal). In this simulation study, water cuts were ranging from 0% to 90% while the flow rates were ranging from 2.03 to 16.21 cm^3/s. The study comprised fluid modelling, physical modelling and running the simulation with the most suitable multiphase flow correlation in PIPESIM. This simulation study used the waxy crude oil has 16.15% of wax content and simulation was performed at 30ºC. The validity of the simulation results was accomplished by comparing the published findings. There were only two types of flow patterns that can be identified by PIPESIM; stratified wavy and dispersed flow. The investigations proved that pressure drop was greatly influenced by flow rates and flow patterns. By decreasing the inclination angle, the boundary between the stratified and dispersed flow regimes shifted to the upper left of the flow pattern map while showing a higher pressure drop than horizontal pipeline due to the combined effect of pressure difference and gravity. The simulation results can be used as a platform for better understanding on more complex cases of gas, oil and water concurrent flow in pipelines.

1. Introduction

Multiphase flow is defined as a combination or simultaneous flow of several phases, which might be liquid, solid or gas. The two distinct phases can be a combination of liquid-liquid, gas-liquid, or solid-liquid phases [1]. These two different phases flow and move together inside the piping system.

The investigation and research area of two-phase flow can be categorized in the form of analysis of flow patterns, pressure drop, heat transfer and void fraction [2,3,4]. The measurement and investigation for the liquids holdup and flow patterns of the dispersed phases received typically less attention for oil-water system as compared to a gas-oil system [5]. Therefore, further prediction on the flow pattern and pressure drops of waxy crude oil and water flow in both horizontal and inclined pipelines, and investigation for the liquid-liquid two-phase flow still in an ambiguity condition. Oil-water flow in a pipeline system is a common phenomenon that happens at various transportation applications all over the world.

During the transportation stage of the oil using a long-distance pipeline system, the presence of water flowing together with oil has become very serious phenomenon since the presence of water contributed to the corrosion effect [5,6,7,8]. One of the main factors that contribute to the fraction amount of oil-water in piping system is the liquid flow patterns [10]. The flow pattern of the liquid/gas consists of several categories such as bubbly flow, stratified-wavy flow, stratified flow, plug flow, intermittent flow, annular flow, slug flow and mist flow. Each type of the flow pattern shows different flow behavior. For example, a stratified flow is defined as the type of flow pattern which occurred at low liquid-liquid/gas velocities with a complete separation of the two-phases in the pipeline system. The liquid with higher density will settle down at the bottom part of the piping structure while the liquid with a slightly lower density will go to the top of the piping structure. Other than that, a bubbly flow is defined as the type of flow which the gas was dispersed in the liquid with a higher concentration in the upper half of the tube. This condition occurs in the piping system due to the buoyancy effect. According to [5], bubbly flow only occurs at a slightly higher mass flow rate in a horizontal flow.

Most of the research works mainly performed on mineral oil, paraffin oil or kerosene [11]. In Malaysia, most of the oilfields were producing waxy crude oil. This phenomenon is due to the presence of naphthenic and/or paraffin in the crude oil composition. [12] was the only researchers used Malaysia waxy crude oil in their studies related to oil-water two-phase flow in horizontal pipes.

Dealing with an oil-water mixture in a pipeline leads to unique and complex problems in the oil and gas industry due to its complicated rheological behavior [13]. This situation is worsened as the number of research work done on crude oil-water flow in pipes were very limited [12]. Thus, this simulation study has been conducted to acknowledge the findings by developing a simulation study using PIPESIM to predict the flow behaviors (i.e., flow pattern and pressure drop) of waxy crude oil-water flow in pipes at different flow rates and water cuts above wax appearance temperature (WAT).

Based on the theory, there are three forces which may affect the liquid-liquid flow either in upward and downward direction which are gravity force, inertia force and buoyancy force. Figure 1 and figure 2 shows free body diagram of forces in upward and downward flow direction.

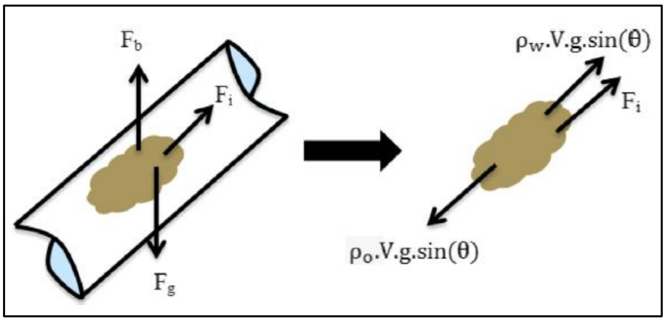

Figure 1. Free body diagram in upward flow direction.

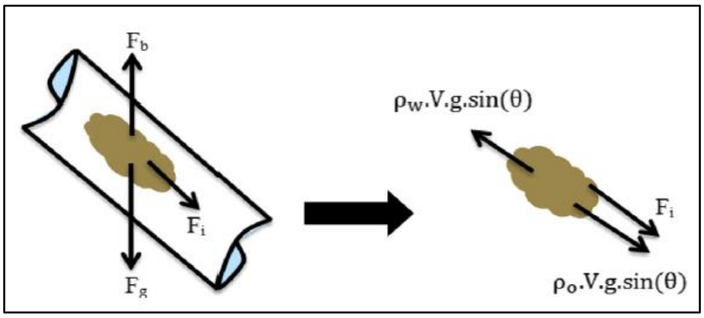

Figure 2. Free body diagram in downward flow direction.

Where F_b, F_g and F_i represent buoyancy force, gravity force and inertia force, respectively. V is the volume of oil bubble and θ is an inclination angle of pipeline. Meanwhile, ρ_w and ρ_o are water density and oil density, respectively.

In figure 1, oil bubble is flowing in upward direction and flow regimes can be predicted from the Newton's second law as in equation (1):

$$F_i + (\rho_w - \rho_o).V.g.\sin(\theta) = m_b.a \tag{1}$$

Where a represents the acceleration of the bubble and m_b represents the oil bubble mass. Based on the equation (1), it is understandable that the density difference between water and oil $(\rho_w - \rho_o)$ is a positive value. This will cause the bubble to accelerate and increase in the velocity of the bubble with the increment of inclination angle.

In figure 2, oil bubble is flowing in downward direction and flow regimes can be predicted from the Newton's second law as in equation (2):

$$F_i + (\rho_o - \rho_w).V.g.\sin(\theta) = m_b.a \tag{2}$$

Based on the equation (2), it is clear that the density difference between oil and water $(\rho_o - \rho_w)$ is a negative value. This will cause the bubble to decelerate and reduce in the velocity of the bubble with a decrement of inclination angle. In addition, the study clarified that all temperature during simulation remain constant (isothermal), at the WAT condition, and assume wax deposits in the pipeline.

2. Methodology

The simulation study was successfully conducted at Petroleum Engineering Modeling and Simulation Laboratory, Faculty of Chemical and Energy Engineering using PIPESIM software. This simulation study used pipeline and facilities analysis to determine the flow behavior characteristics such as flow pattern and pressure drop at horizontal pipeline and at inclination angle of -15˚. OLGAS 7.3.1 (3 phase) was used as horizontal correlations in this study.

2.1. Fluid Modelling

Fluid modelling is an elementary aspect of multiphase flow simulation. It is important to create one or more fluid models before running any simulation study. Fluid models are used to define phase behavior, provide transport and physical properties of the fluid required. Table 1 shows the fluid data used in this study from the experimental research done by [12]. Malaysian waxy-crude oil composition from [12] was described in appendix A. All the crude oil components and their percentage by weight obtained from [12] were added as input data of fluid composition in PIPESIM.

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Table 1. General properties of crude oil [12].

Descriptions	Crude Oil
API gravity (ºAPI)	41.4
Density (kg/m^3)	818
Dynamic viscosity @ 30ºC (cp)	1.75
Flash point (ºC)	<19
Pour point (ºC)	18
WAT (ºC)	30
Wax content (wt%)	16.15
Asphaltenes (wt%)	0.06
Retention time (min)*	<1

*Retention time is separation time between oil and water

2.2. Pipeline and Facilities Model

Simple horizontal and inclined pipeline model has been developed using PIPESIM. Parameters for each component in the pipeline model was successfully be defined according to experimental work done by [12]. These were the following basic steps to build a pipeline and facilities model using PIPESIM; (1) The SI units was selected in this simulation study. (2) A source was added to the model. (3) The flow line was added to the model and the pipeline characteristics was created based on the data as shows in table 2. (4) A sink was added to the model. (5) The fluid specification and suitable horizontal flow correlation were define using OLGAS v. 7.3.1 (3-phase). (6) The model was saved as shows in figure 3 and simulation has been conducted.

Table 2. Pipe specifications from [12].

Data	Pipeline
Type of pipe	Stainless steel
Inside diameter	2 in.
Wall thickness	0.27 in.
Roughness	0.0018 in.
Horizontal distance	3 meters
Elevation difference	0 (horizontal) -0.776 (inclined -15˚)
Heat transfer coefficient	0.2
Ambient temperature	30ºC

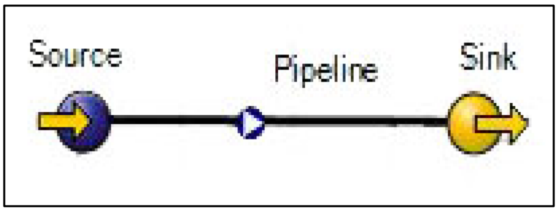

Figure 3. Simple model of pipeline.

For this simulation study, nine different scenarios were conducted on waxy crude oil-water two-phase flows at horizontal and inclination angle of -15˚ downward conditions. The water cut varies from 10 to 90%. While the flow rates of oil and water flowing in the pipelines was varied from 2.03 to 16.21 cm^3/s at ambient condition. A total of 72 runs were accomplished in this simulation works in order to study the flow pattern and pressure drop of waxy crude oil-water in pipeline.

3. Results and Discussion

3.1. Flow Pattern Map

PIPESIM is able to identify the flow pattern map of waxy crude oil-water two-phase flow in pipelines throughout respective water cuts and flow rates. The water cuts were ranging from 0.1 to 0.9 while the flow rates were ranging from 2.03 to 16.21 cm^3/s. Figure 4 represents the flow pattern map of waxy crude oil-water two-phase flow generated using PIPESIM.

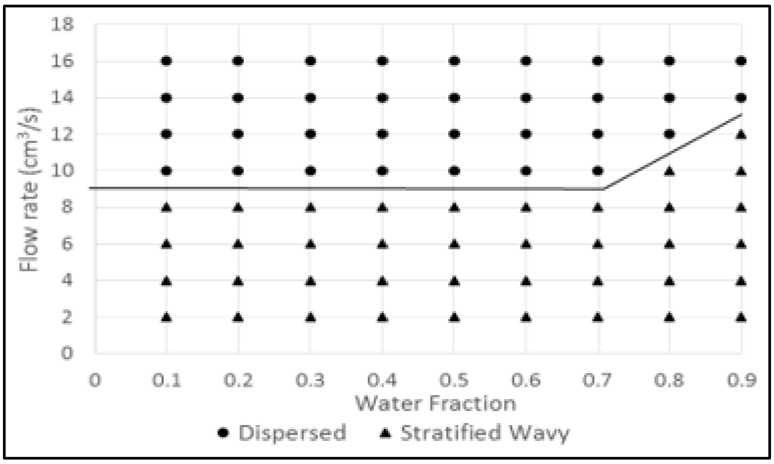

Figure 4. Flow pattern map generated by PIPESIM.

There were only two types of flow patterns that can be identified by using OLGAS 7.3.1 (3-phase) correlation in PIPESIM; Stratified wavy and dispersed flow. Stratified flow was clearly observed in figure 4 for flow rates ranging from 2.03 – 12.15 cm^3/s for all water fractions. According to [14], stratified wavy flow can be categorized when two layers of water and oil are completely separated with water flows at the bottom while oil flows at the top of the pipeline. At low flow rates, oil and water flow tend to fully segregated due to the gravity effect occurs in the pipeline [15]. Furthermore, dispersed flow was clearly observed for flow rates ranging from 10.13 – 16.21 cm^3/s for all water cuts. The respective phases were no longer continuous or segregated as the flow rate increased. [16] stated that velocity of the mixture and water fraction affect the dispersed flow either it is existed in semi or full dispersed from one phase to the other phase.

3.1.1. Comparison of Flow Pattern Map. A comparison study was made on flow pattern maps of waxy crude oil generated using PIPESIM with experimental work done by [12] in order to realise the objective in this research.

Based on figure 5, it was found that the experimental result of flow pattern maps were slightly differences with simulation result generated by PIPESIM for horizontal pipeline as shows in figure 4. There were five flow patterns found by [12] in their experimental works, namely stratified wavy flow (STW), stratified wavy with semi dispersed flow at interface and oil film (STSD&O), semi dispersed flow with semi emulsion at interface and thin oil film (STDE&TO), dispersion of water in oil and oil continuous with emulsion (DWE) and dispersion of oil in water with water continuous (DO). Compared to this simulation study, only two types of flow patterns could be identified using OLGAS 7.3.1 (3-phase) correlation in PIPESIM which were stratified wavy and dispersed flow.

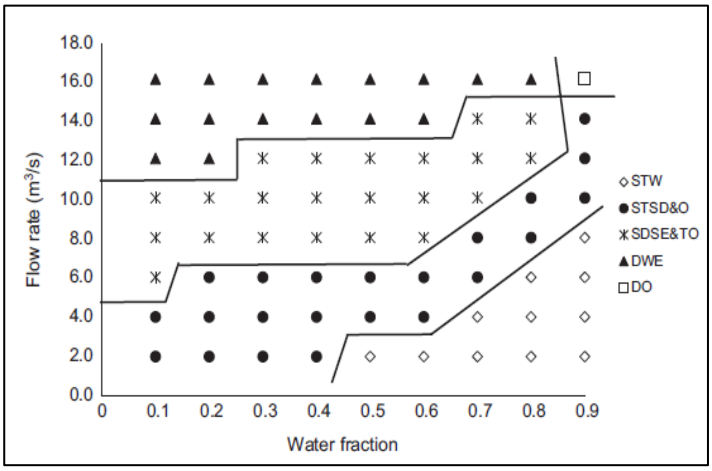

Figure 5. Flow pattern map of waxy crude oil-water generated by [12].

Based on the experimental work done by [12], stratified wavy with semi dispersed flow at interface and oil film (STSD&O) could be clearly observed at flow rates ranging from 2.03 to 14.18 cm^3/s for all water fractions and stratified wavy flow (STW) could be clearly observed during the low and intermediate flow rates ranging from 2.03 – 8.10 cm^3/s for water fraction greater than 0.5. Whereby, stratified wavy flow identified using PIPESIM was in the range from 2.03 – 12.15 cm^3/s for all water fractions. For dispersed flow, semi dispersed flow with semi emulsion at interface and thin oil film (SDSE&TO) could be clearly seen in the experimental work done by [12] at water fraction ranging from 0.1 to 0.8 with flow rates from 6.08 – 14.18 cm^3/s.

Next, dispersion of water in oil and emulsion (DWE) could be seen at water fractions from 0.1 to 0.8 with flow rates ranging from 12.15 – 16.21 cm^3/s while dispersion of oil in water with water continuous (DO) could be clearly observed at higher flow rate, 16.21 cm^3/s for higher water fraction at 0.9. Whereby, the dispersed flow identified by PIPESIM was ranging from 10.13 – 16.21 cm^3/s for water cut ranging from 0.1 to 0.9. According to [17], while conducted an experimental work to study oil-water flow in horizontal pipeline, they concluded that low density difference between these two phases (oil-water) and the viscosity of the oil were affecting the flow patterns notably. Thin oil film that produced inside of the wall's pipe affects the flow pattern. According to [12], the wettability inside wall of the pipeline also causes the disturbances of flow behavior.

3.2. Pressure Drop Analysis

In this simulation study, there was a relationship between pressure drop, flow patterns and flow rates. This statement was supported by [15], [16] and [18]. As shown in figure 6, pressure drop obtained in this simulation work increased with flow rates and water fraction**.**

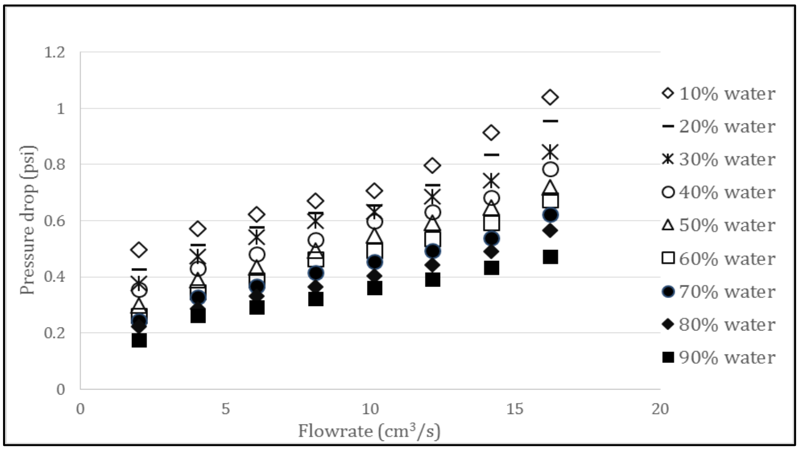

Figure 6. Pressure drop versus flow rate at various water fractions.

Based on figure 6 and table 3, it is shown that at the highest flow rate which is 16.21 cm^3/s and lowest water fraction, $C_w = 0.1$, highest pressure drop of 1.04 psi was recorded. Whereby, at the lowest flow rate which is 2.03 cm^3/s and lowest oil fraction, $C_o = 0.1$, lowest pressure drop of 0.174 psi was recorded.

Table 3. Statistics of pressure drop for different flow rate and oil-water fraction.

Flow rate (cm^3/s)	Minimum pressure (psi)	Maximum pressure (psi)	Average	Standard deviation
2.03	0.174	0.498	0.317444	±0.098224
4.05	0.263	0.573	0.400111	±0.099238
6.08	0.293	0.623	0.442333	±0.101735
8.10	0.321	0.672	0.498556	±0.112938
10.13	0.362	0.708	0.539333	±0.111575
12.15	0.392	0.798	0.588889	±0.127232
14.18	0.435	0.913	0.652889	±0.148746
16.21	0.472	1.040	0.741778	±0.172892

3.2.1. Comparison of Pressure Drop. A comparison study was made on pressure drop of waxy crude oil generated using PIPESIM with experimental work done by [12] as shows in table 4.

Table 4. Comparison of pressure drop between simulation work and experimental work done by [12].

Flow rate (cm^3/s)	Minimum pressure (psi)		Maximum pressure (psi)	
	Simulation	Experiment	Simulation	Experiment
2.03	0.174	0.44	0.498	1.36
4.05	0.263	0.64	0.573	2.59
6.08	0.293	0.76	0.623	1.86
8.10	0.321	0.87	0.672	2.02
10.13	0.362	1.01	0.708	2.16
12.15	0.392	1.17	0.798	2.39
14.18	0.435	1.33	0.913	2.87
16.21	0.472	1.56	1.040	3.86

Based on table 4, it was noticeable that the results of pressure drop obtained from simulation work were less than the results that acquired by [12], but there are similarities in term of curve generated. There might be some other elements that caused the disturbances in waxy-crude oil-water flow behavior in pipelines. Pipe roughness, liquid rheology and pipe wettability were the elements that might affect the pressure drop. Stainless steel pipes was used by [12] while conducting their experimental work to study the flow behavior of waxy crude oil-water two-phase flow, therefore pipe roughness and pipe wettability could be the contributing factor which may affect the value of pressure drop.

Inside wall of the stainless-steel pipe can be oil wet and water wet. According to [19], pressure drop can either be higher or lower when oil-water flows together in pipeline, depending on the types of wettability. The pressure drop is lower when the inside wall of the pipeline is a water wet and vice versa [19]. Concurrently, another major contributor to the pressure loss in pipeline is pipe roughness. [20] stated that pressure drop is created inside the pipeline of liquid-liquid flow due to the interference from pipe roughness may cause liquid not moving smoothly inside the pipeline.

3.3. Inclination Analysis

3.3.1. Flow Pattern Map. Further analysis was made by making the horizontal pipeline inclined -15˚ downward in order to analyse the flow pattern map of waxy crude oil-water in pipeline. Figure 7 shows the flow pattern maps of waxy crude oil-water flow in the inclination angle of -15˚ downward generated by PIPESIM.

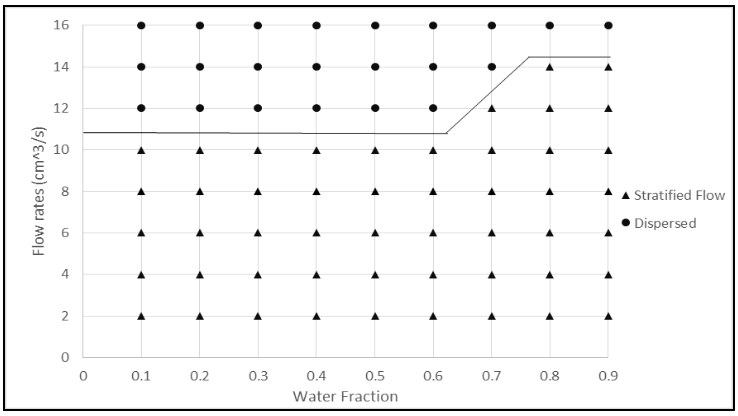

Figure 7. Flow pattern maps of waxy crude oil-water flow in -15° downward from simulation work.

Figure 7 shows that two types of flow patterns were identified using PIPESIM; stratified wavy and dispersed flow. The boundary between stratified and dispersed flows shifts slightly to the upper left when the pipeline was inclined (-15˚ downward). Stratified wavy was clearly seen in this simulation study during flow rates ranging from 2.03 – 14.18 cm^3/s for all water fractions. As for dispersed flow, this flow pattern was clearly seen during flow rates ranging from 12.15 – 16.21 cm^3/s for water cut ranging from 0.1 until 0.9. According to [21], stratified wavy flow becomes dominant flow as the transition boundaries between stratified and non-stratified shifts to the upper left of the flow pattern map when decreasing the inclination angle of the pipeline.

3.3.2. Comparison of flow pattern map (horizontal and inclined -15⁰ pipeline). Comparison study of flow pattern maps was made between horizontal pipeline and -15˚ inclined pipelines. It is shown that the transition boundary between stratified and non-stratified flow shifts to the upper left of the flow patterns map. According to [21], stratified flow become supreme and the transition boundaries between stratified and non-stratified shifts to the upper left of the flow pattern map when decreasing the inclination angle of the pipeline. This is because buoyancy force will decelerate the dispersed phase and gravity force accelerates the dispersed phase for inclined downward flow. Since gravity force is greater than buoyancy force, therefore velocity of dispersed phase was decelerating. It is because wax density is greater than oil density. Thus, the differentiation between buoyancy and gravity force turns out greater as the rise of pipeline inclination angle.

3.3.3. Pressure Drop. Figure 8 represents the pressure drop of waxy crude oil-water two-phase flows at -15° inclination generated by PIPESIM and table 5 shows the statistics of pressure drop from simulation study.

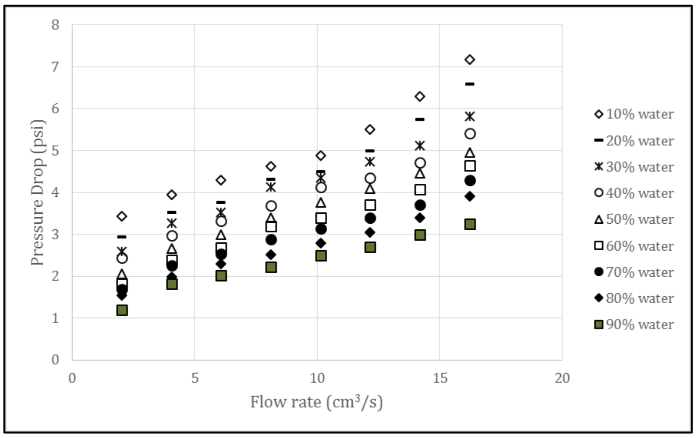

Figure 8. Pressure drop versus flow rate at various water fraction for -15⁰ inclined pipeline generated by PIPESIM.

Table 5. Statistics of pressure drop for PIPESIM.

Flow rate (cm^3/s)	Minimum pressure (psi)	Maximum pressure (psi)	Average	Standard deviation
2.03	0.217	0.541	0.360444	±0.098224
4.05	0.306	0.616	0.443111	±0.099238
6.08	0.336	0.666	0.485333	±0.101735
8.10	0.364	0.715	0.541556	±0.112938
10.13	0.405	0.751	0.582333	±0.111575
12.15	0.435	0.841	0.631889	±0.127232
14.18	0.478	0.966	0.700333	±0.152956
16.21	0.515	1.100	0.787089	±0.176616

Based on figure 8 and table 5, it is shown that at the highest flow rate which is 16.21 cm^3/s and lowest water fraction, $C_w = 0.1$, highest pressure drop of 1.10 psi was recorded. Whereby, at the lowest flow rate which is 2.03 cm^3/s and lowest oil fraction, $C_o = 0.1$, lowest pressure drop of 0.217 psi was recorded.

3.3.4. Comparison of pressure drop (horizontal and inclined -15⁰ pipeline. Table 6 shows the comparison of pressure drop value between horizontal and -15⁰ inclined pipeline obtained from simulation study using PIPESIM.

Table 6. Comparison of pressure drop between horizontal and -15° inclined pipeline generated by PIPESIM.

Flow rate (cm^3/s)	Minimum pressure (psi)		Maximum pressure (psi)	
	Horizontal pipeline	-15° inclined pipeline	Horizontal pipeline	-15° inclined pipeline
2.03	0.174	0.217	0.498	0.541
4.05	0.263	0.306	0.573	0.616
6.08	0.293	0.336	0.623	0.666
8.10	0.321	0.364	0.672	0.715
10.13	0.362	0.405	0.708	0.751
12.15	0.392	0.435	0.798	0.841
14.18	0.435	0.478	0.913	0.966
16.21	0.472	0.515	1.040	1.100

Based on table 6, the results of pressure drop generated by PIPESIM at -15˚ inclined pipelines were greater than those in horizontal pipelines. This condition occurs when the flow is driven by the combined effect of pressure difference and gravity. Gravity effect supports downward flow but has no effect on the flow rate in the horizontal condition. Downward flow can occur even in the absence of an applied pressure difference. The flow rate increases as the tilt angle of the pipeline from the horizontal is reduced to the negative direction but would reach its maximum value when the pipe is vertical.

4. Conclusion

A simulation study of waxy crude oil-water two-phase flow in pipeline system has been successfully conducted using PIPESIM. A total of 72 runs were accomplished in this simulation works. The water cut was varied from 10 to 90%, while the flow rates of oil and water flowing in the pipelines were varied from 2.03 to 16.21 cm^3/s at ambient condition. The following conclusions were made accordingly based on the analysis of the simulation results:

(1) A simulation model was successfully developed using PIPESIM based on the experimental data obtained from [12] which all the components of crude oil listed in Appendix A were taken into account during the simulation study.

(2) There was slightly difference in terms of flow pattern generated from experimental work done by [12] and this simulation work. PIPESIM only enables to identify two types of flow patterns which are stratified wavy and dispersed flow.

(3) A flow regime was successfully generated using PIPESIM for the waxy crude oil-water two-phase flow system at 30˚C which is above WAT. It was then compared with the flow regimes from the previous researchers such as [22]. In fact, Wang and Gong was the only researcher that have used actual crude oil in the oil-water two-phase flow studies. There were discrepancies in the form of flow patterns and flow regions due to the waxy crude oil compositions and characteristics. Generally, different types of fluid used in a two-phase flow system produce different flow behaviours.

(4) The highest pressure drop of 1.04 psi was recorded in horizontal pipeline at the highest flow rates which is 16.21 cm^3/s and at the lowest water fraction, $C_w = 0.1$. Whereby, the lowest pressure drop of 0.174 psi was recorded in horizontal pipeline at the lowest flow rates which is 2.03 cm^3/s and at the lowest oil fraction, $C_o = 0.1$.

(5) Pressure drop that was generated from this simulation work was lower than published data conducted by [12]. There might be some other elements that caused the disturbances in waxy crude oil-water flow behaviour in pipelines. Pipe roughness and pipe wettability were the other elements that might affect the value of pressure drop.

(6) By decreasing the inclination angle of the pipeline with -15º downward, the stratified flow became a dominant flow pattern. The transition boundary between stratified and non-stratified flow shifted to the upper left of the flow pattern map. Generally, buoyancy force will decelerate the dispersed phase and gravity force accelerate the dispersed phase for inclined downward flow. Since gravity force is greater than buoyancy force, the velocity of dispersed phase decelerates.
(7) The highest pressure drop of 1.10 psi was recorded in -15˚ inclined pipeline at the highest flow rate which is 16.21 cm^3/s and lowest water fraction, $C_w = 0.1$. Whereby, the lowest pressure drop of 0.217 psi was recorded at the lowest flow rate which is 2.03 cm^3/s and lowest oil fraction, $C_o = 0.1$.
(8) Pressure drops generated by PIPESIM at -15˚ inclined pipeline were greater than those in horizontal pipelines when the flow is driven by the combined effect of pressure difference and gravity. Gravity effect supports downward flow, but it has no effect on the flow rate in horizontal conditions. Downward flow can occur even in the absence of an applied pressure difference.

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Appendixes
Table A1 consists of Malaysian waxy crude oil composition data obtained from [12] was attached in appendix A.

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Appendix A

Table A1. Malaysian waxy crude oil composition data obtained from [12].

Number of components	Components	Carbon, C	Percentage (%) by weight
1	Nonane	C_9H_{20}	2.40
2	Decane	$C_{10}H_{22}$	3.94
3	Undecane	$CH_3(CH_2)9CH_3$	1.64
4	Hexacosane	$CH_3(CH_2)24CH_3$	3.31
5	Pentacosane	$CH_3(CH_2)23CH_3$	3.09
6	Tetradecane	$CH_3(CH_2)12CH_3$	3.68
7	Pentadecane	$CH_3(CH_2)13CH_3$	4.20
8	Hexadecane	$CH_3(CH_2)14CH_3$	5.07
9	Heptadecane	$CH_3(CH_2)15CH_3$	4.38
10	Tetracosane	$CH_3(CH_2)22CH_3$	4.71
11	Octacosane	$CH_3(CH_2)26CH_3$	3.89
12	Nonadecane	$CH_3(CH_2)17CH_3$	4.33
13	9,10-Dihydrophenanthracene	$C_{14}H_{12}$	4.00
14	Icosane	$C_{20}H_{42}$	4.56
15	Heneicosane	$CH_3(CH_2)19CH_3$	4.60
16	Benzeneacetic acid	$C_8H_8O_2$	3.96
17	Triacontane	$CH_3(CH_2)28CH_3$	4.08
18	Allylpentaspiro [3.0.3.0.3.0.3.0.3.1] henicosan-21	$C_{21}H_{30}O$	3.38
19	Tricosane	$CH_3(CH_2)21CH_3$	4.64
20	Tetracosane	$H(CH_2)21CH_3$	3.94
21	Docoane	$CH_3(CH_2)20CH_3$	2.72
22	Pentaosane	$CH_3(CH_2)23CH_3$	4.28
23	2’,4’-Dimethyloxanilic acid	$C_8H_{16}O_2$	3.32
24	2-Mehyl-3-phenyl-1*H*-indole	$C_{15}H_{13}N$	3.19
25	Dodecahydropyrido[1,2-b] isoquinolin-6-one	$C_{13}H_{21}NO$	5.97
26	1,3-Dimethyl-4-azaphenanthrene	$C_{15}H_{13}N$	0.55
27	2-(Acetoxymethyl)-3-(methoxycarbonyl)biphenylene	$C_{17}H_{14}O_4$	0.95
28	3,3-Diisopropoxy-1,1,1,5,5,5-hexamethyltrisiloxane	$C_{21}H_{32}O_4Si_3$	1.23