Model T as Congeal Determine In Langgak Field Pipeline

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Abstract

Congeal in the pipeline is one of the biggest problems faced by PT.SPR Langgak in piping crude oil from production wells to oil processing unit caused by decreasing oil temperature. The purpose of this study is to study the effect of environmental temperature on fluid temperature in the pipeline, study the effect of wind speed on fluid temperature in the pipeline and to determine the location of the occurrence of congeal in PT.SPR Langgak pipeline. The research method used in determining the location of the trial with the model T is to use analytical methods in Matlab software by entering parameters of pipe temperature, viscosity, density, fluid velocity, wind speed and environmental temperature. The location of the occurrence of congeal in the pipeline determined by Model T is the location of the occurrence of congeal in the Zone C pipeline with a mean error of the model T is 1.88%. This model T can be applied provided the paraffin content is 15-60% and the pipe characteristics (pipe thickness, pipe diameter and pipe material) are the same.

Keywords: congeal, environmental temperature, fluid temperature, model T and pipeline

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INTRODUCTION

The oil and gas industry is one of the largest energy supply industries in the world. Massive exploration and exploitation is carried out all the time in various parts of the world including in Indonesia. This happens because oil and gas are still the main components of energy providers before renewable energy can be mass produced at low cost (Hadi & Jumarlis, 2013).
Exploration and exploitation activities are in the upstream oil and gas region. The upstream oil and gas area consists of the onshore and offshore sectors. The onshore sector is the sector that has the most problems in the upstream oil and gas region, especially in the pipeline. These problems are one of the biggest problems that are almost faced by all upstream oil and gas industries in Indonesia, including by PT. SPR Langgak.

In its case, the problem of the crude oil pipeline is caused by a shrinking oil flow, which can reduce crude oil production. Problems that often occur due to the influence of congeal, but some cases also found the formation of deposits called crust (scale) in the pipe (Syahri & Sugiarto, 2008). This depends on the crude oil composition of each production field/ well. For some upstream oil and gas industries this problem can be overcome by using the electrical heater jacket method. But the use of the electrical heater jacket requires a very high cost in the installation and maintenance, so that certain upstream oil and gas industries use the method (Arisya, Juniati, Sari, & Ulfah, 2014).

Congeal in the pipe is caused by changes in temperature and pressure along with changes in weather that occur in the field/ production well. Weather changes that occur in the production field/ well can change the temperature in the pipe so that it has a direct effect on the oil flow pressure in the pipe, which triggers a loss in the oil flow rate. According to Amin (2013), crude oil that reaches the refinery is only 5/8, the remaining 3/8 is still left in the pipeline due to one of them being congealed in the pipe.

In addition to changes in pressure in the oil flow caused by changes in environmental temperature, other fluid properties such as viscosity and density also affect and cause congeal in the pipe. Pipeline characteristic factors such as pipe type, pipe length, pipe diameter, pipe thickness, pipe roughness and the presence of fittings are also considered to be the cause of congeal in the pipe. For this reason, it is necessary to do further research on changes in environmental temperature on the factors that influence this, so that it influences the reduction of oil flow rate in the pipeline.

Research on this problem has been carried out mostly on horizontal pipelines, but only limited to treatment (Arisya et al., 2014) or just adding platforms (Syahri & Sugiarto, 2008) to oil and pipelines. Therefore, the author raised this issue to explain the effect of decreasing environmental temperature and pipe characteristics on the decrease in oil flow rate. To explain this effect, it is necessary to make an oil flow model in PT.SPR Langgak pipeline.

Energy Transfer

Energy transfer is the study of energy transfer in a material due to differences in temperature gradients. This energy transfer always occurs from a high temperature system to another system that has a lower temperature and stops after both systems reach the same temperature (Yani & Ristyohadi, 2017).

Conduction

Conduction energy transfer is the transfer of energy to solid objects from high temperature regions to low temperature regions. Based on Fourrier, the flow velocity is proportional to the surface area through which energy and temperature differences are inversely proportional to the thickness of the wall passed (Yani & Ristyohadi, 2017).

$$q = KA\frac{\Delta T}{L} \quad (1)$$

Information:

q = conduction ($W/m^2 K$)
K = carbon steel material conductivity (43.3W/m K)
A = surface area located (m^2)
ΔT = temperature difference, Tp - Te (K)
L = pipe length (m)

Convection

Convection energy transfer is an energy transfer mechanism between the solid surface and incompressible and compressible fluids that move and involve conduction and movement of the fluid. The faster the fluid movement, the greater the rate of heat transfer of the convection. On the basis of a process of cooling a heat pipe which is blown by cold air, the process of convection energy transfer will occur through several stages, first heat energy will flow conduction from the surface of the solid object to the adjacent fluid layer particles, then this energy will be lowered away from solid body surface through a convection mechanism, where there are two processes that occur simultaneously, namely a combination of the effects of conduction in the fluid due to random movements between fluid particles that occur microscopically so that fluid particles that have higher energy will move some of their energy to the particles fluid that has a lower energy, as well as the presence of macroscopic fluid movements that will replace the fluid that has been heated around the surface of solid objects with cold fluid (Yani & Ristyohadi, 2017). The convection and Nusselt equations are written as follows (Bird, Stewart, & Lightfoot, 2002)

$$\mathrm{NuD} = \left(0{,}4\frac{\mathrm{Re1}}{2} + 0{,}06\frac{\mathrm{Re2}}{3}\right)\mathrm{Pr0{,}4}\frac{(\mu)1}{4} \quad (2)$$

$$h = \frac{Nu_D\ x\ K}{L} \quad (3)$$

Information:
h = convection ($W/m^2 K$)
L = pipe length (m)
K = carbon steel material conductivity (43.3W/m K)
NuD = Nussetl number, valid if 1 <Re <105 (Nu)
Re = Reynolds number
Pr = Prandtl number

Energy Transfer Model

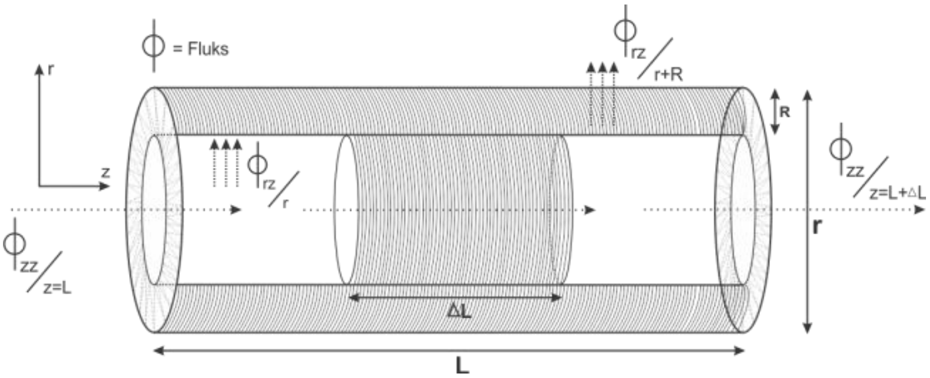

Fig. 1. Increment Model T

Parameters known are (1) pipe skin surface area = W_s, (2) pipe length = L, (3) conduction rate = K_d, (4) wind speed = V_w, (5) environmental temperature = T_e, (6) rate convection = K_v, (7) pipe roughness = R_g, (8) pipe temperature = T_p, (9) area of circle = W_c, (10) pressure = P, (11) density = ρ, (12) viscosity = μ, (13) fluid velocity = V_b, (14) gravity = g, (15) pipe thickness = T_n, (16) fluid volume in pipe = V_p, (17) pipe diameter = r and (18) fluid temperature = T_f. According to the Langgak SPR Management data (2018), the average wind speed (V_w) in Langgak Ujung Batu Village is 0.7 m/s and the fluid velocity (V_b) in the pipe is 2.33 m/s.

The assumptions of congeal problems in the pipeline on the energy balance modeling are known, namely (1) the flow of oil flows in the z direction ($V_z \neq 0$; $V_r = 0$), (2) V_b constant with z and r direction, (3) pipe slope is constant (no influence because the pipe position is relatively straight), (4) pipe thickness is constant ($T_n = 0$) with OD = 1.5mm, (5) wind direction follows z direction, (6) overall pipe material content is constant namely Carbon Steel, (7) the color of the overall #LGK015 pipeline is constant with black, (8) volume of fluid in the pipe = tube volume and (9) fitting in Zone C which divides the section is constant.

In the energy transport application of this problem, there are three hypotheses that occur, namely;
Hypothesis I : Model T can represent fluid temperature data in the PT. SPR Langgak pipeline.
Hypothesis II : Fluid temperature in the PT. SPR Langgak pipeline is influence by environmental temperature.
Hypothesis III : Fluid temperature in the PT. SPR Langgak pipeline is influence by wind speed.

METHODOLOGY

The research was conducted in October 2018 in Langgak Field with the code of production well #LGK015 PT. SPR Langgak Ujung Batu Riau Province. Temperature and fluid pressure measurements have been carried out in each zoning on the #LGK015 pipeline PT. SPR Langgak. Viscosity analysis and the density has been done in Minilab PT. SPR Langgak.

The material used in this study is a crude oil sample in the pipeline of each zone. The tools used in this study are Hg Thermometer, Thermometer Gun, Anemometer, Pressure Gauge, Hydrometer Jar, Personal

Computer (PC) which have installed Microsoft Excel software, Matlab MathWorks, Adobe Autocad and Ansys Fluent 6.

The variables used in this study are fixed variables (fluid temperature, pipe pressure, viscosity and density) and variable changes (measurement time, pipe zone, pipe temperature, environmental temperature, fluid velocity and wind speed).

RESEARCH PROCEDURE

Research on energy transfer modeling in the Langgak field pipeline is carried out in several stages, including; (1) depiction of the shape of the pipeline, (2) calculation of pipe characteristics, (3) measurement of parameters for each zoning section in the pipeline, (4) determination of the type of fluid flow, (5) energy transport model T and (6) description of fluid flow patterns in the pipeline.

The energy balance equation obtained is the fluid temperature model (T_f) (Bird et al., 2002). The fluid temperature model can be symbolized by Model T. Where T can be assumed with fluid temperature congeal, because the frozen fluid oil is caused by a decrease in temperature and high paraffin content in the fluid (Wayan, 2008). The value of k (carbon steel heat conductivity) is 43.3 W/mK. By knowing T, it will know the occurrence of plugging and find out the location of the occurrence of congeal in the pipeline. The Model T will be used in each section of the zoning on the pipeline. According to Wayan (2008), the lower the temperature of crude oil, the higher the congeal concentration and oil density in the pipeline. The height of congeal is caused by the content of paraffin crude oil PT. SPR Langgak that is 53.64% (Langgak, 2018). So the model T is a model used in determining fluid temperature in the PT. SPR Langgak pipeline, if it is below the fluid temperature standard in the pipeline, which is 318.71 K, then it is strong that the location in the determination is congeal. The following is the model T equation obtained:

$$\frac{\dfrac{[Vb\,\rho + (Vb\,\rho\,Vb\,Vb) + \left(Vb\,\left(-2\mu\,\frac{Vb}{L} - \rho\,Vb\right)\right] + \rho g}{(Re\,\mathrm{Pr}\frac{\sqrt{f}}{2})k(Tp - Te)} + [Kd\,Te\,Vw]}{\dfrac{D\left(12{,}48\,Pr^{2/3} - 7{,}853\,Pr^{1/3} + 3{,}613\,InPr + 5{,}8 + 2{,}78\,In\,\left[\frac{1}{45}Re\frac{\sqrt{f}}{8}\right]\right)}{[Kv\,Vb\,Ws]}} = Tf \qquad (4)$$

with:

$$f = \frac{1}{4}\left[\frac{D}{L}\right]\left[\frac{P_0 - P_L}{\frac{1}{2}\rho(Vb)^2}\right] \qquad (5)$$

$$P_0 - P_L = 0{,}198\,\left[\frac{2}{\pi}\right]^{\frac{L}{4}}\left[\frac{\mu\,L}{\rho\,R^{19/4}}\right]W^{\frac{L}{4}} \qquad (6)$$

$$w = \frac{Vb}{r} \qquad (7)$$

Fluid temperature data obtained from equation 4 calculated by Matlab software uses ordinary analytical or algebraic methods, because the model T obtained is linear. After the model T data is obtained every section of the pipeline zoning based on time, zone, environmental temperature and wind speed, then the error is tested against the field fluid temperature data. To calculate the error, you can use the following formula.

$$\text{eror (\%)} = \frac{T_{Data} - T_{Model}}{T_{Data}} \text{ x } 100\% \qquad (8)$$

with:

T Model = fluid temperature of model T (K);
T Data = fluid temperature from the field (K).

After the error is obtained each section of the pipeline zoning based on time, zone, environmental temperature and wind speed, then graphs are made the influence of environmental temperature and graph of the influence of wind speed. The aim is to see the effect of environmental temperature and wind speed on the model T that has been obtained.

RESULTS AND DISCUSSION

The data parameters of the research results that have been analyzed for each section of the pipeline zoning for 7 days at 3:00 a.m. 6:00 a.m. 9:00 a.m. 12.00 p.m. 3:00 p.m. 6:00 p.m. 9:00 p.m. and 12.00 a.m. consist of general parameters which are homogeneous in the pipeline consisting of environmental temperature parameters, wind speed and fluid velocity. Obtained environmental temperature data with a range of 293.7-312.9 K and wind speed data with a range of 0.5-0.9 m/s. The fluid velocity data obtained per zonation data by the SPR Management force, namely in Zone A fluid velocity is 3 m/s, Zone B fluid velocity is 2.54 m/s and Zone C fluid velocity is 1.45 m/s. For more details, consider Table 1, the average parameters of environmental temperature and wind speed based on time and velocity of fluid.

Table 1. Average Environmental Temperature Parameters, Wind Speed and Fluid Speed

Parameters	**Time**							
	03am	**06am**	**09am**	**12pm**	**03pm**	**06pm**	**09pm**	**12am**
Env. Temperature (K)	295	296	303	308	304	301	297	296
Average (K)	300.38							
Wind Speed (m/s)	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.6
Average (m/s)	0.7							
Fluid Velocity	**Zone A**			**Zone B**		**Zone C**		
	3 m/s			2.54 m/s		1.45 m/s		

The main parameters consist of fluid temperature, pipe temperature, pressure, viscosity and density. The main parameters are measured based on the daily average accumulation of time. Fluid data obtained with a range of 315.15-347.15 K, pipe temperature data with a range of 315.65-353.25 K, pressure data with a range of 254,930-165,360 Pa, viscosity data with a range of 94 x 10^{-3}-64 x 10^{-3} Pa.s and density data range 956.0-755.1 kg/m^3.

Congeal Location with Model T

Fluid temperature is the temperature measured manually in the #LGK015 field in each zoning section of the pipeline. Based on fluid temperature data obtained in the field that the location of the occurrence of congeal is in section 1 Zone C (pipeline distance 490-534.9 m from well) and section 10 Zone C (distance pipeline 894.1-939 m from well).

Model T is the fluid temperature obtained from energy transport calculations and analyzes. Model T is made to facilitate measurement of fluid temperature in the pipeline without having to manually measure it in the field. Based on time, zone and environmental temperature, the lowest and highest environmental temperature data is selected. The lowest environmental temperature data was selected on October 22, 2018 at 3:00 a.m. with data on environmental temperature which was 293.7 K. The highest environmental temperature data was selected on October 24, 2018 at 12:00 p.m. with data on environment temperature of 312.9 K. The following is an effect of environmental temperature graph on fluid temperature in Fig. 2.

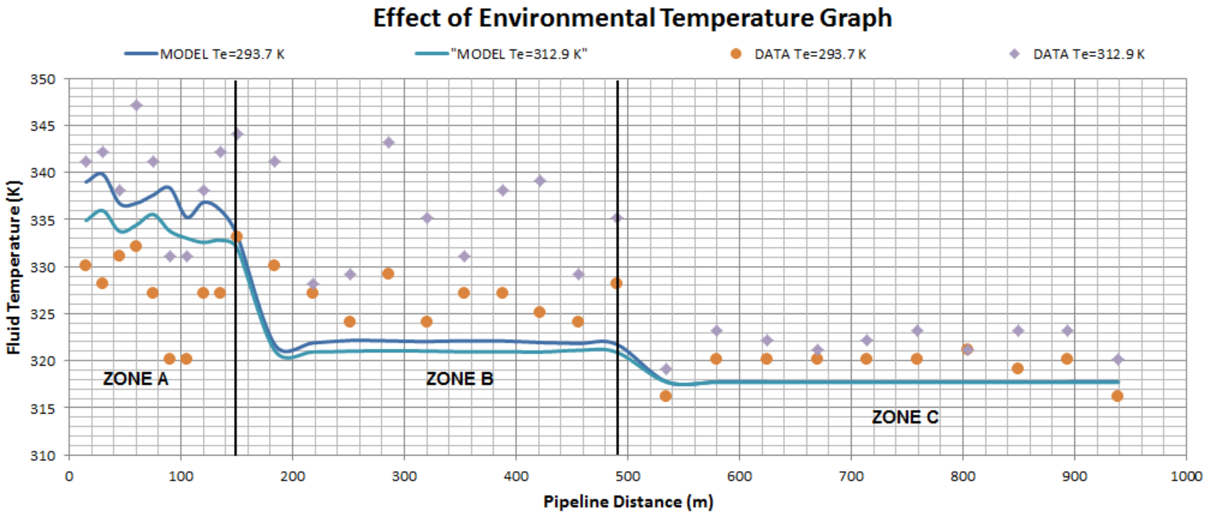

Fig. 2. Effect of Environmental Temperature

Based on time, zone and wind speed, the wind speed data is selected as the lowest and highest. The lowest wind speed data was chosen on October 24, 2018 at 9:00 a.m. with wind speed data of 0.5 m/s. The highest wind speed data was selected on October 26, 2018 at 6:00 p.m. with data on wind speed of 0.9 m/s. The following is a wind speed effect graph on fluid temperature in Fig. 3.

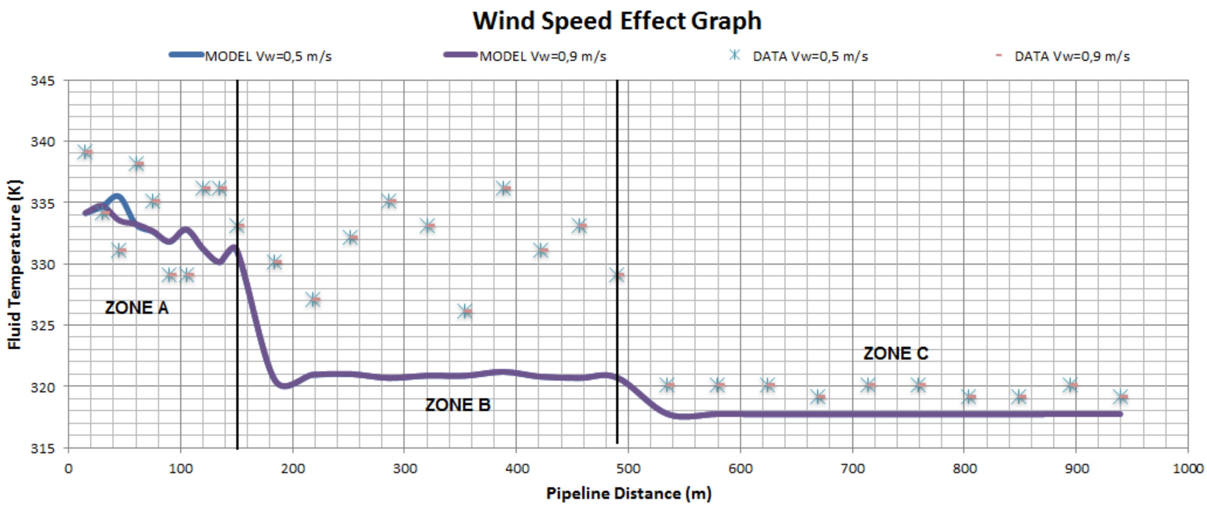

Fig. 3. Wind Speed Effect

The graph of the effect of environmental temperature on fluid temperature in Fig. 2 obtained the lowest and highest model T error on the lowest and highest environmental temperature data, which is 2.04%. In Fig. 2 it is also explained that there is an effect of environmental temperature on fluid temperature in the pipeline. The effect of environmental temperature on fluid temperature causes congeal in the Zone C pipeline. Based on the model T, congeal occurs in all Zone C sections while based on data, congeal occurs only in section 1 Zone C (pipeline distance 490-534.9 m from well) and section 10 Zone C (distance of pipeline 894.1–939 m from well).

The effect wind speed graph on fluid temperature in Fig. 3 obtained the lowest and highest model T error on the lowest and highest wind speed data, which is 1.73%. In Fig. 3, it is explained that there is no effect of wind speed on fluid temperature in the pipeline. Based on the model T, congeal occurs in all Zone C sections while based on data, congeal does not occur in the pipeline. The lowest fluid temperature data on the graph of the effect of the lowest and highest wind speed is 319.15 K, meaning that there is no congeal in the pipeline. This refers to the Management of PT. SPR Langgak (2018), that the formation of wax so that the occurrence of congeal will occur at temperatures below 318.71 K.

Based on the relationship of the effect of changing variables, namely time, zone and environmental temperature, the presence of congeal in the Zone C pipeline will result in an influence on the velocity of fluid in the pipe. The speed of the fluid will shrink because the flow of oil in the pipe shrinks due to plugging (blockage) on the pipe due to congeal. The flow of oil in the pipe will still be able to flow despite the congeal. This was explained by Amin (2013) that the frozen crude oil in the pipe would still be able to flow. The occurrence of congeal in the Zone C pipeline will increase energy transport in the pipe so that it affects the decrease in pipe temperature.

Based on Figure 2 and Figure 3, the average error of the model T with respect to time, zone, environmental temperature and wind speed is 1.88%. Thus, the first and second hypotheses in this study are accepted, namely the model T can represent fluid temperature data in the PT. SPR Langgak pipeline with error rate is 1.88% and fluid temperature in the PT. SPR Langgak pipeline was affected only by the environment temperature.

Determining Color of Fluid Temperature In Pipeline Using Ansys

The results of the analysis with the model T for each pipeline zone section found that Zone C all sections were suspected of occurring in the pipeline. To support the results of analysis with the model T, the flow pattern of each pipeline zone is described by using CFD on Ansys software. The flow pattern described by Ansys aims to compare zones that do not occur congeal (Zone A and Zone B) with zones that occur congeal (Zone C) only in terms of color.

In Zone A, the average Model T was 334.44 K with an average pipe temperature of 342.92 K, average pressure of 214,192 Pa, average density of 777.57 kg/m^3, average viscosity of 67x10^{-3} Pa.s and average fluid flow rate 3 m/s. The following is an illustration of the temperature of the fluid in terms of color using Ansys in Figure 4.

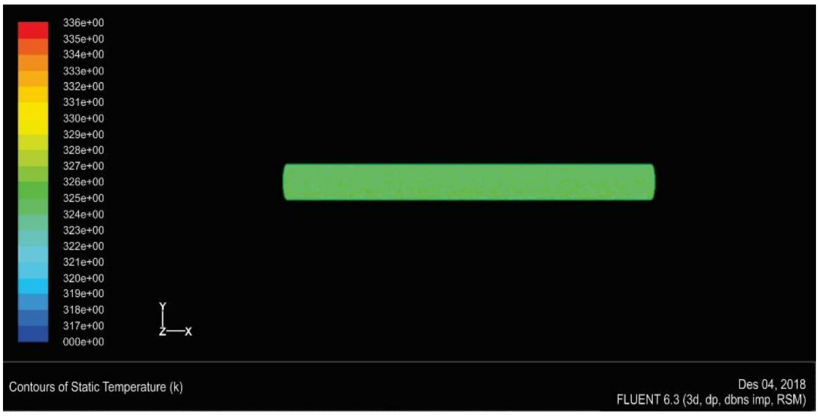

Fig. 4. Zone A with Ansys

In Zone B, the average model T was 321.47 K with an average pipe temperature of 334.69 K, average pressure of 214,192 Pa, average density of 846.26 kg/m^3, average viscosity of 80x10^{-3} Pa.s and average fluid flow rate 2.54 m/s. The following is an illustration of the temperature of the fluid in terms of color using Ansys in Figure 5.

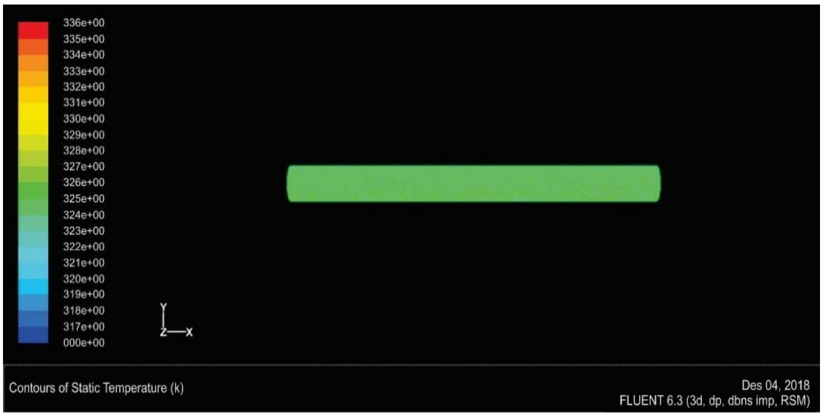

Fig. 5. Zone B with Ansys

In Zone C, the average model T is 317.75 K with a average pipe temperature of 318.35 K, average pressure of 213.847 Pa, average density of 913.83 kg/m^3, average viscosity of 89x10^{-3} Pa.s and average fluid flow rate 1.45 m/s. The following is an illustration of the temperature of the fluid in terms of color using Ansys in Figure 6.

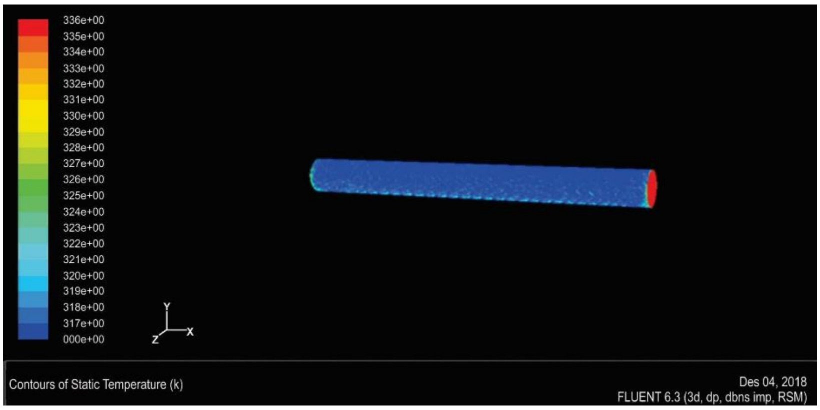

Fig. 6. Zone C with Ansys

Observations in Figure 4 and Figure 5 can be seen that the flow pattern at the same fluid temperature is green. This means that the temperature of the fluid is at an intermediate temperature gradient. Unlike Figure 6, the flow pattern at the fluid temperature is blue. This means that the temperature of the fluid is at the lowest temperature gradient. From the observations of the three images above, that Zone C has occurred congeal because the temperature of fluid (K) is small symbolized in blue in Figure 6. This was stated by Inc (2006), that if it gets higher (towards red) the temperature gradient is then the greater the fluid temperature (K). Conversely, if the lower (towards blue) temperature gradient is lower, the smaller the fluid temperature (K).

CONCLUSION

Based on the results of the oil flow modeling research in the Langgak field pipeline it can be concluded that:

1. There is an effect of environmental temperature on fluid temperature in the pipeline PT.SPR Langgak.
2. There is not effect of wind speed on fluid temperature in the pipeline PT. SPR Langgak.
3. Based on the model T the location of congeal is in the Zone C pipeline of all sections at a distance of 490-939 m from well.

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