PROCEEDINGS
JOINT CONVENTION BANDUNG (JCB) 2021
November 23rd – 25th 2021

Tanjung-Balikpapan Oil Transportation Pipeline Modeling using PertafloSIM – Software developed by Pertamina Upstream Research & Technology Innovation (URTI)

Merry Marteighianti[1], Agus Wibowo Benny[1], Belladonna Maulianda[1], Sudariyanto[1], Welly Setyawan[1], Andre Albert Sahetapy[1], Erma Nur Prastya Ningrum[1], Sumadi Paryoto[1], Hasian P. Septoratno Siregar[2], Darmadi[2]

Abstract

In order to reduce company's dependence on commercial software, PT Pertamina (Persero) represented by the Upstream Research & Technology Innovation department under cooperation with Bandung Institute of Technology has developed in-house software for modeling fluid flow in pipes and wells called PertafloSIM (Steady-State Multiphase Flow Simulator). A study has been conducted to modelling the Tanjung-Balikpapan Oil Transportation Pipeline system using PertafloSIM. The purpose of this study is to test the capability of the PertafloSIM in calculating multiphase flow in pipes including pressure drop calculations based on current flow conditions. The case study used is an oil-water suspension from Tanjung Field which is flowed through a 230 km pipeline to Balikpapan. The regulation of the oil-water suspension ratio also becomes crucial in this transportation system.

The first step is carried out by entering the data reported form the field such as pipe length, outside diameter, inside diameter, elevation, and roughness into PertafloSIM software as well as Oil-Water rate, temperature, API Gravity, Upstream and Downstream Pressure. The PertafloSIM module used in this case study is "Multiphase Black-Oil" which is a module to simulate multiphase flow in pipeline network by using black-oil approach. Furthermore, we run the PertafloSIM software based on the inputted field data and then do a review and analysis.

The results show that changes in inside diameter have the most significant impact compared to other parameters, so we suspect an indication of a narrowing of the pipeline diameter in the field which can be caused by several things such as deposition/scale. We also compare run results between PertafloSIM and PipeSIM Software. Based on the results of study, it shows that PertafloSIM Software is able and reliable to calculate multiphase flow in pipeline.

Introduction

To reduce company's dependence on commercial software, PT Pertamina (Persero) represented by the Upstream Research & Technology Innovation department has developed in-house software for modeling fluid flow in pipes and wells called PertafloSIM (Steady-State Multiphase Flow Simulator under cooperation with Bandung Institute of Technology. PertafloSIM software has proven its capabilities with various types of data compared to commercial software such as PipeSIM. The purpose of this study is to continue testing the capability of PertafloSIM software in calculating multiphase flow in pipes including pressure drop calculations based on current flow conditions.). The case study used is Tanjung-Balikpapan Oil Transportation Pipeline system.

Tanjung field is located in South Kalimatan province of Indonesia, it was discovered in 1937 and located about 230 Km from the nearby Oil Refinery in Balikpapan, East Kalimantan Province (Fig.1). In order to transport Tanjung crude through long hilly pipeline, mixing with water is one of the alternatives that had been chosen, and considered as the most effective way of transport the crude. Mixing ratio of water and Tanjung crude is currently about 65% Tanjung Crude and 35% Water. Mixing of the water and crude is done on a special mixing device, which able to uniformly mix water and crude in the middle of pipe diameter. The regulation of oil-water mixing ratio becomes crucial in this transportation system, it will determine how the flow behavior of the fluid and also the pressure drop of the flow. This condition will be critical for the transport when it flows through uphill and downhill pipeline.

Figure 1: Crude Oil Pipeline Route Tanjung-Balikpapan

Data and Method

Tanjung-Balikpapan Oil Transportation across hilly terrain, which include two main hill about 240 m elevation above sea level. Before refinery, pipeline cross 4.4 Km Balikpapan bay in about 10 m water depth. The pipeline elevation profile is shown in Figure 2. There are 2 Booster Pump between Tanjung to Balikpapan, they are Booster Station I at Batu Butok, and Booster Station II at Longikis. Tanjung-Balikpapan Route Schematic can be seen at Figure 3. The pipeline is 20-inch diameter with total length 237.12 Km.

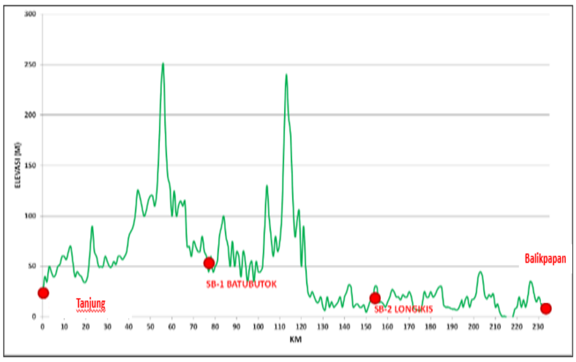


Figure 2: Tanjung-Balikpapan Pipeline Elevation Profile

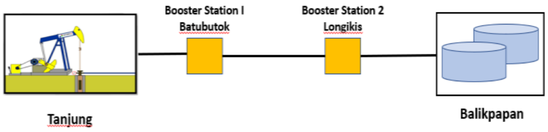


Figure 3: Tanjung-Balikpapan Route Schematic

The first step is carried out by entering data reported from the field such as pipe length, inside diameter, outside diameter, elevation, and roughness, as well as flow rate, temperature, API Gravity and Pressure into PertafloSIM Software. At this stage, the PertafloSIM calculation result will first be validated against the field data, The PertafloSIM module called "Multiphase Black-Oil" will be used in this case study. Furthermore, several scenarios for optimization are carried out such as the sensitivity of the percentage ratio of oil and water as well as pipe diameter. Flow chart of the methodology used can be seen figure 4, while PertafloSIM input data for network model, pipeline segment properties, pipeline elevation profile, and "Source" data can be seen in figure 5 until figure 12.

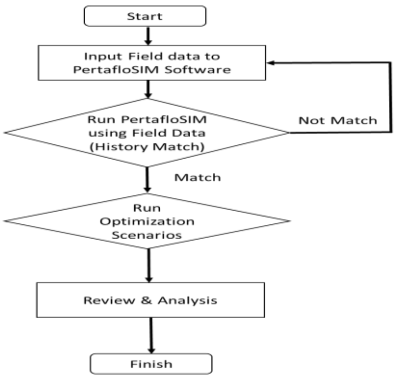


Figure 4: Flow Chart Methodology

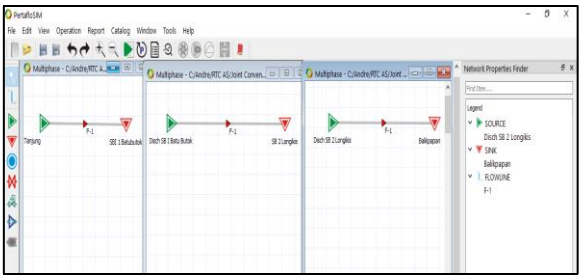
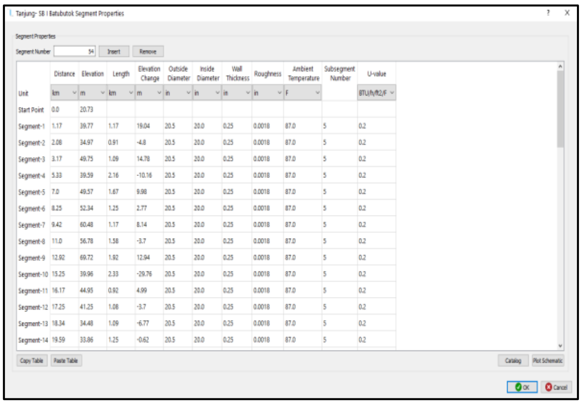


Figure 5: PertafloSIM Network Model



Tanjung- SB I Batubutok Segment Properties

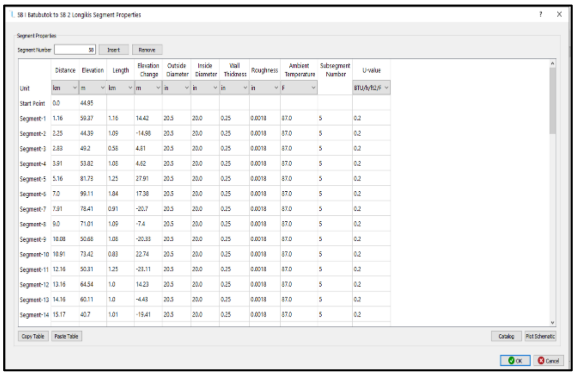
Segment Properties

Segment Number 54 Insert Remove

	Distance	Elevation	Length	Elevation Change	Outside Diameter	Inside Diameter	Wall Thickness	Roughness	Ambient Temperature	Subsegment Number	U-value
Unit	km	m	km	m	in	in	in	in	F		BTU/h/ft2/F
Start Point	0.0	20.73									
Segment-1	1.17	39.77	1.17	19.04	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-2	2.08	34.97	0.91	-4.8	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-3	3.17	49.75	1.09	14.78	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-4	5.33	39.59	2.16	-10.16	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-5	7.0	49.57	1.67	9.98	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-6	8.25	52.34	1.25	2.77	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-7	9.42	60.48	1.17	8.14	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-8	11.0	56.78	1.58	-3.7	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-9	12.92	69.72	1.92	12.94	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-10	15.25	39.96	2.33	-29.76	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-11	16.17	44.95	0.92	4.99	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-12	17.25	41.25	1.08	-3.7	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-13	18.34	34.48	1.09	-6.77	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-14	19.59	33.86	1.25	-0.62	20.5	20.0	0.25	0.0018	87.0	5	0.2

Copy Table Paste Table

Figure 6: Tanjung – SB I Batubutok Segment Properties



SB I Batubutok to SB 2 Longikis Segment Properties

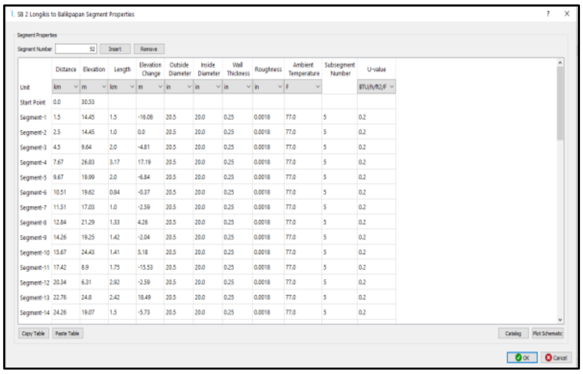
Segment Properties

Segment Number 58 Insert Remove

	Distance	Elevation	Length	Elevation Change	Outside Diameter	Inside Diameter	Wall Thickness	Roughness	Ambient Temperature	Subsegment Number	U-value
Unit	km	m	km	m	in	in	in	in	F		BTU/h/ft2/F
Start Point	0.0	44.95									
Segment-1	1.16	59.37	1.16	14.42	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-2	2.25	44.39	1.09	-14.98	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-3	2.83	49.2	0.58	4.81	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-4	3.91	53.82	1.08	4.62	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-5	5.16	81.73	1.25	27.91	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-6	7.0	99.11	1.84	17.38	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-7	7.91	78.41	0.91	-20.7	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-8	9.0	71.01	1.09	-7.4	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-9	10.08	50.68	1.08	-20.33	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-10	10.91	73.42	0.83	22.74	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-11	12.16	50.31	1.25	-23.11	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-12	13.16	64.54	1.0	14.23	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-13	14.16	60.11	1.0	-4.43	20.5	20.0	0.25	0.0018	87.0	5	0.2
Segment-14	15.17	40.7	1.01	-19.41	20.5	20.0	0.25	0.0018	87.0	5	0.2

Copy Table Paste Table

Figure 7: SB I Batubutok – SB II Longikis Segment Properties



SB 2 Longikis to Balikpapan Segment Properties

Segment Properties

Segment Number 52 Insert Remove

	Distance	Elevation	Length	Elevation Change	Outside Diameter	Inside Diameter	Wall Thickness	Roughness	Ambient Temperature	Subsegment Number	U-value
Unit	km	m	km	m	in	in	in	in	F		BTU/h/ft2/F
Start Point	0.0	30.53									
Segment-1	1.5	14.45	1.5	-16.08	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-2	2.5	14.45	1.0	0.0	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-3	4.5	9.64	2.0	-4.81	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-4	7.67	26.83	3.17	17.19	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-5	9.67	19.99	2.0	-6.84	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-6	10.51	19.62	0.84	-0.37	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-7	11.51	17.03	1.0	-2.59	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-8	12.84	21.29	1.33	4.26	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-9	14.26	19.25	1.42	-2.04	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-10	15.67	24.43	1.41	5.18	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-11	17.42	8.9	1.75	-15.53	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-12	20.34	6.31	2.92	-2.59	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-13	22.76	24.8	2.42	18.49	20.5	20.0	0.25	0.0018	77.0	5	0.2
Segment-14	24.26	19.07	1.5	-5.73	20.5	20.0	0.25	0.0018	77.0	5	0.2

Copy Table Paste Table

Figure 8: SB II Longikis – Balikpapan Segment Properties.

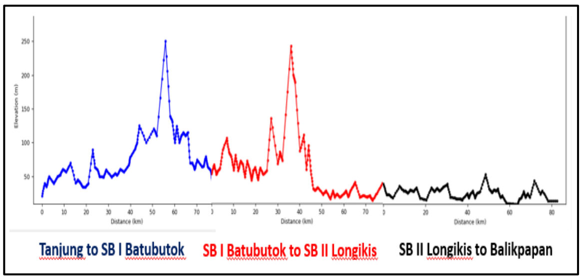


Figure 9: Pipeline Elevation Profile

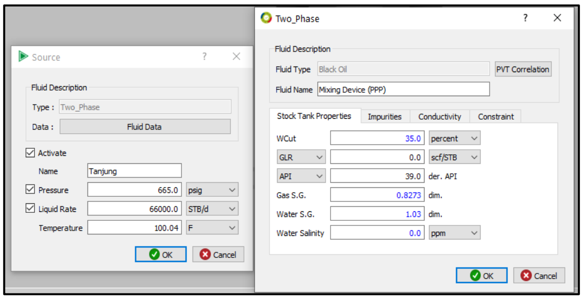


Figure 10: Tanjung "Source" Data

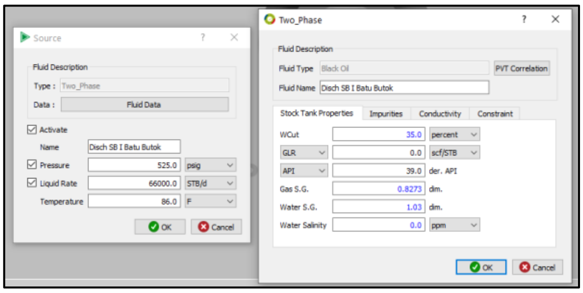


Figure 11: Booster Station I Batubutok Data

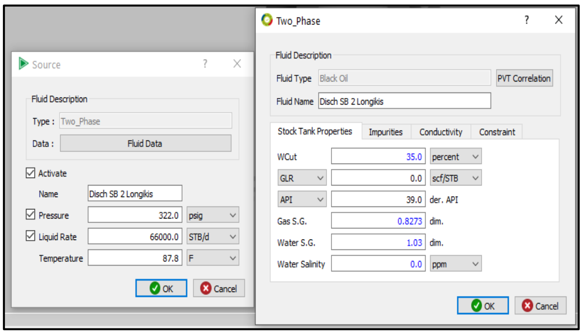


Figure 12: Booster Station 2 Longikis Data

Result and Discussion

The results of the PertafloSIM run using current field data are shown in Table 1, where the outlet pressure/SINK in PertafloSIM has been set as "calculated" so the software will calculate the amount of pressure in the SINK based on input data in SOURCE. The results of the outlet pressure calculation are shown in table 2, where there is a difference between the outlet pressure calculated by PertafloSIM compared to the actual pressure in the field.

PertafloSIM Calculation using current Field Data						
Inlet	Outlet	Inlet Pressure	Outlet Pressure	Pressure Drop	Inlet Temperature	Outlet Temperature
		psig	psig	psig	F	F
Tanjung	SB I Batubutok	665	525.95	139.05	100	91.7
SBI I Batubutok	SB II Longikis	525	441.15	83.85	86	82.8
SB II Longikis	Balikpapan	322	241.91	80.09	87.8	83.8
Actual Field Data						
Inlet	Outlet	Inlet Pressure	Outlet Pressure	Pressure Drop	Inlet Temperature	Outlet Temperature
		psig	psig	psig	F	F
Tanjung	SB I Batubutok	665	420	245	100	86
SBI I Batubutok	SB II Longikis	525	168	357	86	87.8
SB II Longikis	Balikpapan	322	39.2	282.8	87.8	87

Data to be validated

Table 2: Comparison between PertafloSIM Run Results and Field Data.

Based on this, we tried to take several approaches so that the calculation results of PertafloSIM approach the actual field data, such as changing the oil-water ratio, and pipeline inside diameter. Figure 13 is the result of the sensitivity analysis between the change of Oil-Water ratio from 85%:15%, 75%:25%, 65%:35%, 55%:45%, and 45%:55% to the result of outlet pressure at SB I Batubutok, where it can be seen that the change in the oil-water ratio does not have a significant impact on outlet pressure at SB I Batubutok so that in the end it will not have an impact on pressure drop in Tanjung-SB I Batubutok Pipeline and and also the pipeline as a whole.

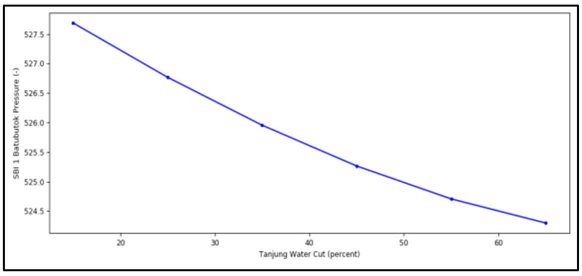


Figure 13: PertafloSIM Sensitivity Analysis Result (Tanjung Water Cut vs Outlet Pressure at SB I Batubutok)

Figure 14 is the result of the sensitivity analysis between the change of inside diameter of Tanjung-SB I Batubutok pipeline to outlet pressure that occur at SB I Batubutok, it can be seen that the inside diameter value which is close to the actual field outlet pressure data is about 17-inch.

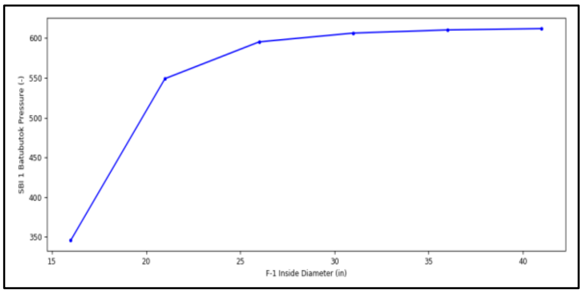


Figure 14: PertafloSIM Sensitivity Analysis Results (Inside Diameter of Tanjung – SB I Batubutok vs Outlet Pressure at SB I Batubutok).

Figure 15 is the result of the sensitivity analysis between the change of inside diameter of SB I Batubutok-SB II Longikis pipeline to outlet pressure that occur at SB II Longikis, the inside diameter value which is close to the actual field outlet pressure data is about 15-inch.

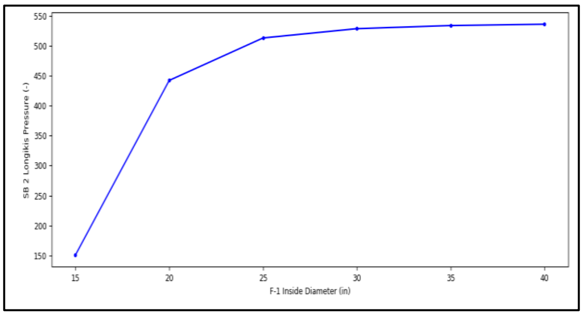


Figure 15: PertafloSIM Sensitivity Analysis Results (Inside Diameter of SB I Batubutok – SB II Longikis vs Outlet Pressure at SB II Longikis).

Figure 16 is the results of outlet pressure at Balikpapan in the form of a node summary, where the inside diameter closest to the actual field data is about 16-inch.

Node Summary

	Name	Type	Pressure	Temperature	Oil Rate	Water Rate	Gas Rate
Unit	-	-	psig	F	STB/d	STB/d	MMscf/d
	Disch SB 2 Longikis	Source	322.0	87.8	42900.0	23100.0	0.0
	Balikpapan	Sink	40.413333	84.47682	42900.0	23100.0	0.0

Figure 16: PertafloSIM Node Summary Results of Outlet Pressure at Balikpapan.

Based on the results of history matching above, changes in inside diameter have the most significant impact compared to other parameters, so we suspect an indication of a narrowing of the pipeline diameter in the field which can be caused by several things such as deposition/scale. The results from Figures 14 to 16 also show that the optimum diameter of the pipeline that produces the lowest pressure drop is around 30-inch.

Table 3 shows PertafloSIM results if not consider two booster pump so that the flow from Tanjung is "direct" to Balikpapan, and then use the above pipeline diameters that match the field data (17-inch, 15-inch, and 16-inch), it can be seen that there was a significant pressure drop from SB I Batubutok to SB II Longikis (about 358.4 psig), while PertafloSIM could not generate the pressure calculation results in Balikpapan, this is presumably because with the existing pipeline diameter and elevation data input, the flow fluid from SB II Longikis cannot reach Balikpapan. Thus, based on this, it can be a recommendation to operators in the field to operate the SB II Longikis booster pump only.

PertafloSIM Calculation (without booster pump)					
Inlet	Outlet	Inside Diameter	Inlet Pressure	Outlet Pressure	Pressure Drop
		inch	psig	psig	psig
Tanjung	SB I Batubutok	17	665	420	245
SBI I Batubutok	SB II Longikis	15	420	61.6	358.4
SB II Longikis	Balikpapan	16	61.6	NaN	-

Table 3: PertafloSIM Calculation Results using Match Pipeline Diameter and Without Booster Pump.

We also tried to analyze the calculation of the minimum Tanjung pressure to reach Balikpapan without using two booster pumps, Figure 17 shows the sensitivity analysis of changes in Tanjung pressure to changes in Balikpapan pressure, it can be seen that the Tanjung pressure needed to reach Balikpapan without a booster pump is around 900 psig.

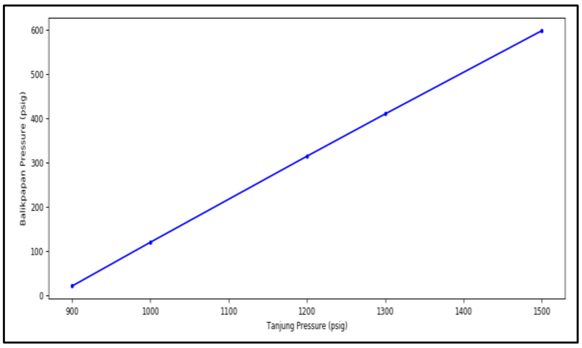


Figure 17: PertafloSIM Sensitivity Analysis Result (Tanjung Pressure vs Balikpapan Pressure) – No booster Pump Consideration.

We also calculated the Tanjung-Balikpapan pressure drop with Commercial Software (PipeSIM) and compared the results with the PertafloSIM calculation (Figure 18), while we used the same inside diameter data as the field data, it can be seen that although there are differences in some pressure points between PertafloSIM and PipeSIM, the pressure drop pattern produced by the two softwares is overall quite similar, so this is a confirmation that if the Tanjung-Balikpapan pipeline data is run with the PipeSIM software, the results will be similar to PertafloSIM..

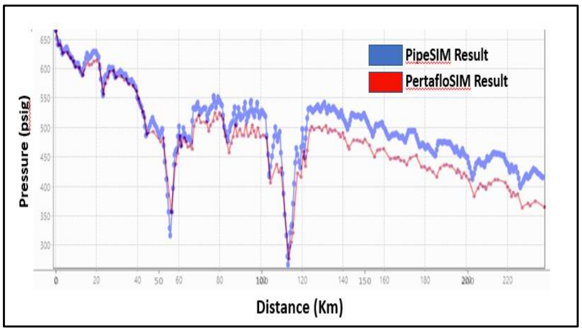


Figure 18: Pressure Drop Comparison between PertafloSIM and PipeSIM

Conclusions

1. A simple pipe modeling and simulation of oil-water flow through a hill was simulated to describe flow behavior such as pressure drop.
2. Regulation of Oil-Water Ratio do not significantly affect the pressure drop performance of the Tanjung-Balikpapan pipeline.
3. Based on the results of history matching to current Field Data, changes in inside diameter have the most significant impact compared to other parameters, so we suspect an indication of a narrowing of the pipeline diameter in the field which can be caused by several things such as deposition/scale.
4. PertafloSIM calculation results show that fluid from Tanjung to Balikpapan can still flow if only activating one booster pump in SB II Longikis and deactivating one booster pump in SB I Batubutok, while without activating two booster pumps, the minimum pressure required at Tanjung is around 900 psig (previously 665 psig).
5. From the results of the comparison of pressure performance between PertafloSIM and PipeSIM both are quite similar, so if the Tanjung-Balikpapan pipeline data is run using the PipeSIM software, the results will be similar to PertafloSIM..
6. More accurate model will be done in future to evaluate other aspects of High Pour Point Transport in pipeline.

References

PERTAMINA Report., 2020, Maintenance and Development PertafloSIM,

PERTAMINA EP Tanjung, 2020, Overview Tanjung Field.

Putra, A. S., and Waspodo, 2004, Society of Petroleum Engineering, SPE 86929

Acknowledgements

The author would like to thank PT PERTAMINA (PERSERO) for permission and support to publish this paper.