IATMI22-002

Flow Assurance Improvement by Injecting Pour Point Depressant Chemical to Heavy Oil Well in South Mahakam Field

Ni Made Truly Pinanti Sastra[*1], Gita Evelina[2]
[1,2]PT. Pertamina Hulu Mahakam
* Email: truly.pinanti-sastra@pertamina.com

Abstract. Background: South Mahakam (SMK) as an offshore field had many challenges to produce and transfer hydrocarbon by underwater pipelines. One of the challenges was the wax formation due to declining temperature in the oil production system. The production was restricted by a heavy oil well with API 28.6º and pour point (PP) 29°C. The oil was thickened at arrival point of a 10 inches-6.5 km underwater pipeline. It was suspected that the paraffin content was crystallized as wax around seabed sections with lowest temperature was 24ºC. Therefore, the wax deposit should be avoided by modifying the fluid handling system. Due to the unavailability of heating process and limited dilution with additional hot liquids, the pour point depressant (PPD) injection could be one of the alternative solutions. In principle, the chemical injection should be adjusted with flowing temperature is above wax appearance temperature (WAT). Therefore, the objective of this project was to study the application of PPD in SMK for solving the flow assurance issue. **Methodology:** There were four main steps in the study methodology. First, the representative samples were collected at well flow line and manifold during stable condition (by monitoring flow & pressure indicators). Second, laboratory test was performed, included WAT analysis by WAT 70X-i analyzer and PP measurement by ASTM D97, to support PPD lab performance test with target PP temperature was <24ºC. Third, the PPD field trial monitored actual PP during baseline period (without PPD injection) and treatment period (with PPD injection) at each end-point pipeline sections during heavy oil stable flow. Finally, the PPD optimum dosage was determined by considering the PP value at downstream section was maintained below target temperature. **Result:** Based on lab test result, the WAT of well effluent was 42.9ºC and PP was 29ºC. PPD performance test showed that 1 out of 2 tested products could modify PP to 20ºC with minimum dosage of 100 ppm. The selected injection point for PPD was at wellhead considering that it has higher temperature (80°C) than oil WAT and the chemical would be well-agitated along the pipeline. After performing 7 days of field trial, the SMK flow assurance was improved by injecting 60-100 ppm of PPD chemical continuously with the actual PP at departure point (SMK manifold) was 29ºC (similar with oil PP) and at arrival point (receiving facility) was 5ºC (below oil PP), resulting more than 1,000 bpd production without wax formation issue. **Conclusion:** SMK heavy oil flow assurance could be unlocked by PPD injection. The chemical operation should be continuously assessed based on actual production network that might have different target temperature and feasibility of dilution with other hot liquid. Therefore, the PPD injection could be optimized and wax issue could be controlled.

Keyword(s): flow assurance; pour point; pour point depressant; offshore pipeline; wax appearance temperature

1 Background

South Mahakam (SMK) field in East Kalimantan, Indonesia, produces natural gas and condensate with many operation challenges to produce and transfer hydrocarbon by underwater pipelines. One of the challenges was potential wax formation after perforation of a heavy oil well with the oil gain of around 1000-2000 bpd. The production was restricted due to the risk of wax appearance along declining temperature in a10inches-6.5km-subsea pipeline for the liquid transfer system. The production effluent was routed from the offshore platform with temperature at the departure section of around 80°C to the receiving facility through the subsea pipeline with the arrival temperature of around 24°C. The oil API was 28.6º and the pour point (PP) was 29°C as the minimum temperature for flowing, which was higher than the arrival point. If the waxy oil is produced from subsurface to surface facility, it might lead to crystallization and form wax on the pipeline surface. The wax accumulation in the pipeline and receiving facility might create operational problems, such as plugged pipes and instruments, and loss of flow pressure. The produced oil could not meet the customer specifications due to higher viscosity and emulsion stabilization. Therefore, the flow assurance issue from a heavy oil well in SMK should be improved prior to the long production period to meet the production target.

1.1 Wax Formation

Paraffin in crude oil is composed of carbon and hydrogen with formula C_nH_{2n+2} and is also referred to as Saturates. The formation of paraffin can be normal chained (straight), branched, and cyclic [1]. The paraffin content can be crystallized and form wax if the production temperature is below the Wax Appearance Temperature (WAT) or cloud point [2]. There are three main stages of wax formation in crude oil. First, the molecules of paraffin in the liquid state of crude oil experience nucleation due to the declining temperature in the system. Second, the crystal grows and forms a dense, strong crystal network around wax appearance temperature (WAT). The liquid will be difficult to pour. In the final stage, the 3-dimensional-lattices form through and trap the liquid fraction [3]. Crude oil containing a large amount of wax has a high pour point and exhibits non-Newtonian flow characteristics. The wax formation can be visualized in Figure 1.

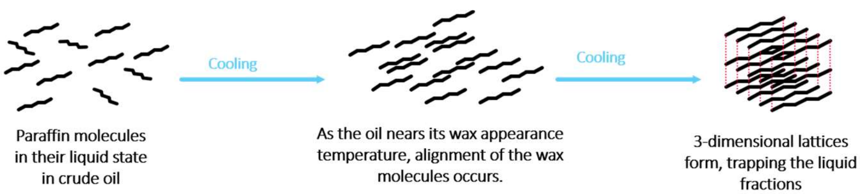

Figure 1. Wax Formation (Ecolab International Indonesia, 2018)

There are some techniques that might be effective for preventing wax formation. By non-chemical techniques, the wax prevention methods are by pigging, modifying the heat transfer inside the flow, such as insulation or heating system, and diluting with hot oil or other hot effluent (water or steam) [4]. As an alternative, the chemical techniques can be an effective option through continuous or batching injection. For maximum benefit, the chemical injection point is located at flow temperature above the oil WAT [4]. For heavy oil in the SMK Field, the Pour Point Depressant (PPD) injection was selected to enhance the heavy oil flow assurance as consideration of resource availability in the field.

1.2 Pour Point Depressant (PPD) Mechanism

Pour point depressant (PPD) are a polymer-based chemical with n-alkyl chains (primary or side groups) that added to the production system on a continuous basis to prevent a significant increase of crude viscosity and reduce the wax deposition into the surfaces [5]. The behavior of PPD could be visualized in Figure 2. The chemical will modify the rate of crystal agglomeration through water wetting of the surfaces of the wax crystals [6]. This crystal modifier will only slow down the kinetic processes of deposition and not completely stop the formation of wax crystals. The length of the alkyl chain in PPD component is important as it determines the temperature at which these chains will crystallize and adsorb onto the surface of the wax particles in the crude [7]. Ethylene-vinyl acetate (EVA) copolymers are commonly used as PPD component.

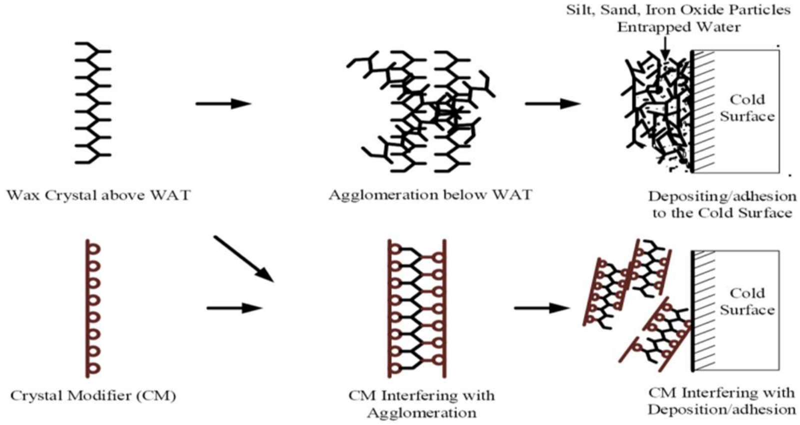

Figure 2. PPD as Crystal Modifier Mechanism (Makhwashi et al, 2019)

2 Methodology

2.1 Representative Samples Collection

It is important to characterize the crude oil analysis and to establish the nature of the precipitating solid. Prior determining the appropriate treatment, these important oil parameters should be determined to understand the wax behavior, which are WAT, initial pour point, degree of API, and oil viscosity. The parameters are analyzed based on representative crude samples from the field, included the heavy oil well and total liquid in the platform as final mixture in the effluent. The samples were retrieved in well flow line and production manifold, then transferred to the laboratory for further analysis.

2.2 Laboratory Analysis

2.2.1 Oil Characteristics

There were some laboratory studies to define the fluid parameters for well effluent and total liquid from the manifold. Oil WAT was analyzed by using WAT 70X-I Analyzer method, pour point by ASTM D97, API by ASTM D1298, and oil viscosity by ASTM D455. WAT is mandatory to determine the location of the injection point, which at the higher temperature than WAT. BSW data is to define the multiphase of liquid and solid in the flow and oil viscosity data is to monitor the rheology condition. Therefore, the initial characteristics of each liquid was determined prior mixing for composite as per volume ratio of each liquid component in the effluent. As per production rate, the ratio of the SMK liquid mixture was 1:2 between heavy oil well and total liquid.

2.2.2 PPD Performance Test

Based on the product availability in operation site, there were two PPD products that proposed to be tested for SMK heavy oil and the SMK liquid mixture. Each product was tested with dosage variation 100 ppm, 250 ppm, 500 ppm, and 1000 ppm. The objective of treatment was to achieve liquid PP less than 24 °C, referred to arrival temperature in receiving facility. If the PP target were achieved, the chemical was selected based on the most efficient chemical dosage for field application.

2.3 Start-Up, Continuous Quality Monitoring, and Dosage Optimization

2.3.1 Start-up chemical injection

The chemical injection package was prepared at the highest temperature in the system. The package included chemical tank, injection pump, rate calibration tool, instrument air, and tubing connections for the injection point into the piping system. The chemical stock should be adequate for continuous injection and refilling process was necessary to prevent untreated wax in heavy oil.

2.3.2 Liquid Quality Monitoring & Chemical Dosage Optimization

There were 7 main steps of workflow to perform oil quality monitoring and chemical dosage optimization and it could be summarized in Figure 3. The blank samples (no PPD injection) were collected prior injection start up as the baseline. After start up the injection, the pour point was monitored at well flow line, production manifold, and receiving facility. Once the pour point was lower than 24°C as the target, the PPD was optimized. Otherwise, operation should maintain the last injection dosage recommendation.

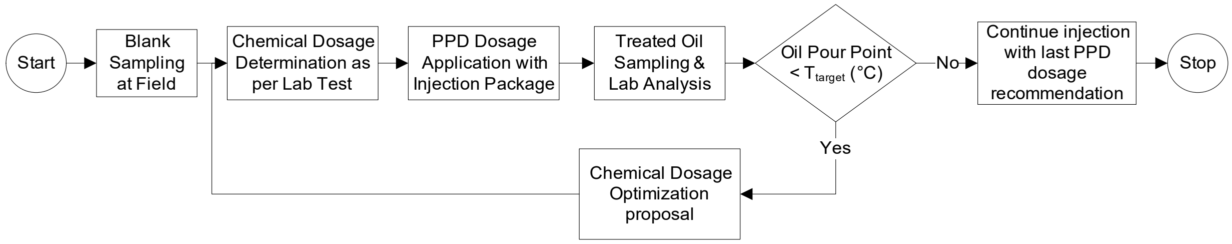

Figure 3. Workflow of Heavy Oil Quality Monitoring & Chemical Dosage Optimization

3 Results

3.1 Oil Characteristic of Representative Samples based on Lab Analysis

Based on lab analysis of representative samples of SMK heavy oil resource, the characteristic of liquid from well flow line and platform manifold is listed in Table 1.

Table 1 SMK Liquid Characteristics based on Lab Analysis.

Parameter (Unit)	Method	SMK Heavy Oil Well	SMK Liquid (before mixing with SMK Heavy Oil Well)	SMK Liquid Mixture (after mixing with SMK Heavy Oil Well)
Flowing Temperature (°C)	Process indicator	92.3	80.0	80.0
API (°)	ASTM D1298	28.6	42.1	35.7
Pour Point (°C)	ASTM D97	29.0	-19	29.0
Viscosity at 40 °C (cSt)	ASTM D455	5.1	1.4	4.7
Wax Appearance Temperature (°C)	WAT 70X-I Analyzer	42.9	-	-

3.2 PPD Performance Test for SMK Heavy Oil & Liquid Mixture

Based on the performance test of two PPD chemicals, the pour point of each samples are shown in Figure 4 & Figure 5. The PPD 1 could reach the temperature target (<24°C) at minimum 100 ppm, while PPD 2 met the target at minimum 250 ppm. Therefore, PPD 1 was more efficient and selected for field trial in SMK.

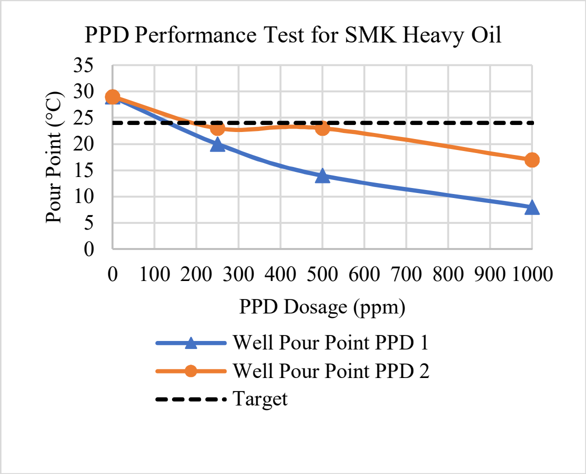

Figure 4. PPD Performance Test for SMK Heavy Oil

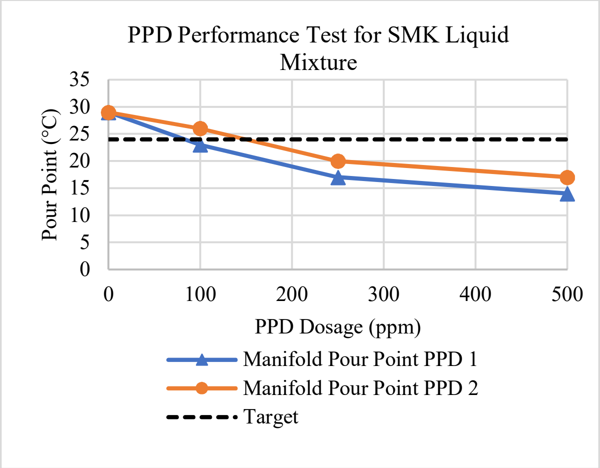

Figure 5. PPD Performance Test for SMK Liquid Mixture

3.3 PPD Start-Up, Monitoring, and Dosage Optimization

Based on observation on site, it was determined that the well flow line had the maximum temperature, which was 92.3°C, while platform manifold was around 80°C. Therefore, the PPD injection package was installed in well flow line (downstream choke valve, upstream platform manifold) to accommodate the dosage of 100 ppm during chemical start up. The injection was started at the same time of well opening and ramp up. After performing 7 days of field trial, the SMK flow assurance was improved by injecting 60-100 ppm of PPD chemical continuously with the actual PP at the departure point (SMK manifold) was 29ºC (similar to oil PP) and at arrival point (receiving facility) was 5ºC (below oil PP), resulting more than 1,000 bpd production without wax formation issue. The liquid properties monitoring during field trial and monitoring phase is shown Table 2.

Table 2 SMK Liquid Properties during PPD Injection Periods.

Period of Injection	**Baseline Period (without PPD injection and heavy oil well shut in)**			**PPD Injection Start Up Period (heavy oil well opening)**			**Monitoring Period (Day-7 after Start Up)**		
Sampling point	**Heavy Oil Well Flow line**	**Platform Manifold**	**Receiving Facility**	**Heavy Oil Well Flow line**	**Platform Manifold**	**Receiving Facility**	**Heavy Oil Well Flow line**	**Platform Manifold**	**Receiving Facility**
PPD Dosage (ppm)	Blank (0)			100			60		
API (°)	29.7	28.8	42.1	32.3	32	33.1	32.9	32.6	36.5
Pour Point (°C)	**29**	**23**	**-19**	**29**	**29**	**-1**	**29**	**26**	**5**
Viscosity at 40 °C (cSt)	4.92	4.11	1.44	4.68	4.21	4.11	4.40	3.80	2.60

4 Conclusions

The perforation of oil zone in SMK field was opening the new oil resource from the gas field. However, the wax content in SMK heavy oil could lead to flow assurance issue and impact the liquid production facility. Therefore, it is important to identify the liquid physical properties data and production temperature profile as the basis before the modification of operating system, included additional PPD treatment package. Based on the application in SMK field, the flow assurance was improved by injecting 60-100 ppm of the PPD chemical so the PP could be decreased from 29°C to 5°C. The appropriate injection point supported the treatment benefit so the pour point at lowest temperature sections would not experience the wax formation. The requirement of PPD injection should be continuously assessed based on the actual production network in SMK field. The heavy oil well could be routed to other downstream section with different target temperature and had feasibility of dilution with other hot liquid. Therefore, the PPD injection could be optimized and wax issue could be controlled.

References

[1] Speight JG. Wax Deposition and Fouling. Fouling in Refineries, Elsevier; 2015, p. 155–73. https://doi.org/10.1016/B978-0-12-800777-8.00007-3.
[2] Theyab MA. Wax deposition process: mechanisms, affecting factors and mitigation methods. Open Access J Sci 2018;2. https://doi.org/10.15406/oajs.2018.02.00054.
[3] Jafari Ansaroudi HR, Vafaie-Sefti M, Masoudi S, Behbahani TJ, Jafari H. Study of the Morphology of Wax Crystals in the Presence of Ethylene-co-vinyl Acetate Copolymer. Pet Sci Technol 2013;31:643–51. https://doi.org/10.1080/10916466.2011.632800.
[4] Sousa AL, Matos HA, Guerreiro LP. Preventing and removing wax deposition inside vertical wells: a review. J Pet Explor Prod Technol 2019;9:2091–107. https://doi.org/10.1007/s13202-019-0609-x.
[5] Elganidi I, Elarbe B, Ridzuan N, Abdullah N. Synthesis, characterisation and pre-evaluation of a novel terpolymer as pour point depressants to improve the Malaysian crude oil flowability. J Pet Explor Prod Technol 2022;12:2067–81. https://doi.org/10.1007/s13202-021-01445-2.
[6] Elkatory MR, Soliman EA, El Nemr A, Hassaan MA, Ragab S, El-Nemr MA, et al. Mitigation and Remediation Technologies of Waxy Crude Oils' Deposition within Transportation Pipelines: A Review. Polymers (Basel) 2022;14:3231. https://doi.org/10.3390/polym14163231.
[7] Poornachary SK, Chia VD, Schreyer MK, Chow PS, Tan RBH. Relating Alkyl Chain Length of Additives to Wax Crystallization Inhibition: Toward the Rational Design of Pour Point Depressants. Cryst Growth Des 2022;22:4031–42. https://doi.org/10.1021/acs.cgd.1c01310.
[8] Makwashi N, Soraia D, Barros D, Sarkodie K, Zhao D, Diaz PA. 2 SPE-195752-MS. 2019.
[9] Ecolab International Indonesia. 2018 Pour Point Depressant. Chemical Workshop 2018. Bogor: Ecolab International Indonesia.