

WAX CONTENT DETERMINATION THROUGH TESTS AND SIMULATION COMPARISON

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Abstract

Petroleum can exist in the three states of matter: as natural gas in the gaseous state, crude oil in a liquid state and wax in the solid state. Its state at any time is a function of its thermodynamic (pressure and temperature) properties and composition. Petroleum production is essentially a flow process and to guaranty flow, petroleum has to remain in fluid states (gas and liquid). This means that production engineers have to prevent and control wax deposition. Companies have these Comprehensive wax control programs with wax deposition monitoring at the very heart. Monitoring wax deposition simply involves regular wax content determination which can be expensive when the service is contracted. Alternatively, simulation can provide a cheaper and faster option. This research used two wax deposition models with the PVTP(Petroleum Experts Fluid thermodynamics package) software to determine the wax content of a sample from a field in the Niger delta and compared the results with that of a laboratory test. The Pedersen model gave a result of 3.67% which is close to that of the laboratory test of 3.45%. While the Won original model gave a result of 28.71%. The Pedersen model is a better model for wax content determination and is recommended in the absence of laboratory tests.

Keywords: Petroleum; Wax; flow; wax deposition; wax content; simulation; laboratory test.

1. Introduction

Crude oil waxes are either paraffins, asphalteens or a mixture of both [1]. Paraffinic waxes have a smooth oily feel when rubbed in between the fingers and melt when heated. This distinguishes paraffin wax from asphaltene wax [2]. In the reservoir, crude oil exists in a liquid state with no waxes because the temperatures are high enough and the composition is unaltered by materials or operations that can trigger wax precipitation. As the oil is produced to the surface, its composition is altered by the process and it loses heat to its surroundings and thus precipitates and deposits wax. The production process alters the crude oil composition by;

- Comingling of fluids from different sources.
- Loss of volatile components
- The presence of impurities (silt, scale, salt, corrosion by products, etc) which act as nuclei around which precipitate can crystallize for continued growth and deposition.

The produced crude oil loses heat in the following ways;

- Heat loss by radiation and convection from the high temperature fluid to its lower temperature surroundings of tubular and pipes.
 - Heat loss from the release of solution gas.
 - Heat loss from vaporization of lighter components.
 - Heat loss from expanding through an orifice.
 - Heat loss form comingling with streams of higher water cut.
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The conditions that initiate, and encourage wax precipitation and subsequent deposition are prevalent in the production system. In tackling the problem, Engineers have brought in measures to help retain most of the heat in the fluid by the use of insulated pipes. Most production facilities are equipped with heater treaters for reheating and some wells are periodically treated with hot oil to re-melt deposited wax [3]. This works best for paraffin wax. Other wax control measures include the use of solvents and dispersants to dissolve the deposited wax and keep wax crystals in suspension. The solvents do not stop wax precipitation, but ensure that the pipes are not plugged by deposits. The best solvents are those of hydrocarbon origin as they do not cause problems at the refining stage. Some of them are; condensate, casing head gasoline, pentane, light gas oil, xylene, toluene, carbon tetrachloride.

Before wax control measure is selected certain tests must be conducted to determine fluid and wax properties. Tests to determine the wax reaction to the control chemicals at different dosages are also carried out. Some of these tests are Cloud point test according to ASTM D2500-66 standard, Wax Centrifuge tube test, Hot xylene test, Melt test, and Pentane solubility test. The tests that screen inhibitors and monitor deposition include; Paraffin Cold Finger (or Cold Coil) Deposition Test, ASTM D-97 Pour Point Test, Constant Temperature Ramp Down Pour Point Test, Crude Oil Rheology Test (using different Viscometers to test for various properties in varying temperatures and shear rates), Paraffin Flow Loop, Restart Flow Loop, H.P (High Pressure) Gas Chromatography, DSC (Differential Scanning Calorimeter) Instrument Tests. For asphaltene, there are Asphaltene flocculation point test, Asphaltene screening test and Asphaltene dispersant test [2]. The tests for monitoring wax deposition are conducted to determine wax content at standard or field simulated conditions.



Fig.1. Wax deposited in the pipe

The past thirty years has witnessed extensive research in wax deposition studies which resulted in the development of a number of models some of which has been commercialized in softwares. Some of the popular ones are; Chung [4], Hansen *et al.* [6], Coutinho *et al.* [7], Lira-Galeana *et al.* [8], Mei *et al.* [9], Pan *et al.* [10], Pedersen *et al.* [11], Prausnitz *et al.* [13], Reddy [14], Won original [15]. The earlier models over estimate wax content. But they provided the foundation on which the more accurate and recent models were built.

2. Methodology

A sample was collected from a field in the Niger delta, ten days after pigging, was characterized and wax content determined at 0°C (32 F). The sample was analyzed using Gas Chromatography to determine the SCN (Single Carbon Number) fractions. Fluid properties like molecular weights and densities were determined. Flow parameters like viscosity, water cut and wax content were determined. The paraffin cold finger deposition test was used to determine the

sample wax content. The sample was cooled to 0°C (32 F) and the amount of wax precipitated was scrapped and measured. The result was given in percentage (%) by weight of the sample. Results are shown in Table 1. The laboratory test is the Control and the Simulation results are compared with it.

Table 1. Sample I Fluid Composition

Component	Recombined Separator Oil Mole %	Component	Recombined Separator Oil Mole %
C2	0.077	C16	2.491
C3	1.907	C17	2.170
i-C4	1.540	C18	2.847
n-C4	4.962	C19	1.879
i-C5	3.492	C20	1.535
n-C5	3.464	C21	1.375
C6	5.758	C22	1.284
C7	9.263	C23	1.185
C8	11.797	C24	1.141
C9	6.714	C25	1.122
C10	5.800	C26	0.967
C11	4.407	C27	0.982
C12	3.727	C28	0.956
C13	3.691	C29	1.047
C14	3.547	C30+	5.266
C15	3.609	TOTAL	100.00
M.wt(g/gmol)	176.0354	Density(gm/cm ³)	0.8307

2.1. Wax Content Determination Using PVTP

PVTP is a fluid thermodynamic software that is part of the Petroleum Expert Suit. It can be used to determine among other things, the wax content of crude oil streams of known composition at known operating conditions of temperatures and pressures. The PVTP package comes with a range of popular models for studying the wax or hydrate properties of crude oil streams. For this work, The Peng-Robinson Equation of State [12] and Won [15] and Pedersen wax models [11] were selected and used in PVTP to determine the amount of wax that would be deposited in the range of 20 to 40F and at Opsig pressure simulating the laboratory condition in which the Cold finger test was done. In the Cold Finger test, the sample was cooled to 0°C (32 F). The results of the test were compared with the simulation. The software was also used to generate the fluid phase envelope Fig 4.

3. Results

The laboratory Cold finger test gave a result of 3.45% of the sample. This result is included in Table 2. The graph of the calculated results is shown in Fig 4 and 5. The laboratory and PVTP simulated results are compared in Table 3 below.

Table 2 Sample I Crude Oil Flow Assurance Parameters

Parameter	Method	Value
Base Sediment and Water (%)	ASTM D97	<0.01
Copper Corrosion	ASTM D130	Slightly Tarnished (1A)
Wax Content (%) @ 0°C	ASTM D5452	3.45

Table 3 Comparison of Wax Content Results

Sample	Laboratory result	PVTP result	
I	3.45 %	[15] 28.71%	[11] 3.67%

4. Discussion of results

The laboratory Cold finger test gave a wax content of 3.45%. This means that at 32 F (0°C), the solid phase content of the sample under test was 3.45% of the whole. Simulating laboratory test pressures (0psig) and temperatures (0°C) PVTP determined the solid phase in percentage, obtaining a result of 3.67% with the Pedersen model and 28.71% with Won's original model. The Pedersen model gave a value close to the laboratory result showing its superiority over Won's Original model.

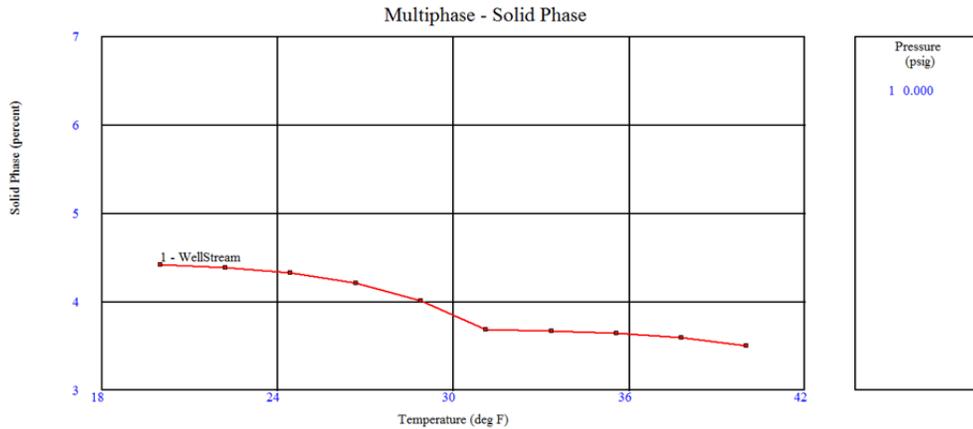


Figure 2. Graph of Solid phase (%) with Pedersen model

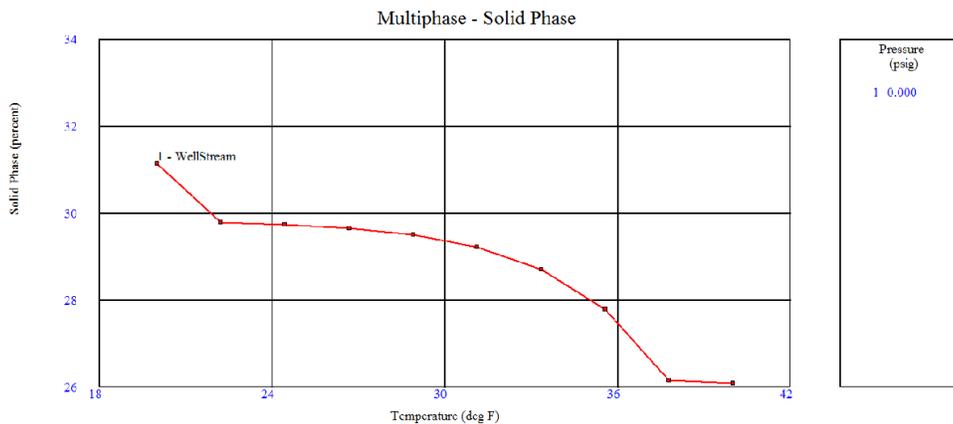


Figure 3. Graph of Solid phase (%) with Won Original model

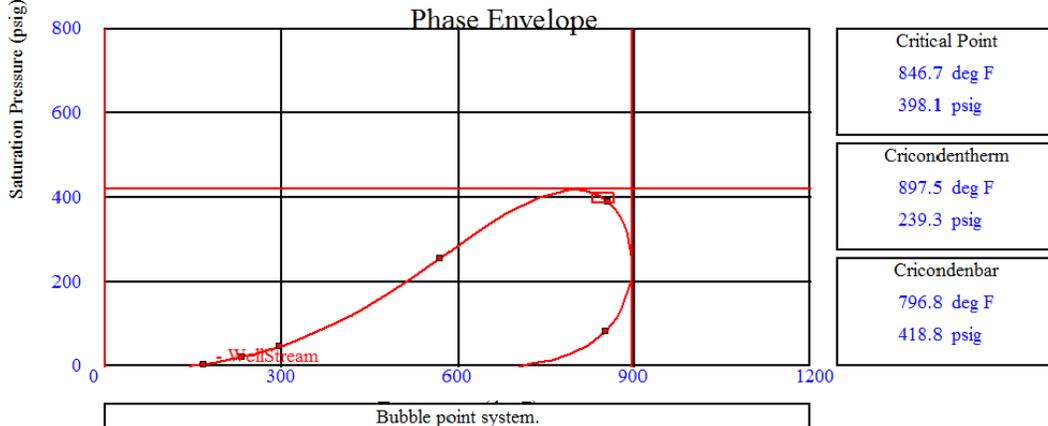


Figure 4. Phase envelope of the fluid sample

Won's original model is one of the earliest wax content models. Its greatest flaw is seen in its overestimation of wax content as indicated in the results obtained. There have been modifications to Won's original model. The Pedersen is a more recent model. Its result shows that it can be used in the absence of laboratory tests for determining wax content of crude oil samples. However, it did not give a perfect match. The difference of about 0.22% between the control and PVTP simulation with Pedersen model shows that there is still room for improvement to arrive at a model a lesser error margin.

5. Conclusion

1. Wax deposition is a major petroleum production challenge with the production process enabling wax precipitation and deposition.
2. In the absence of Laboratory tests, the Pedersen wax deposition model can be used to estimate wax content rates as it gave a result of 3.67% against the control which was 3.45%.
3. The difference of 0.22% between the Pedersen model and the Control is a gap for improvement for a better model with a lesser error margin.

Recommendation

1. Wax precipitation is greatly influenced by fluid heat loss, so measures that retain fluid heat should be adopted where they are cost effective.
2. Field surveys and laboratory tests are a prerequisite for a comprehensive wax control strategy.
3. The PVTP package is a useful tool for wax deposition studies with its wide range of models, margins for all possible operating conditions (temperature, pressure, density, viscosity, composition).
4. The Pedersen model gave a result close to that of the control (laboratory test), and so can be used in the absence of laboratory tests. However, the error margin leaves room for a better model.

Contribution To Knowledge

This work successfully determines the wax content of a sample of crude oil using the paraffin cold finger test and the Won original and Pedersen wax deposition models in PVTP software. The results were compared. The Pedersen model gave a result of 3.67% which is close to the control; 3.45%. While the Won original model gave a result of 28.71%, very far from the control.

References

- [1] Allen OT, Roberts AP. (1982) Wax Deposition, Production Operations Vol 2. 2nd Edition, Oil and Gas Consultants Inc. Oklahoma.
- [2] Nalco Energy Services (2004) 'Paraffins' and 'Asphaltene' Oil field Chemicals Training Manual. Capex College, Nalco Energy Services, Sugar land, Texas.
- [3] Billingsley DL. How To Control Paraffin Wax In Shallow Pumping Wells. World Oil, July 1963.
- [4] Chung TH. (1992) Thermodynamic Modelling for Organic Solid Precipitation SPE 24851, 67th Annual Technical Conference and Exhibition-Washington DC, October 1992.
- [5] Coutinho JAP and Stenby EH 1996. Predictive Local Composition Models for Solid/Liquid Equilibrium in n-Alkane Systems: Wilson Equation for Multicomponent Systems. Industrial Engineering Chemistry Research, 35: 918.
- [6] Hansen, JH, Fredenslund A, Pedersen KS. 1988. A thermodynamic model for predicting wax formation in crude oils. AIChE J. 34 (12): 1937-1942.
- [7] Coutinho JAP, Pauly J and Daridon J. (2003) Modeling phase equilibria in systems with organic solid solutions. Presented at Departamento de Química da Universidade de Aveiro, 3810-193 Aveiro, Portugal and Laboratoire des Fluides Complexes, Université de Pau et des Pays de l'Adour, 64013 Pau Cedex, France.

- [8] Lira-Galeana C, Firoozabad, A and Prausnitz JM. 1996. Thermodynamics of wax precipitation in petroleum mixtures. *AIChE J.* 42 (1): 239-248.
- [9] Mei H, Kong X, Zhang M. 1999. A Thermodynamic Modeling Method for Organic Solid Precipitation. Presented at the SPE Annual Technical Conference and Exhibition, Houston, 3-6 October. SPE-56675-MS.
- [10] Pan H, Firoozabadi A and Fotland P. 1997. Pressure and Composition Effect on Wax Precipitation: Experimental Data and Model Results. *SPE Prod & Operations*, 12 (4): 250-258. SPE-36740-PA.
- [11] Pedersen WB, Hansen AB, Larsen E. 1991. Wax precipitation from North Sea crude oils. 2. Solid-phase content as function of temperature determined by pulsed NMR. *Energy Fuels*, 5(6): 908-913.
- [12] Peng DY and Robinson DB. 1976. A New Two-Constant Equation of State. *Industrial & Engineering Chemistry Fundamentals*, 15 (1): 59-64.
- [13] Prausnitz JM, Lichtenthaler RN and Azevedo EG. (1986). *Molecular Thermodynamics of Fluid Phase Equilibria*, Chap. 9, Prentice-Hall, Englewood Cliffs, NJ (1986).
- [14] Reddy SR 1986. A thermodynamic model for predicting n-paraffin crystallization in diesel fuels. *Fuel* 65(12): 1647-1652.
- [15] Won KW. (1980) Thermodynamic for Solid-liquid Vapour Hydrocarbon Equilibrium: Wax phase formation from Heavy Hydrocarbon Mixtures, *Fluid Phase Equilibrium* 30 pg.265-279

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