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Viscosity reduction of Water in Oil emulsions stabilized by waxes

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Abstract
A Brazilian crude oil produced from an offshore oilfield is higly waxy. The high content of waxes and operating conditions subsea are leading difficulties to pump and produce this crude leading to a drop of production. As waxes cristallized at low temperatures encountered subsea the viscosity is dramatically increased, as the content of water increase a strong and viscous emulsion is formed and the pumpability of the crude is even worse. This increase of viscosity is linked to the stabilisation of this emulsion with solid waxes. A specific chemical solution has been developped in order to avoid the formation of strong and highly viscous emulsion. This chemical solution has been developed through an extensive formulation and rheology study. The chemical solution has been field tested.

Keywords
Waxes; Emulsions; Viscosity; Flow Assurance

Introduction
Waxy crude oils are known as challenging to be produced at temperatures below their Wax Appearance Temperature (WAT). This challenge can be even worse when the well is starting to produce water as it will form emulsions that can be stabilized by particles. In the case of this Brazilian waxy crude oil, it is produced subsea where the external temperature can be as low as 4°C leading to a temperature of crude in the flowline as low as 16°C while the WAT is at 57,8°C. In these conditions a dramatic increase of viscosity is observed, deposition of paraffins in the flowline and a loss of production. As the water produced is increasing with time a very stable and highly viscous emulsion is formed leading to an even much higher viscosity. In order to overcome this rise in viscosity and maintain the production to an optimized level an original chemical solution has been developed. Laboratory results and field experience are presented in this paper.

Methodology

The rheological behavior of the crude oil across flowline has been studied through a rheometer (coaxial geometry) simulating the temperature profile in the flowline and the shearing of crude oil across the flowline. A temperature profile has been set in order to be as close as possible from the field conditions.
The viscosity of crude is measured in coaxial cylinder according to the gradient of temperature. The measurement is performed on the neat crude oil and in presence of water under emulsion form. The crude oil has been also analyzed with and without the chemical added directly on crude oil and on the emulsion.

Experimental Procedure
The crude oil is placed in a cylindrical coaxial geometry and then submitted to a gradient of temperature from 60°C (outlet of the well subsea) to 16°C (temperature of crude at the surface). A gradient of decreasing temperature is applied in order to simulate the temperature as seen by the crude oil along the flowline from the head well to the surface.
The viscosity is measured across this gradient of temperature. The viscosity is reported against the time and temperature.
The crude oil is analyzed in these conditions with and without a viscosity reducer. The viscosity curves are then superposed and compared in the same conditions.

The Brazilian well parameters have been reproduced in a coaxial geometry to match as accurately as possible the real conditions:
- Thermal gradient reproduced (drilling part & flowline part).
- Shear rate variation reproduced according to flow line and topside tubbing geometry.

The aim of this study is to simulate the crude crystallization while cooling (out from reservoir to the topside process part) and observe the evolution

of the oil viscosity during 24h of topside process conditions in presence of water.
Our model has been verified by comparing shear stress from the rheometer data and operator data.

By reproducing exact cooling rate and shear conditions, we are matching thermal history, crystals size and shape as accurately as possible.
2 compromises are made:

- No possibility to simulate pressure. But the flow (so the shear rate) is resultant of pressure, so we take into account a part of it.
- We need to warm the crude sample up to 80°C to be sure we get rid of the thermal history. A significative part of the lighter components of the crude will evaporate causing an increase in viscosity.
- Consequently, the sample appears more viscous, we can speak about an apparent viscosity.

The geometry used is the Concentric Cylinder CC27 from Anton Paar. Cup C-CC27/T200/SS (internal diameter 28,923 mm) and Cylinder CC27/145 (Length 40,006 mm; Bob diameter 26,670 mm.
A shear rate of 90 s^{-1} is applied from 70 to 24°C then a shear rate of 38 s^{-1} is applied from 23°C to 16°C.

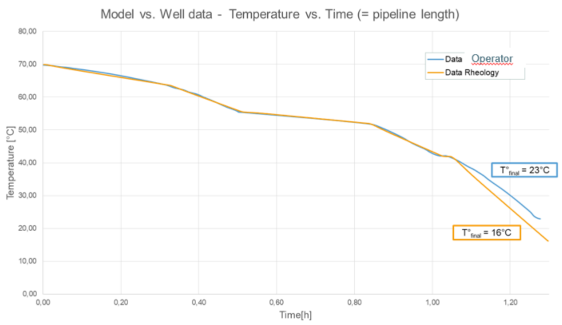

Figure 1. Temperature profile vs. time

Results and Discussion

The Brazilian crude oil has been analyzed according to this rheology protocol. In Figure 2 are displayed the viscosity curves obtained on the neat crude oil, crude oil emulsion containing 10% of water and the emulsion additivated with 200 ppm of the viscosity modifier, DEEP 2200.
The results indicate that the viscosity of crude oil is increased when the temperature decrease below the wax appearance temperature (58,7°C). When introducing 10% of water the increase of viscosity is even worse with an increase of 33% in comparison to the neat crude oil. The additivation of the emulsion W/O:10/90 with 200 ppm of DEEP 2200 allows to reduce the viscosity by 23% in comparison to the emulsion W/O:10/90 without additivation. These data are showing the viscosity reduction effect that can be obtained when using the DEEP 2200 at the concentration of 200 ppm. This chemical act both on waxes crystallization and on the emulsion interface.

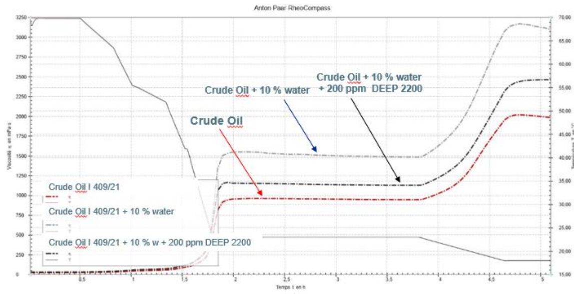

Figure 2. Viscosity curves vs. time.

The viscosity measured is reported in Table.1.

Table 1. Viscosity results

Properties	Neat Crude Oil	Emulsion W/O : 10/90	Emulsion W/O : 10/90 +200 ppm DEEP 2200
Viscosity at 23°C (mPa.s)	1000	1500	1150
Delta Viscosity (%)		+33	-23

Field test validation

Unfortunately, field temperature evolved during time of the study and moved to a safer temperature (above WAT) at the time of the field test (Figure 3).

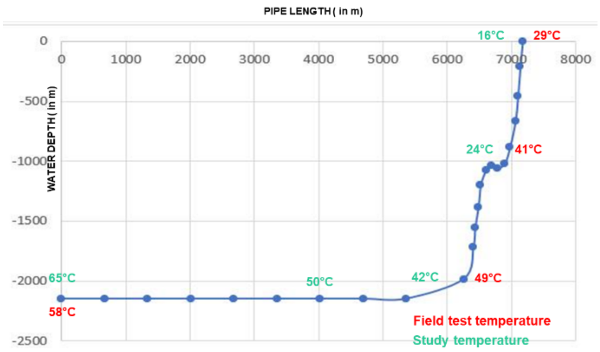

Figure 3. Temperature profile of flowline and riser

A slight production increase was noticed during DEEP 2200 injection (Figure 4), an apparent viscosity decrease was observed in laboratory (Table 2).

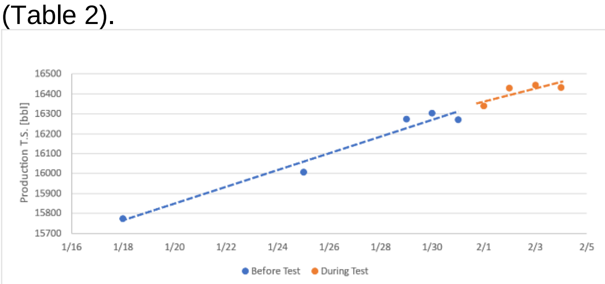

Figure 4. Production before and after DEEP 2200 injection

However, this slight increase was not representative since production was already presenting daily gain at the same rate (Evolve with gas injection rate).

CHOKE SAMPLE						
Temperature	28 ºC			40 ºC		
Type	Din. Viscosity (cP)	Kin. Viscosity (mm2/s)	Density (g/cm³)	Din. Viscosity (cP)	Kin. Viscosity (mm2/s)	Density (g/cm³)
Oil	223,34	245,08	0,9113	111,33	123,20	0,9036
Oil + 200 ppm DEEP	159,24	174,80	0,9110	85,35	94,50	0,9032
Oil + 400 ppm DEEP	125,62	138,10	0,9096	66,49	73,72	0,9020
Viscosity reduction (%)	**28,70%**	**28,68%**		**23,34%**	**23,30%**	
	43,75%	**43,65%**		**40,27%**	**40,16%**	

Table 2. Viscosity of additivated crude oil

The viscosity decrease, despite visible, does not impact much the production flowrate because temperature of fluid in the flow line is much higher than expected. Any field approaching the field study temperature, generating dense emulsions stabilized by crystallized waxes, would be interesting to be field tested with the DEEP 2200.

Conclusions

A rheology protocol has been developed to simulate the rheological behavior of a paraffinic Brazilian crude oil in subsea production conditions. It is showing that the dramatic increase of viscosity linked to waxes crystallization and presence of water could be controlled and reduced by using a specific chemical formulation, DEEP 2200. This chemical is designed to control waxes crystallization as well W/O emulsion interface. By decreasing the viscosity of the emulsion, it is expected an increase of flowrate and increase of production thanks to this chemical solution on this type of highly viscous emulsions. This solution has been field tested in conditions allowing to confirm partially this expectation however the field conditions (oil temperature and GO ratio) were not optimal.

Acknowledgments

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Responsibility Notice

The authors are the only responsible for the paper content.

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