SPE Brazil Flow Assurance Technology Congress
Rio de Janeiro, Brazil, November 15 – 18 2022

Into the importance of emulsion properties characterization for the optimization of gas lifted deep water oilfield production

Mohamed Saidoun[1*], Roel Belt[2], Cedric Picher[3], Enric Santanach-Carreras[2], Annie Fidel-Dufour[1], Thierry Palermo[1]
[1] TOTALENERGIES, CSTJF Avenue Larribau - 64018 PAU Cedex, France
[2] TOTALENERGIES, PERL, BP 34, 64170 Lacq, France
[3] TOTALENERGIES, Tour Couple, La Defense, 92400 Courbevoie, France
* mohamed.saidoun@totalenergies.com

Abstract
The inversion point of crude oil – water emulsions is usually the main parameter used in multiphase flow simulators to tune emulsion viscosity to be considered in transport equations. However, the transport properties of such emulsions may be more complicated than considering a single relative viscosity curve function of the water content only (e.g. Pal & Rhodes model). Indeed, dense emulsions may exhibit a non-Newtonian behaviour or saturation under specific conditions. The impact of emulsions stability and complex transport behaviour on the flow stability is investigated at multiple scales (i.e. laboratory, pilot, industrial). In this study, a monophasic liquid flow loop combined with rheological characterization of emulsions are used to understand the flow behaviour of pre-mixed water and crude oil to replicate commingling flow of multiple wells through choke valves. In parallel field data are gathered from subsea and riser pipelines to compare laboratory measurements to observed flow regimes at industrial scale. Lastly, the effect of production chemicals such as corrosion inhibitors is investigated, the effect of chemicals on emulsion properties is linked to their effects the flow controllability in gas-lifted risers.

Keywords
Emulsions; Chemicals; Multiphase flow

Introduction
Severe slugging is a major constraint to efficiency in offshore oil production [1].
The flow of emulsions in vertical pipelines is usually considered to be dominated by hydrostatic pressure drops using average densities to calculate the weight of the hydrostatic column. The weight of the column is recalculated as a function of time depending on the flow regime in dynamic multiphase flow simulators. Respective local volume fractions of dispersed gas and water have strong impacts on gravitational pressure losses. However, although emulsions viscosity parameters are adjustable [2] and let us define the fraction of each liquid in the emulsion, viscous friction pressure losses have limited contribution under vertical flow. The related stability emulsions can however cause local accumulation of water and cause slugging phenomena. Indeed, emulsions are assumed homogeneous in commercial flow simulators, which does not let us to study the impact of emulsions stability on flow parameters despite the possible coexistence of emulsion and free water at saturated water-in-oil emulsion conditions as illustrated in Figure 1.

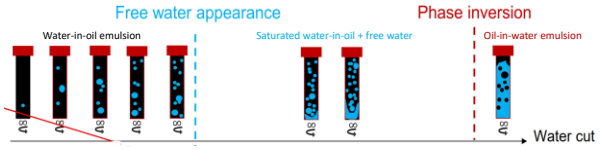

Figure *1*: Schematic of different configurations of oil and water emulsions as a function of the water cut

In addition, considered viscosity laws in simulators can only consider Newtonian emulsions while non-Newtonian emulsion behaviour [3] may significantly contribute to pressure drop uncertainties under horizontal flow and to liquid hold-up calculation at inlet boundary conditions of vertical risers.
Severe slugging is usually explained by the behaviour of gas/liq flowing interfaces.
However, the observed magnitude of hydrodynamic slugging remains unexplained under specific field conditions.
This study has 2 major objectives:

i) investigate the effect of emulsion properties experimentally and industrially on pipe flow parameters
ii) understand indirect impacts of subsea injected chemicals on the flow regime in deep water risers.

Methodology

A couette-type and custom-made transparent rheometer are used to characterized crude oil from one of the one West African field and synthetic water emulsions.

A 1 inch diameter flow loop pilot with promoted flow of the same emulsion by a moineau pump is used to study the flow of emulsions at multiple conditions (temperature, water cut) in pipelines.

Observations from above experiments are compared to field data.
Pressure and flow rate fluctuations are recorded in risers of 2 operated assets located in West Africa.

Results and Discussion

Results obtained in the present study show that emulsions can be extensively non-Newtonian under a range of water cut and that inversion points can be as high as 85%, as illustrated in Figure 2.

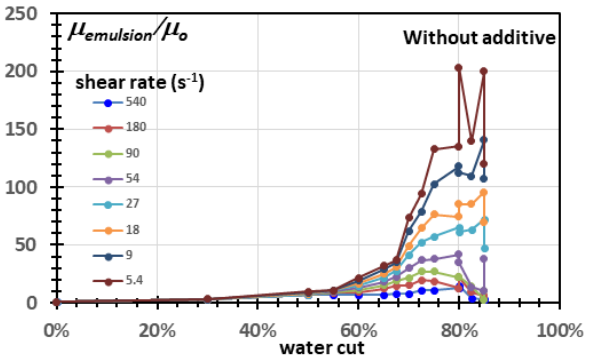

Figure 2: Relative viscosity of the emulsion as a function of water cut and shear rate

Pal & Rhodes type of equation must be modified to capture the measured rheological behaviour of the emulsion by defining parameters as a function of the shear rate.
Despite a good match between the modified viscosity law and rheometer data, flow loop data are only partially in agreement with simple homogeneous emulsion flow equations within the range of tested conditions. The experimental flow-loop data reveal strong instability at sufficiently elevated dispersed water concentration in oil. In fact, it is found that the coexistence of free water and saturated non-Newtonian emulsion induces large fluctuations in flow parameters (i.e. liquid/liquid severe slugging) under pilot conditions. Interestingly, a similar behavior is observed in risers of 2 fields. Thanks to this understanding, the concentration of injected chemicals is used as a leverage to optimize field production efficiencies and corrosion protection by optimizing corrosion inhibitors availability.

Conclusions

The intimate links between complex emulsion properties, chemicals and flow assurance are revealed by studying the emulsion behaviour in laboratory tests under selected conditions at multiple scales. The study reveals that predicting the quantity and the transport properties of coexisting fluid types is crucial to control crude oil, water and gas multiphase flow.
This study allowed optimization at industrial level, such as corrosion inhibitor selections, dosage, routing of wells through subsea pipeline network, production performance increase etc.
In addition, the gained understanding suggested to modify our methodology of subsea injected chemicals selection by verifying their impact on emulsion viscosity and stability for flow assurance optimization.

Acknowledgments

Our acknowledgement go to the field operations team and to the technicians who performed the laboratory tests

Responsibility Notice

The authors are the only responsible for the paper content.

References

[1] Ivy Chai Ching Hsia; Bishop Falope; Nor Hadhirah Halim; M Azmeer Rodzali *SPE IPTC-22235-MS*,
[2] Vahid Hoshyargar; Seyed Nezameddin Ashrafizadeh; *Ind. Eng. Chem. Res*. 52, 4, 1600–1611 , 2013
[3] I. Masalova; A.Ya. Malkin, P. Slatter; K. Wilson; *Journal of Non-Newtonian Fluid Mechanics* 112, Issues 2–3, 101-114, 2003