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Effects of Laboratory Test Sensitivities on the Efficiency of Scale Inhibitors for Brazilian Applications

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Abstract

The inorganic salts precipitation control during oil production at various stages of crude oil processing is a complex task, especially with the increase in criticality of produced water compositions and working conditions (high calcium content, high salinity and temperatures for instance). Use of reliable models for predicting saturation index and choosing the ideal conditions for laboratory tests are critical for effective selection of scale inhibitors capable of ensuring production flow. The Dynamic Tube Blocking Test is a commonly used test to assess the performance of scale inhibitors. In some scenarios of the Brazilian pre-salt it has been determined that this test is very sensitive to some factors such as the brine pH, as well as the internal diameter of the capillary and other operating conditions. The objective of this work was to evaluate the influence of the variation of these factors on scale inhibitors' efficiency and thus bring to light some important aspects related to comparative laboratory testing for challenging scenarios. Evaluations were performed considering the performance of inhibitors in Brazilian pre-salt scenarios varying only the capillary and pH of brine within a stipulated narrow range and the impact on product efficiency discussed.

Keywords

Scale; Inhibitors; Efficiency

Introduction

The formation of inorganic scale during oil production is a major challenge in flow assurance. Different types of scale can be formed being the main insoluble salts of sulfate and carbonate. Sulfate scales are mainly formed due to the process of injecting seawater into the reservoir for oil recovery and the mixture of incompatible waters is responsible for the formation of these salts due to sea water being rich in sulfate and formation water being rich in metals such as calcium, barium, and strontium. The interaction between these ions promotes the formation of sulfates. Carbonate scales are formed mainly due to thermodynamic variations in the system during the oil production process, such as changes in pH, pressure, and temperature and these variables directly affect the solubility of the salts. Scale inhibitors have been an excellent tool to mitigate problems caused by the formation of these insoluble salts. For the development of scale inhibitors to be applied during oil production, laboratory tests are required with aim of simulating conditions in the field when a product is applied. Thus, there are some important tests that are performed during product development or screening, such as Compatibility Tests, which aim to evaluate the tolerance of an inhibitor to the calcium ion present in brine; Static Efficiency Test that evaluates efficiency of a product against the prevention of sulfate scales under static conditions; and finally, Tube Blocking Test (TBT), which is the main focus of this work. In a Tube Blocking Test, synthetic brines are prepared based on the composition of the produced water from a field and they are pumped into the DSL (Dynamic Scale Loop) as separate non-scaling anion and cation brines. Scale formation is assessed by monitoring the pressure differential over the inlet and outlet of a stainless-steel micro-bore capillary contained inside a heating cabinet. The DSL is conditioned to the pressure and temperature of the field, and the flow of the anionic and cationic brines is undertaken such that they mix immediately before entering the micro-bore coil. Initially, a test is done without the presence of inhibitors, called a blank test. It is important to perform this test initially because it determines the duration of the pass time for tests undertaken with scale inhibitor. Depending on the scenario, the result of a TBT is very dependent on the pH of the brine used when carbonate scales are in concern and the internal diameter of the capillary. Usually, both conditions are pre-determined by the Operator for the performance test during development, but depending on the range of tolerable variation for pH, as well as the diameter chosen for the capillary, there may be significant impacts on the performance of the evaluated product to the point of a slight increase in pH still within the established range or a reduction in the internal diameter of the capillary is responsible for a significant increase in the dosage of product required to prevent the scale formation in laboratory tests. This assessment becomes important in order to reflect on the extent to which the laboratory is reproducing what will happen in the field, or whether too conservative conditions are being considered.

Methodology

Experimental Procedure

Dynamic tests with a DSL equipment were performed to understand the impact of the variation of brine pH and the internal diameter of the capillary in the product efficiency. A product based on PAPEMP (Polyamino Polyether Methylene Phosphonate) was evaluated and the scenarios are from the Brazilian pre-salt, one of them for topside application and another for subsea.

For the performance tests, synthetic brines were prepared according to the composition of Table 1. Test conditions are outlined in Table 2.

Table 1. Brine Composition

	Subsea (mg/L)	Topside (mg/L)
Sodium	33257	76040
Potassium	2329	4728
Magnesium	805	1984
Calcium	4850	7886
Barium	6	44
Strontium	919	3043
Chloride	64048	134290
Bromide	386	744
Acetate	0	962
Sulfate	136	86
Bicarbonate	2317	717
pH	7.1	7.0

Table 2. Test Parameters

	Subsea	Topside
Temperature (ºC)	66	135
Pressure (psi)	1000	120
Flow rate (mL/min)	10	10
Pass criteria	ΔP increase <0.5psi for 3 x blank	ΔP increase <0.5psi for 2hours

During the evaluation of the influence of the brine pH variation on the product efficiency, a range of ±0.20 was allowable from the stated pH. For the study of the influence of the capillary internal diameter, capillaries of 0.50 mm ID, 0.75 mm ID and 1.00 mm ID were evaluated.

Results and Discussion

pH Sensitivity

In order to evaluate the influence of brine pH on the scale inhibitor efficiency, the subsea scenario was used. For TBT, the produced water in Table 1 was divided into cationic and anionic brine so that when they are mixed inside the equipment the desired composition is obtained. pH adjustment of the cationic brine was performed with HCl and/or NaOH and the anionic brine with CO_2 such that when the brines were mixed, the pH obtained was within the range of 6.90 to 7.30 (7.1 ±0.20).

The theoretical sensitivity in the pH variation was observed through simulations using ScaleChem software considering a range of 7.50 to 6.80 for the pH of the mixture. Figure 1 shows that when the pH is above 7.20, the saturation ratio increases rapidly for $CaCO_3$.

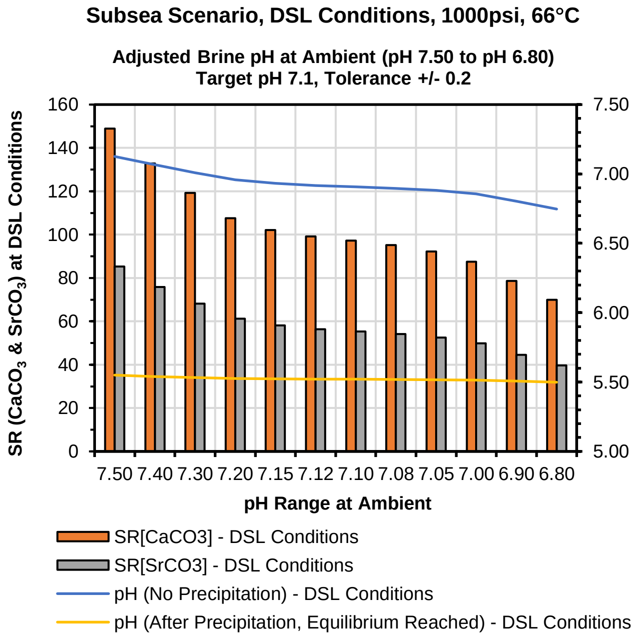

Figure 1. Evaluation of the influence of the pH mixture on the predicted saturation ratio for the Subsea scenario

Based on laboratory results for the subsea scenario, it can also be observed that considering a ±0.20 variation for pH, different results for the efficiency of the same product are obtained. The test results are shown in Figure 2 and it is possible to conclude that above pH 6.90, there is an increase in the Minimum Inhibitory Concentration of the product due to the increase in the saturation ratio of the scenario.

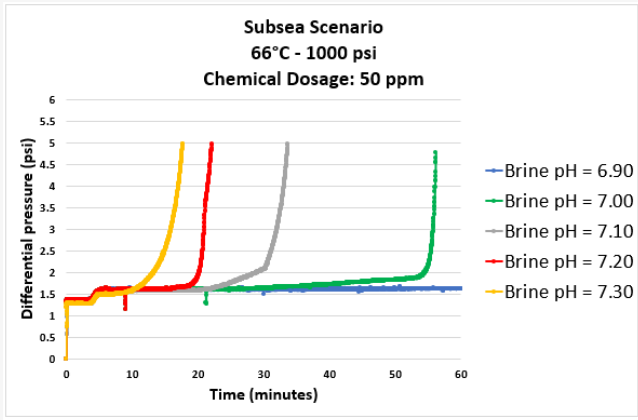

Figure 2. TBT Result for subsea scenario with brine pH variation

ID Coil Influence

The Topsides scenario was used for this TBT evaluation. Capillaries of 0.50 mm, 0.75 mm and 1.00 mm internal diameter were used. The tests were performed at a fixed dosage of 75 ppm with a PAPEMP based product and it was possible to observe that the internal diameter of the capillary significantly influences the scale inhibitor efficiency testing results. Using the 0.75 mm ID and 1.00 mm ID capillaries, the product was shown to pass the inhibition efficiency tests at a dosage of 75 ppm, whereas using the 0.50 mm ID capillary, 75 ppm of the same product was not enough to prevent the increase in differential pressure below the criteria for 2 hours. The test results are shown in Figure 3.

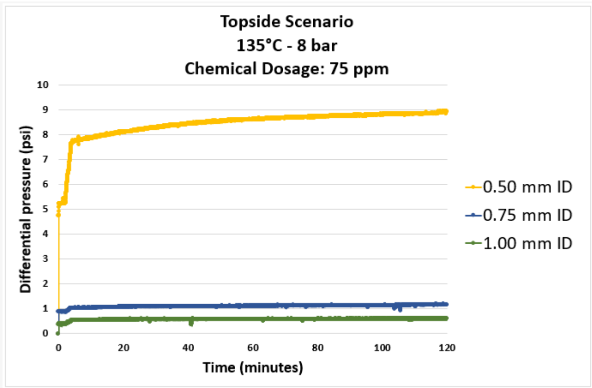

Figure 3. TBT Result for topside scenario with capillary internal ID variation

Based on these evaluations, it can be concluded that the smaller the internal diameter of the capillary used, the more critical, severe and restrictive the TBT is, and often molecules with better performance and / or higher dosages are necessary to pass a test under those conditions.

Conclusions

Based on these evaluations, it can be concluded that the pH tolerance range should be narrow enough to capture the field conditions and be reproduced in the laboratory without, however, allowing exacerbated variations in the saturation index of the evaluated scenario. This is often the case for high scaling tendency brines. A little increase in brine pH could significantly change the saturation index/ratio of scaling carbonate minerals. As a result, the minimum inhibition concentration of a scale inhibitor is increased substantially. With regard to the internal diameter of the capillary, tests carried out considering the internal diameter of 0.50 mm, when combined with the addition flow of anionic and cationic brines could make the scenario much worse than the field conditions. At such harsh conditions, the MIC of a chosen scale inhibitor obtained through laboratory TBT testing could be significantly higher than the actual treatment dosage needed in the field. This is a problem because it may not represent the production conditions of the field and as a practical consequence, an increase in the cost with the deposition control of inorganic scale.

Therefore, it is extremely important to always evaluate whether laboratory tests are consistent with the conditions of production in the field and the MIC obtained through laboratory TBT should be considered as an initial recommended treatment rate and the actual treatment rate of a scale inhibitor needs to be optimized after the deployment of the chosen scale inhibitor in the field.

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References

[1] Da Rosa, K.; Fonte, R.; Do Rosário, F.; Freitas, T.; Penna, M.; Castro, B.; Da Silva, M; Da Silva, G.; Silva, J.; Figueiredo, M. *Offshore Technology Conference Brasil.* OTC-29683-MS. Rio de Janeiro, 2019.

[2] Barber, M.; Heath, S. *SPE International Conference on Oilfield Chemistry.* SPE-193580-MS. Galveston-TX, USA, 2019.