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ANTIFOAM PERFORMANCE EVALUATION OF MEDIUM API GRAVITIES PETROLEUMS

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Abstract. *Foam formation represents a major problem in petroleum production processes, being responsible not only for increased residence times in separation equipment (and thus a diminished production rate), but also for damages in pumps, compressors and purifiers. Therefore, the best condition possible to conduct the phase separation between the oil produced and the gas that was released from it is a complete absence of foam. In order to better understand the interaction between a silicon-based antifoam and different kinds of petroleum, foam formation experiments were conducted and recorded using newly developed equipment, which optimizes foam generation during experiments. During the tests, foam formation and decay were analyzed under the influence of different antifoam concentrations (0, 10, 20, 40 and 60 ppm), and in petroleum samples of 20 and 30 API gravities. Foam behavior was observed through video recordings of oil decompression experiments, in which the petroleum is heated and pressurized until saturation, and posteriorly depressurized in a transparent chamber. Tests with the 20ºAPI oil showed that the antifoam indeed inhibits foam formation at all concentrations tested, while the 30ºAPI oil exhibited a different behavior, in which the antifoam just prevented foam formation when applied in a concentration of 60 ppm.*

Keywords: *crude oil, petroleum, foaming, antifoam, depressurization foam*

1. INTRODUCTION

Foaming is a phenomenon that can occur naturally in petroleum production processes and be the source of great economic losses. According to Shaban (1995), foaming occurs as soon as crude oil enters high pressure separators, but can also occur on lower pressure separators ahead in the production line as well. The operational problems introduced by foaming in separators include an increased difficulty in controlling the liquid level, since the control device would have to deal with an additional phase made by foam; loss of available space inside the separator, leaving little of it to the liquid and gaseous phases; liquid carry-over and gas carry-under to the next separation vessels, which cause damage in other equipment such as compressors, as mentioned by Poindexter, *et al.* (2001).

Pugh (1996) elucidates that the formation of foam occurs when a gas bubble moves through a liquid medium that contains surfactants, in an attempt of transferring to a gaseous phase; as the bubble passes through the interface, a liquid film traps it if the interface is elastic enough, which is the result of a low interfacial tension. Foam is formed when multiple bubbles are trapped by a liquid film, and the system is stable enough that it will not break down immediately. It is noteworthy that a liquid medium without surfactants is not capable of foaming since its interfacial tension will be high, which means that the interface won't be able to deform with the passage of the gas to be able to trap it, causing an immediate rupture of the bubbles.

Various methods of dealing with foam on separators were proposed, as mentioned by Blázquez, *et al.* (2016), including mechanical breaking, operating at higher temperatures and operating on specially designed units. Even so, employing antifoams is still a preferred method in many situations due to its ease of use and effectiveness. Karakashev and Grozdanova (2012) discourse about the importance of silicone-based antifoams, which use silica particles, that represented a performance breakthrough from older antifoams used before that time. Even in the present silicone-based antifoams are regarded as highly effective and widely used.

Recent works (Blázquez, *et al.*, 2016 and Fortkamp, 2014) proposed methodologies to generate foam in laboratory. We based our experimental procedure on those past experiences and aimed to improve the method with a temperature-controlled decompression chamber made by us. Said new equipment has the capacity to impose higher head loss to the oil-gas mixture, thus generating greater foam heights and a more efficient foam formation procedure overall.

2. METHODOLOGY

2.1 Materials

Two types of crude oil provided by Petrobras were used in foam formation experiments; their properties, including density (d), viscosity (µ), equilibrium surface tension (σ), SARA, total acid number (TAN) and water content (A), were determined and summarized in Tab. 1 and Tab. 2. We also used pressurized nitrogen gas, and antifoam identified as silicone dispersion (27.5% m/m PDMS).

Table 1. Density, viscosity and surface tension measures for both crude oils.

° API	T (±0.01 °C)	d (g/cm³)	µ (mPa·s)	σ (mN/m)
20	15.55	0.93181 ± 0.00002	-	-
	40	0.91575 ± 0.00001	118	29
	50	0.90905 ± 0.00001	61.69	28
	60	0.90238 ± 0.00001	38.75	-
30	15.55	0.87625 ± 0.00002	-	-
	40	0.85930 ± 0.00002	21.7	28
	50	0.85061 ± 0.00001	16.69	26
	60	0.84252 ± 0.00001	13.2	-

Table 2. SARA, TAN and water content properties of both crude oils used.

° API	Saturates (%)	Aromatics (%)	Resins (%)	Asphaltenes (%)	TAN (mg KOH/g)	A (%)
20	62.7	7.8	23.4	6.1	*	0.03
30	77.0	5.5	16.7	0.8	0.029	0.04

* below equipment detection limit

The densities were determined using an Anton Paar DMA 4500 densimeter. Viscosity measures were made using a HAAKE Mars III rheometer. The superficial tension values were measured using a Sinterface PAT-1M tensiometer. SARA analysis was carried out using the standard test method ASTM D6560-12 for the asphaltenes, while aromatics, resins and saturates were determined through standard test method ASTM D2007-11. TAN was determined by the potassium hydroxide quantity required to neutralize the acidity in 1 g of crude oil. The water contents were obtained with a Mettler Toledo T50 Titrator through the Karl Fischer method.

The equipment used during the experiments consists of a Drial Service aging cell made of stainless steel, a Panam PNV-H-S-4-FF-SG needle valve, a decompression chamber we designed and manufactured made of stainless steel, borosilicate glass and acrylic, similar to the one proposed by Fortkamp (2014), an agitation system for the aging cell we also developed. We also employed a Higher Flex belt heater, an Ecil Industrial Temperatures resistance thermometer, a HG Resistances temperature controller and a Thermo Scientific AC200 water bath to heat and monitor the crude oil temperature. A Prolab universal stand with clamp was used to fixate the aging cell in an inverted position. A Canon Rebel T6i video camera was also used to record the experiments. Figure 1 illustrates a schematic of the experimental setup on the moment of the decompression chamber loading with oil, adapted from Blázquez, *et al.* (2016) and Rezende (2009).

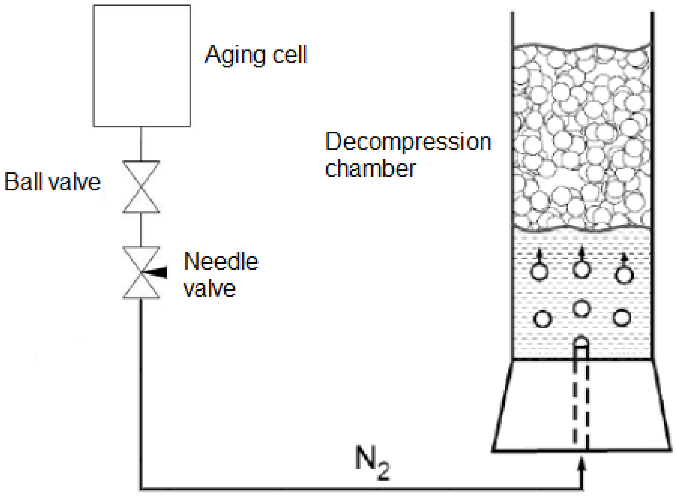

Figure 1. Experimental setup schematic, adapted from Blázquez, *et al.* (2016) and Rezende (2009).

2.2 Experimental procedure

The tests were performed in duplicates, and were carried out by first loading half of the aging cell volume with crude oil, closing the equipment and pressurizing it with nitrogen gas until 15 bar. The aging cell was then covered with the belt heater and fixated on the agitation system. The agitation system was turned on, as is the temperature controller, after having the set point of 50 ºC determined. This aging process was kept for until the crude oil inside the aging cell is at 50 ºC, and the pressure read at the aging cell's barometer was stabilized, indicating that the chemical equilibrium has been reached; if there is pressure drops during the aging process, it was compensated by loading more gas into the aging cell, until it was at the desired value again. After the aging process was done, the aging cell was removed from the agitation system and the belt heater with the aid of a heat resistant glove, and set in inverted position in the universal stand. The video camera was turned on and put to record, and the valves in the aging cell and decompression chamber were opened. Oil-gas mixture was transferred from inside the aging cell to the interior of the decompression chamber, with its flow controlled via the needle valve at the aging cell, until a sufficient height of oil was achieved inside the chamber. The valves were all closed at this moment, and the recording continued until all the foam generated inside the decompression chamber had decayed.

In order to obtain foam height data, the videos recorded on the camera were transferred to a computer. The videos were played and, from the point the foam ceases being formed in them, paused at 10 second intervals to register the foam height. This process was done until there is no remaining foam in each video. Equation (1) was then used to calculate the foam percentage (F_p) at each time period, considering the foam height at a certain moment (H) and the final liquid height, when the foam has decayed completely (H_f).

$$F_p = 100 \cdot (H-H_f)/H_f \qquad (1)$$

Foam percentage values were plotted against time to generate dispersion graphs, which made possible to analyze foam behavior under the influence of different antifoam concentrations.

3. PRELIMINARY RESULTS

Arithmetic averages were done for foam height in each set of duplicate experiments in the same conditions. Foam percentages were plotted for the average foam heights of the duplicates versus decay time. Crude oils of API gravities of 20 (Fig. 2) and 30 (Fig. 3) were used, while the antifoam was either absent or applied in concentrations of 10, 20, 40 or 60 ppm.

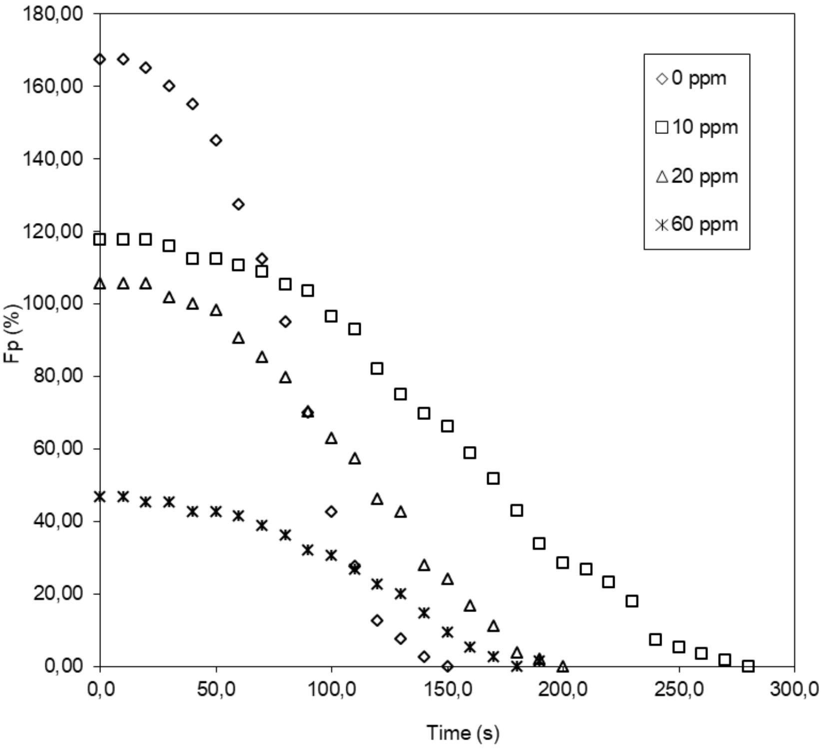

Figure 2. Diagram of foam percentage versus time for 20 ºAPI oil

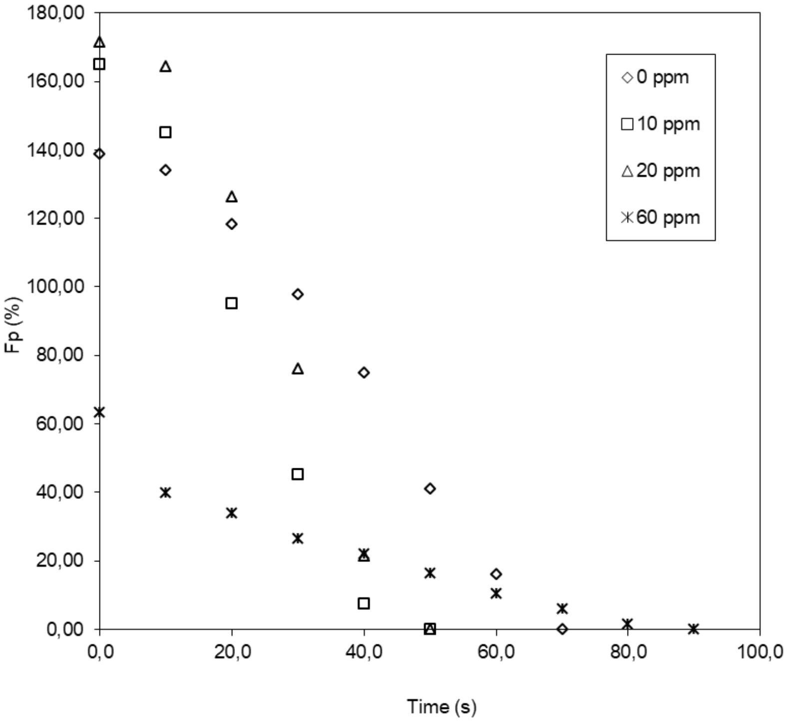

Figure 3. Diagram of foam percentage versus time for 30 ºAPI oil

The antifoam had a clear antifoaming effect on the 20 ºAPI oil, as expected. When applied at 60 ppm, the antifoam lowered the initial foam formation from 167.5% to 44.8%. A subtler effect can be seen when it was applied in lesser concentrations, presenting an initial foam formation range from 105.5% to 122.0%, which is fairly close when comparing results from 10 to 40 ppm. It’s also noteworthy that the antifoam displayed a stabilizing effect, increasing foam decay time when applied to the oil; total decay time increased from 150 seconds, in the absence of antifoam, to 180 seconds when present at 60 ppm, or even greater values in other concentrations, reaching 280 seconds when antifoam was applied at 10 ppm.

The 30 °API oil displayed a more complex behavior, in which the antifoam was only efficient at preventing foam formation when applied at 60 ppm, which reduced the initial foam formation from 138.6% to 63.24%. At other concentrations, it acted as a foaming substance, increasing initial foam formation to a range of values from 157.5% to 171.4%. A subtle stabilizing effect can also be noted at 60 ppm, which increases the foam decay time from 70 to 90 seconds. This result is under a deeper investigation.

4. CONCLUSIONS

The antifoam indeed inhibited initial foam formation for both oils used in the experiments; however, this only occurred when applied at 60 ppm in the 30 °API petroleum. It is currently unknown if this phenomenon only occurs at 60 ppm for the 30 °API oil or if the same behavior can be expected for higher concentrations as well. Seeking to clarify this question, more experiments will be carried out in higher antifoam concentrations. It is expected to conclude an optimal antifoam concentration for the 30 °API oil, where the foam formation inhibition will be most efficient.

5. ACKNOWLEDGEMENTS

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