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# Experimental Investigation of the Shear Effect on Oil-Water Emulsion Flow in a Pipeline

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***Abstract*** – Emulsion flows have been a severe flow assurance issue, mainly in mature oil fields. Its formation occurs due to shear on oil-water flows caused by artificial lift methods, such as Electrical Submersible Pumps (ESP), and/or valves. The shear rate has an important role in emulsion flow behavior related to its relative viscosity and phase inversion. Therefore, this work presented an experimental investigation of the shear effect on three emulsion systems flowing in a pipeline. The shear element used was a combination of an 8-stage ESP and a glob valve. The emulsion systems analyzed were unstable emulsion and stable emulsion with and without a demulsifier. The experimental investigation was carried out for two ESP rotational speeds, 2400 and 3500 rpm, and one total volumetric flow rate, varying the water cut. From this study, it was observed that phase inversion occurred with increasing shear. Moreover, the effective viscosity was the same regardless of the surfactant presence for the three emulsion systems tested.

***Keywords*****:** water/oil emulsion, phase inversion, effective viscosity, shear effect, electrical submersible pump

## 1. Introduction

Oil-water dispersed flows occur frequently in the petroleum industry during the exploitation and transportation of crudes. The water present in oil production can come from the reservoir and/or of the injection on well as an enhanced oil recovery method. During this process, these immiscible fluids can be subjected to shearing devices, such as chokes, valves, pumps, elbows, and separators [1,2]. When the oil-water flow passes through these elements, a dispersed flow pattern is formed. Whether the dispersed phase is composed of small droplets (0.1-100 µm), the mixture is called emulsion [3].

There are two particular subjects related to oil-water emulsion flow that have taken attention recently: effective viscosity and phase inversion process. The effective viscosity of the emulsion can present values many times higher than the continuous phase viscosity [4,5], increasing the energy consumption during oil production and transportation [6]. Phase inversion occurs when there is a change in the continuous phase, i.e., oil-continuous to water-continuous or vice-versa, due to the addition of a volumetric fraction of the dispersed phase until a critical point [2,7]. When this process occurs, there is a significant change in the spatial arrangement of the phases and, consequently, in the way that energy is dissipated. Therefore, the operation near the phase inversion point can provoke severe operational problems [8]. Moreover, the effective viscosity and phase inversion can be directly affected by surfactants present in the oil-water mixture [9]. Demulsifiers are added to the emulsion flow during oil production to anticipate phase inversion and/or decrease the effective viscosity [10,11].

In this context, the objective of this study is to investigate the shear effects on phase inversion and effective viscosity for oil-water unstable emulsion, stable emulsion with and without demulsifier addition, flowing in the pipeline. The shear elements are composed of an 8-stage centrifugal pump (8-stage Electrical Submersible Pump - ESP) and a choke valve, as presented in Fig. 1.

## 2. Experimental Procedure

During the experimental campaign, mineral oil and tap water were the base for emulsion preparation. The mixture temperature was kept constant at approximately 26 °C, resulting in an oil viscosity of approximately 122 cP. The experimental tests with unstable emulsion were performed without surfactant addition at a total flow rate of 27 m³/h. For the stable emulsion tests, the initial emulsion was stabilized by the addition of 1 wt% lipophilic emulsifier. In the tests with demulsifier, 100 ppm emulsion breaker was added to the mixture mass. All tests were performed from oil-continuous to water-continuous flows. The tests related to stable emulsion systems were carried out for one total flow rate, 27 m³/h. All tests were carried out at ESP rotational speeds of 2400 and 3500 rpm.

The pressure gradient before ($\Delta P_1\ /L$) and after ($\Delta P_2\ /L$) the shear elements were measured first for stable emulsion systems and second for unstable ones. The indirect method based on differential pressure proposed by [12] and [13] was used to estimate effective viscosity. The results are presented as the relative viscosity, which is the ratio between the emulsion effective viscosity ($\mu_e$) and oil viscosity ($\mu_o$).

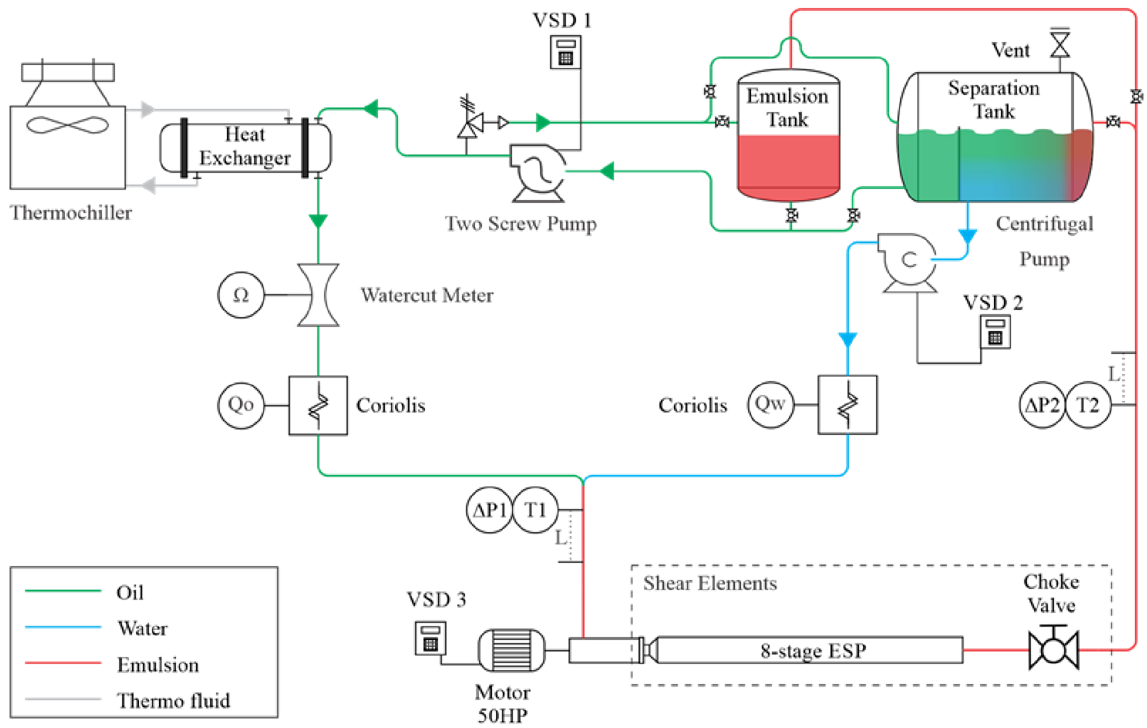


Fig. 1: Experimental flow loop.

## 3. Results

Initially, the pressure gradient before ($\Delta P_1\ /L$) and after ($\Delta P_2\ /L$) the shear elements were measured for the stable emulsion at 2400 and 3500 rpm and 27 m³/h, as shown in Fig. 2. The phase inversion point is related to the maximum pressure gradient, which corresponds to the higher effective viscosity of the emulsion [13]. For the stable emulsion, it was observed that there was no change at this point for a rotation of 2400 rpm (Fig. 2a), occurring at an approximately 65% water cut. However, at 3500 rpm, there is an anticipation of phase inversion after the shear elements, from 65% to 60%. Thus, it can be achieved that an increase in shear leads to an anticipation of the phase inversion point.

The same analysis was performed for the stable emulsion with demulsifier addition, as presented in Fig. 3. As expected, the phase inversion was anticipated compared to the stable emulsion for all conditions tested from 60~65% to 40%. The influence of the shear effect on phase inversion was not observed with the addition of demulsifier.

The relative viscosity in pipeline flow after shear elements of the three emulsion systems tested as a function of water cut for 2400 rpm and 27 m³/h as a function of the water cut is presented in Fig. 4. As one can see, it was the same for all systems regardless of surfactant presence until the phase inversion point of each emulsion system.

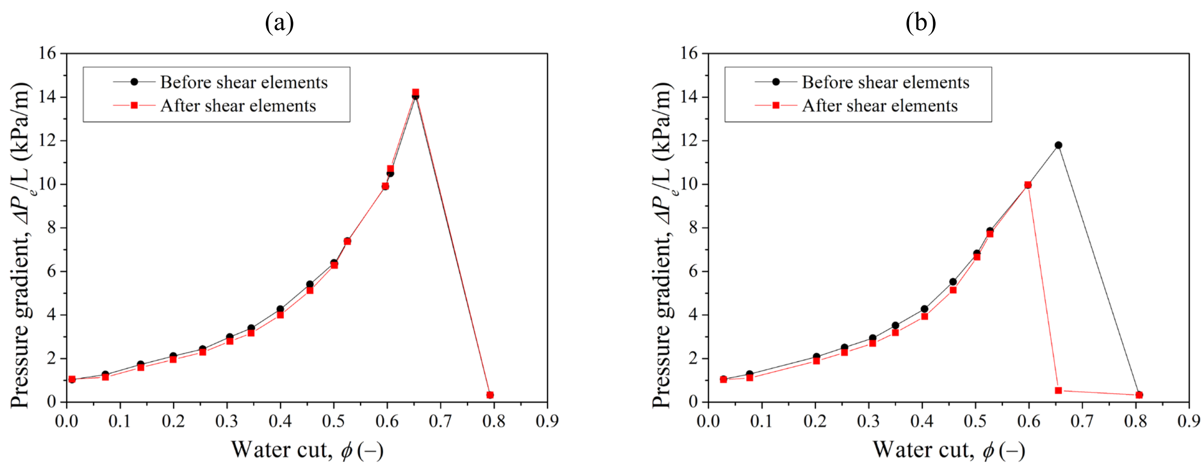


Fig. 2: Pressure loss of flow of the stable emulsion with demulsifier before and after shear elements as a function of (a) 2400 and (b) 3500 rpm ESP rotational speed at 27 m²/h.

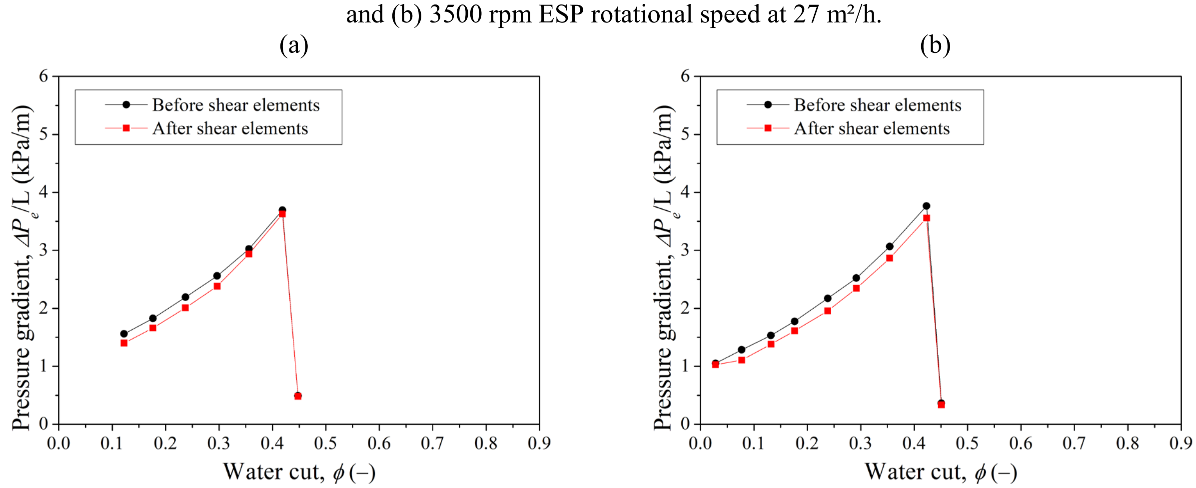


Fig. 3: Pressure loss of flow of the stable emulsion with demulsifier before and after shear elements as a function of (a) 2400 and (b) 3500 rpm ESP rotational speed at 27 m²/h.

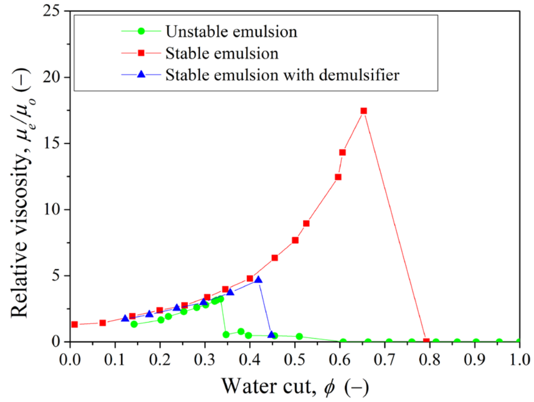


Fig. 4. Emulsion relative viscosity in pipeline flow of the three emulsion systems as a function of water cut for 2400 rpm and 27 $m^3/h$.

## 4. Conclusion

In this study, an experimental analysis of the shear influence on the phase inversion phenomenon and effective viscosity for three emulsion systems in pipeline flow due to shear elements was performed. An 8-stage ESP and a choke valve were used as shear elements. Two ESP rotational speeds, 2400 and 3500 rpm, and one total volumetric flow rate was tested, varying the water cut. Anticipation of phase inversion with increasing shear was observed. For the three emulsion systems tested, the effective viscosity was the same regardless of the surfactant presence.

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