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Investigation of Flow Behavior Characteristics for Iraqi Crude Oil with Different Polymeric Additives

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ABSTRACT: In this work, the flow behavior characteristics for Iraqi crude oil using different polymer additives were investigated. Polyacrylic acid (PPA) was added to the crude oil at different concentrations of (0, 50, 100, 150, 200 and 250 ppm) and Polyethylene glycol (PEG) at different concentrations of (0, 200, 300, 400, 500 and 600 ppm). Results showed that PPA additions decreases largely the viscosities of the crude oil, and this dropping depends on the DRA concentration in the crude oil. Crude oil viscosity seems to be increases as the PEG concentration raised, increases with increasing shear rate, except with 400 wt.% of PEG. The shear stress increases as the shear rate increased, and its minimum value occurs at 300 wt.% of PEG. Density of crude oil increases with increasing the additives concentrations, both PPA and PEG. The value of surface tension was reduced gradually till to concentration of 200 ppm of PPA and sudden decrease after that. While adding PEG lead to increase the surface tension till to the concentration of 300 ppm and then reduced.

KEYWORDS: Flow Characteristic, Drag Reduction Agents, PEG, PAA, Surface Tension, Surfactants.

INTRODUCTION

Because of their huge effects on the rheological characteristics at the surface as well as the interface**,** surfactants are used excessively in many industrial applications, such as petroleum recovery, oil-well drilling, reservoir injection, petroleum pipeline and transportation and emulsions. Surfactant have an outstanding behavior due to the presence of a hydrophilic head group and a hydrophobic chain (or tail) in its molecule [1-3]. Small amounts of certain additives, can reduces the friction, which resists the flow of liquids in turbulent flow pattern. This phenomenon called drag reduction and these additives named Drag Reduction Agents (DRA). Usually, this accompanied by reduction in the pressure drop along the pipe length, as well as decreasing the required energy to transport the liquid to another location [4].

Surfactants have the ability to reform themselves in very short time (few seconds) during degradation of shear. This property allows to the surfactants to be the suitable candidate in fluid recirculation systems [5]. Up to now, the mechanisms by which DRA works are not understand. They may inhibit the formation of microscopic eddies in the liquid during different flow patterns, such as turbulent flue, laminar flue with high Reynolds number (Re) and in fully developed turbulent flue [6, 7]. Farhan et al. employed a Drag Reducing Agent (DRA) to decrease the drag of Iraqi crude oil using Poly Acrylic Acid (PAA) at different concentrations, they found that the DRA reduces the crude oil viscosity [8, 9]. The main purpose of the current work is to monitoring the effect of using different polymeric additives on the flow manner properties of the crude oil.

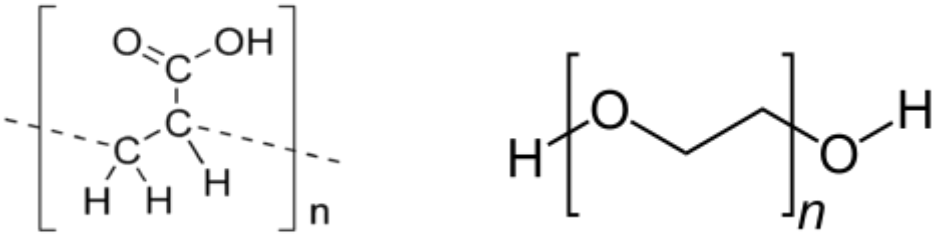
MATERIALS AND METHODS

Crude Oil

Iraqi crude oil was used in this work as a flowing liquid, which is supplied by Al-Najaf refinery–Iraq, with the following properties: viscosity equal to 27.55 cP and specific gravity equal to 0.89 (both at 25 ^{o}C).

Drag Reducing Agent

Poly Acrylic Acid (PAA) is a manmade polymer composed of acrylic acid monmomer repeating unit, which have high-molecular weight (Figure 1). At neutral acidity (PH about 7), PAA behaves as anionic polymer. This is because of the presence of a lot of the side chains of PAA. These chains will lose their protons in the solution and become with a negative charge. This manner makes PAA as a polyelectrolytes, which have high tendency to absorb and retiarn water molecules and swell to many times compared with its original volume. Poly Ethylene Glycol (PEG) is a polymeric material, which used in many applications, such as in medical field, industrial manufacturing, surface lubricating coating and as a DRA. Typically, the molecular weight of PEG is less than 100000 and when exceeds this value, it is named as polyethylene oxide (PEO). PEG chemical structure, also depicted in figure 1.



(a) **(b)**

Figure 1. Chemical structures of (a) Poly Acrylic Acid (PAA) and (b) Poly Ethylene Glycol (PEG).

Description of Circulating Flow Loop System

The test rig (Figure 2) utilized in the current work composed of a crude oil reservoir (tank) with (75 x 75 x 75 cm) dimensions and a pump (flow rate =30 L/min., maximum head=30 m, maximum power =0.74 hp). The pump duty is to circulate the treated crude oil fluid from the tank through the pipe. Flow meter device was used to measure the flow rate (flow rate=0.0081 m^3/s) of the treated crude oil through the system. Two pressure gauges are fixed at two different point on the pipe to measure the pressure drop. A stainless-steel pipe of 5 m in length and inside diameter of 0.0508 m is used. In addition, a viscometer and density tester were used to measure both viscosity of the crude oil and its density as shown in figures 3 and 4 respectively. After the experimental apparatus is built, the crude oil treated with different PAA concentrations is circulated through the flow loop system to measure different affecting parameters.

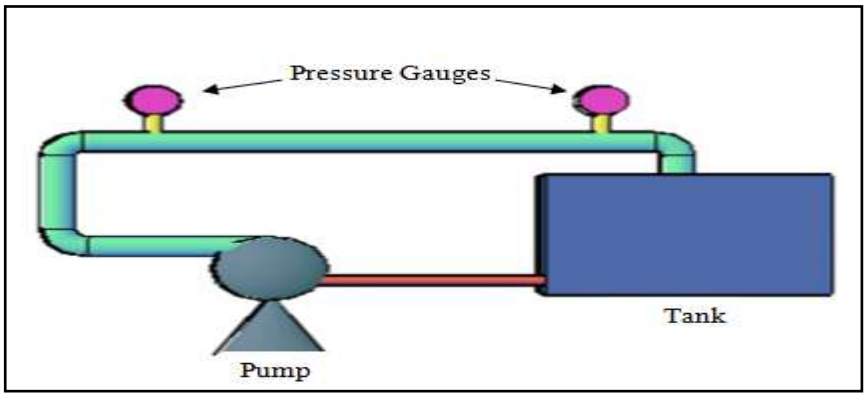


Figure 2. Schematic drawing of circulating flow loop system.

Figure 3. Cone on plate viscometer.

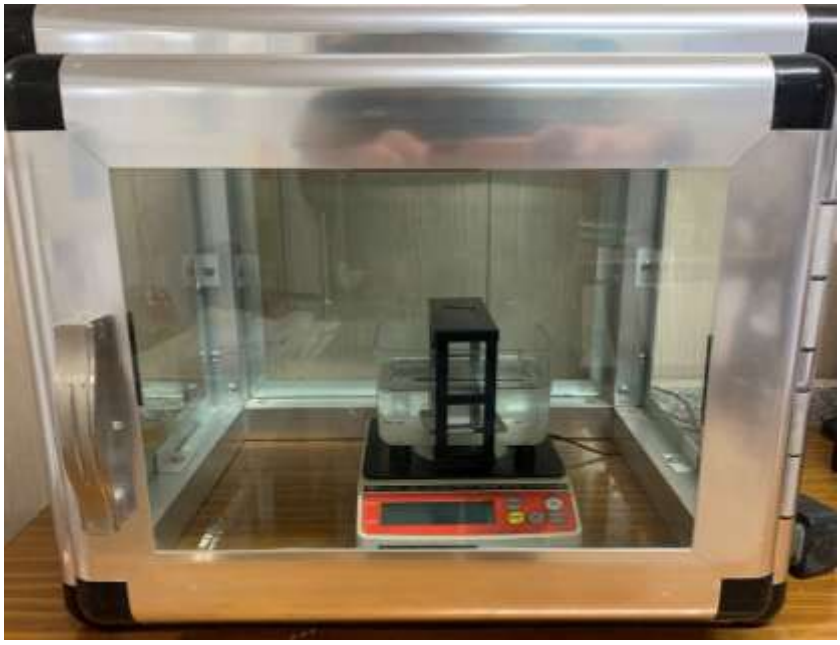


Figure 4. Density tester device.

RESULTS AND DISCUSSION

Results were obtained for adding different PAA concentrations to pure crude oil. The viscosity of crude oil was reduced and the minimum value done for 50 ppm of PAA, as shown in figure 5, which is the best concentration. Figure 6 shows the relation between viscosity and shear rate for the used crude oil, which treated with different concentrations (0, 50, 100, 150, 200 and 250 ppm) of PAA at room temperature. This figure shows that, the PPA addition decreases clearly the viscosity of the tested crude oil and this drop is a function of the DRA concentration in the crude oil. The sample with the 50 ppm shows the lowest reduction, while the sample with the 250 ppm shows the highest reduction value. This behavior is predicted to accompanied with the gradual reduction in the shear stress as shown in Figure 7. This can be attributed by the effect of DRA on pressure drop due to reducing the turbulence energy within the pipeline network [10-15].

Figure 8 shows the viscosity behavior of crude oil after adding different concentration of PEG. Crude oil viscosity seems to be increases as the polymer concentration increased. Also, the crude oil viscosity increases with increasing shear rate, except with 400 wt.% of PEG, increasing with increase shear rate as shown in figure 9. Figure 10 presents the relationship between shear stress and shear rate of the used crude oil which contains different PEG ratios. Shear stress increases as the shear rate increased and the minimum value of shear stress occurs at 300 wt.% of PEG. Figures 11 and 12 show density curves of crude oil with different additive concentrations of PPA and PEG, respectively. Density of crude oil increases with increasing the additives concentrations.

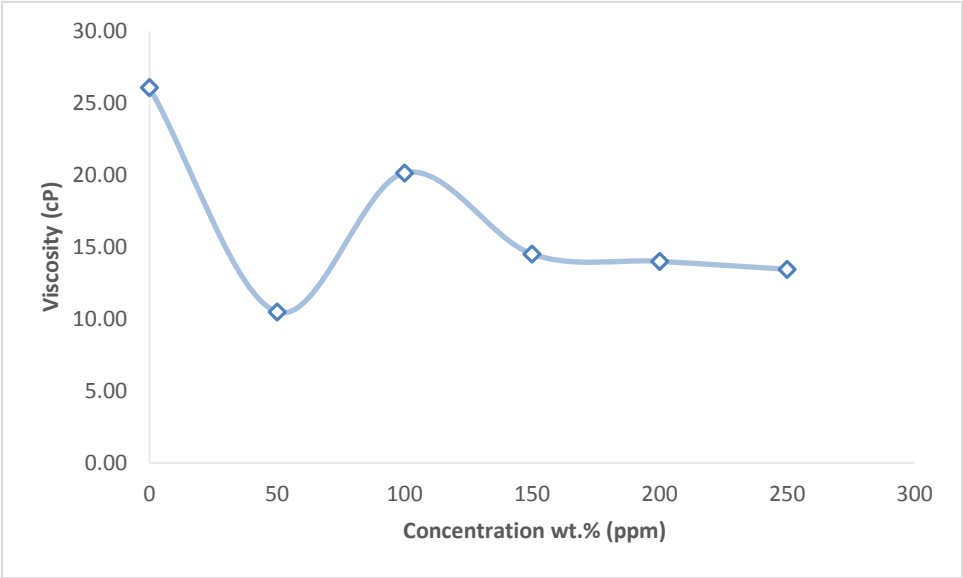


Figure 5. Viscosity behavior of crude oil as a function of PAA concentrations (0, 50, 100, 150, 200 and 250 ppm).

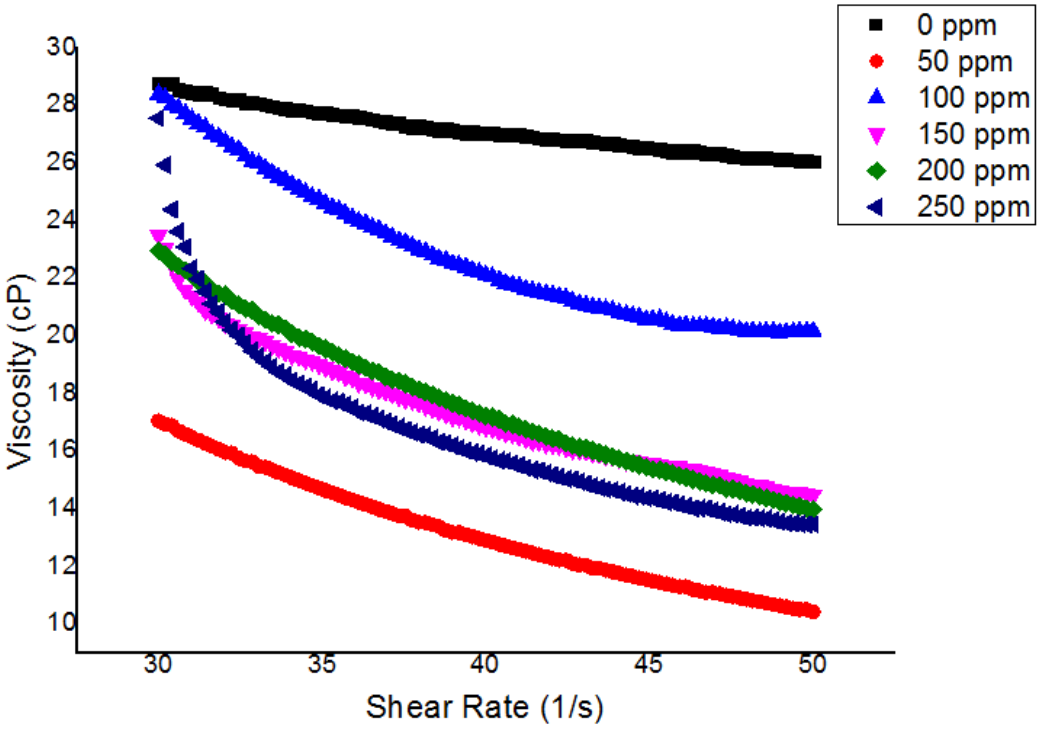


Figure 6. Viscosity-shear rate behavior of crude oil for different PAA concentrations (0, 50, 100, 150, 200 and 250 ppm)

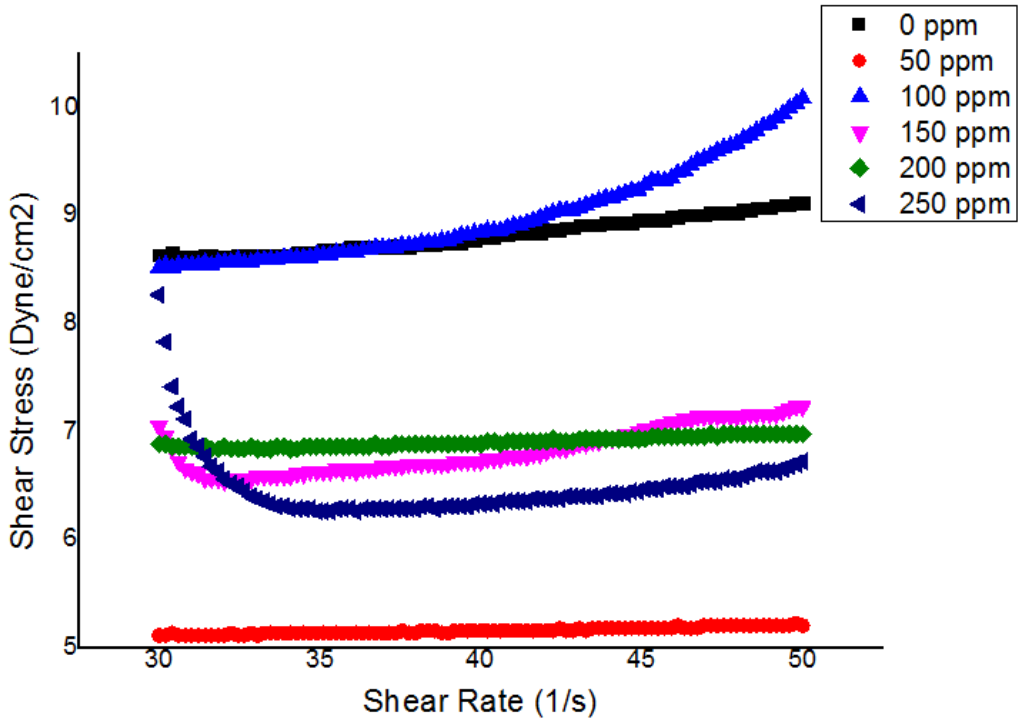


Figure 7. Shear stress – shear rate behavior of crude which having different PAA concentrations (0, 50, 100, 150, 200 and 250 ppm)

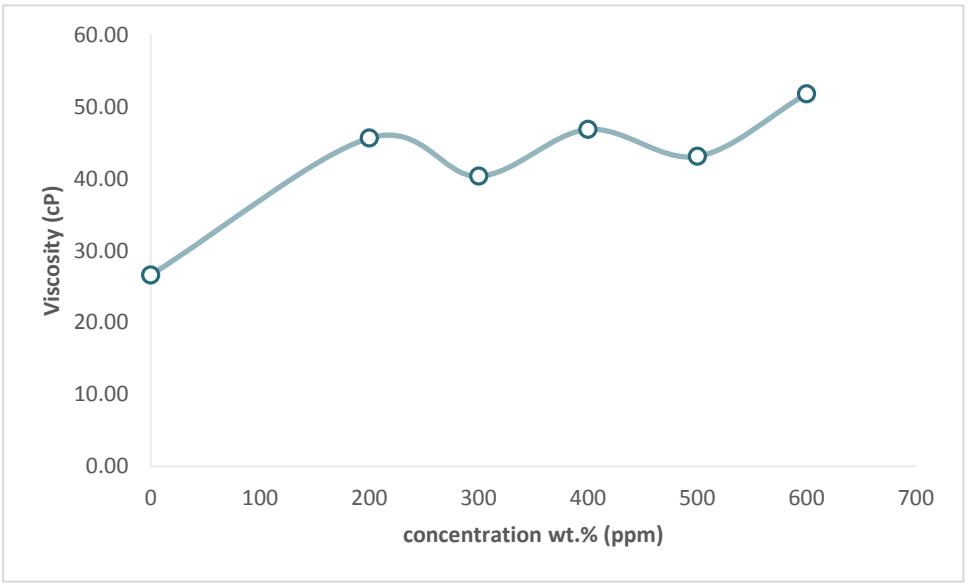


Figure 8. Viscosity behavior of crude oil which having different PEG concentrations (0, 200, 300, 400, 500 and 600 ppm)

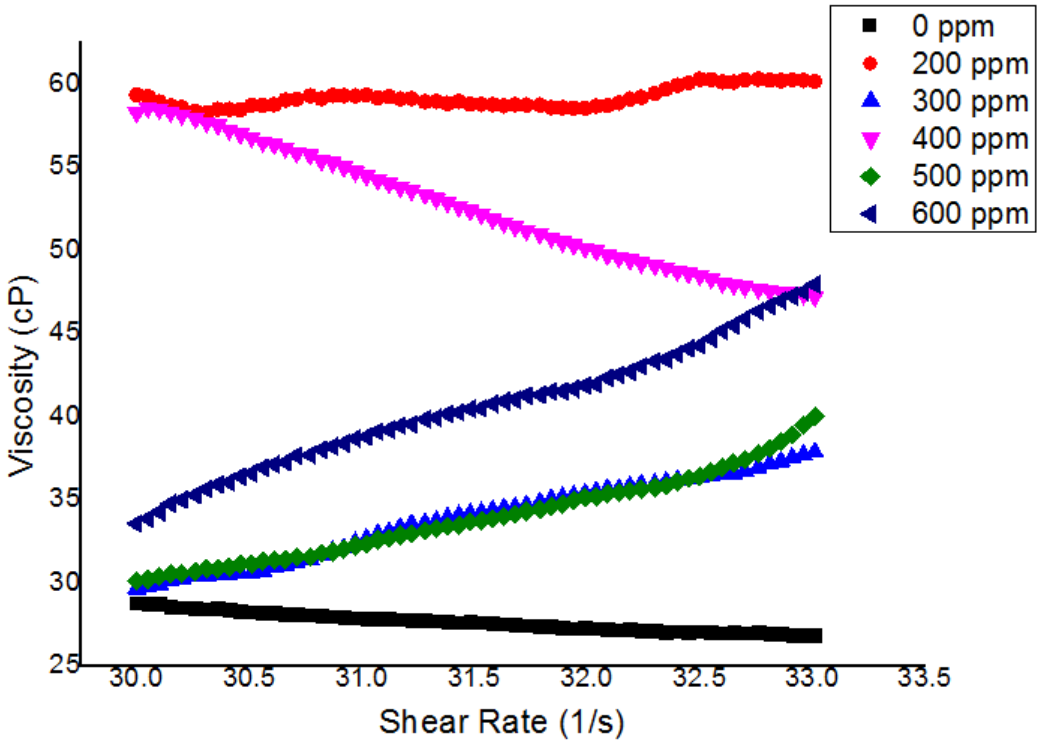


Figure 9. Viscosity-shear rate behavior of crude oil which includes different PEG concentrations (0, 200, 300, 400, 500 and 600 ppm)

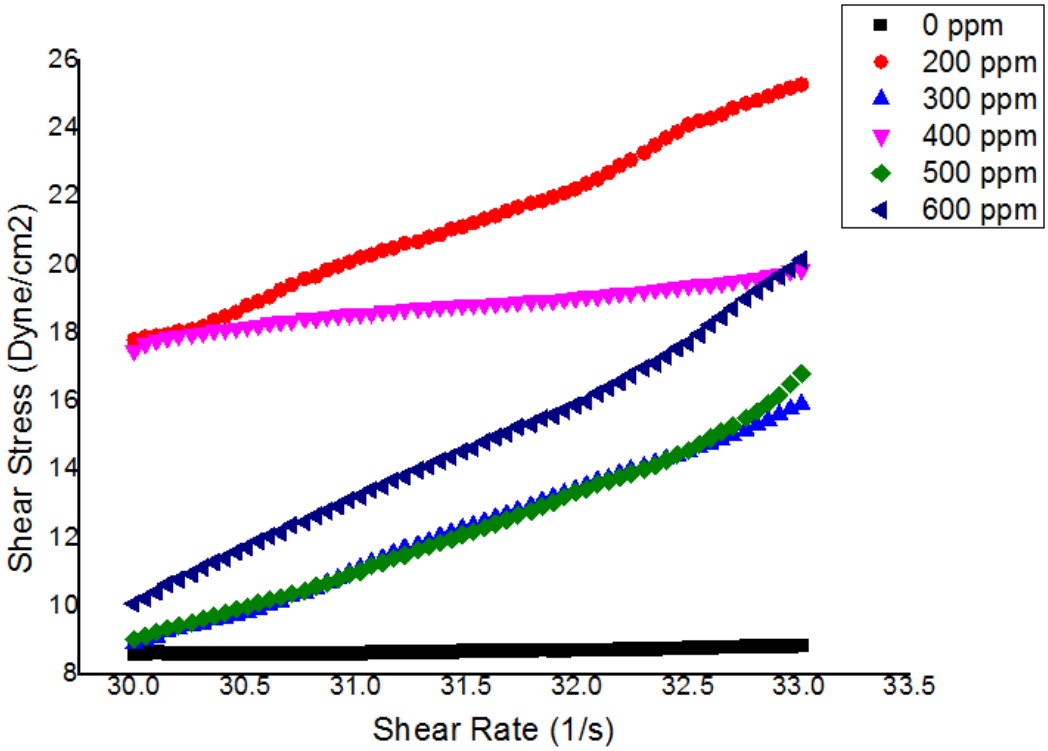


Figure 10. Shear stress – shear rate behavior of crude oil which includes different PEG concentrations (0, 200, 300, 400, 500 and 600 ppm)

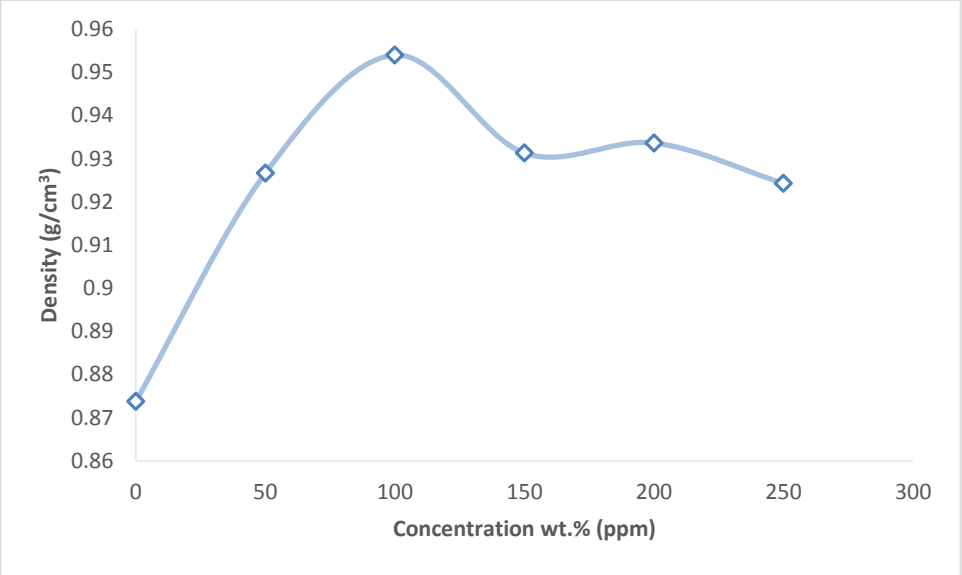


Figure 11. Density curve of crude oil which includes different PPA concentrations (0, 50, 100, 150, 200 and 250 ppm)

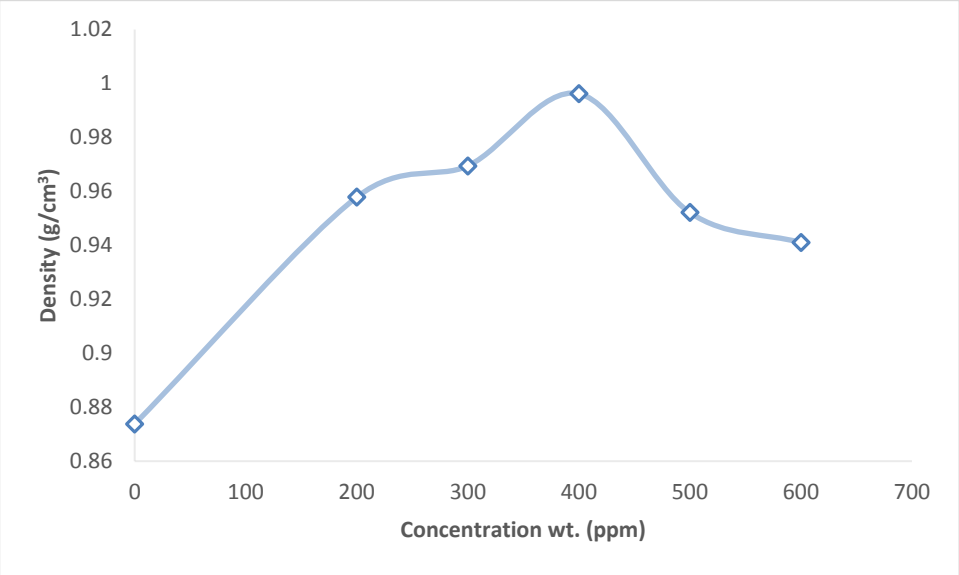


Figure 12. Density curve of crude oil which includes different PEG concentrations (0, 200, 300, 400, 500 and 600 ppm)

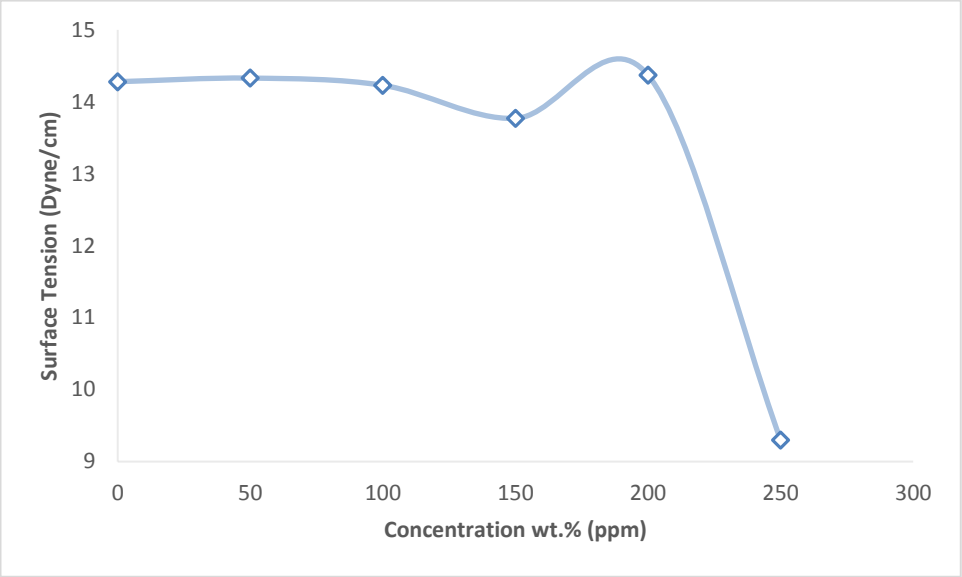


Figure 13. Surface tension of crude oil which includes different concentrations of PAA (0, 50, 100, 150, 200 and 250 ppm)

Figures 13 and 14 presents the behavior of surface tension for crude oil with different additive concentrations of PAA and PEG, respectively. The value of surface tension seems to be reduced gradually till to concentration of 200 ppm of PAA and sudden decrease after that. While, adding PEG lead to increase the surface tension till to the concentration of 300 ppm and then reduced.

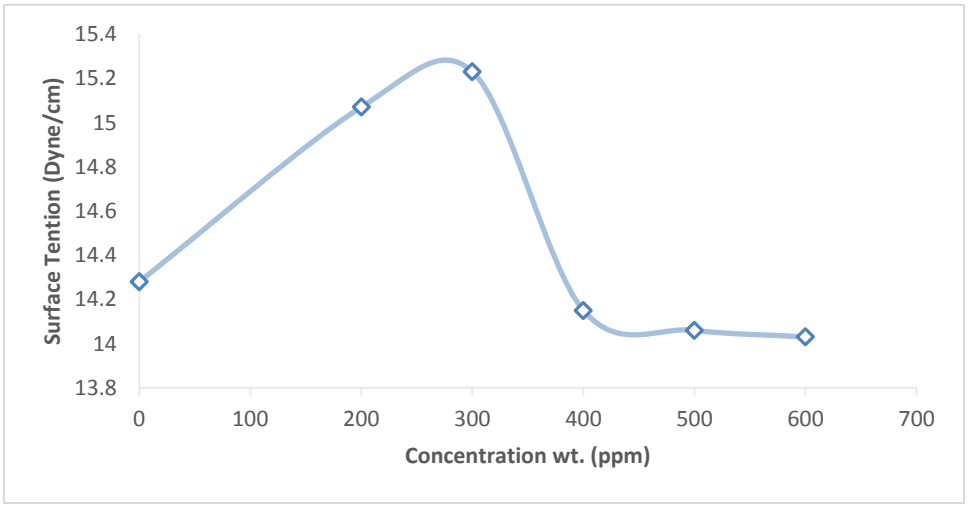


Figure 14. Surface tension of crude oil which includes different e concentrations of PEG (0, 200, 300, 400, 500 and 600 ppm)

CONCLUSIONS

The experimental investigation of flow behavior characteristics for Iraqi crude oil with different polymeric additives gave the following conclusions:

1. PAA acts as a DRA for Iraqi crude oil and its addition decreases significantly the crude oil viscosity.
2. The crude oil viscosity increased as the PEG concentration increased, and increases with increasing shear rate, except with 400 wt.% of PEG.

3. Shear stress increases as the shear rate increased, the minimum value of shear stress occur at 300 wt.% of PEG.
4. Density of crude oil increases with increasing the additives concentrations, both PPA and PEG.
5. The value of surface tension was reduced gradually till to concentration of 200 ppm of PAA and sudden decrease after that. While adding PEG lead to increase the surface tension till to the concentration of 300 ppm and then reduced.

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