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Studying the Interaction between a New Mixture in Enhancing Drag Reduction Efficiency

Hayder A. Bari and Emsalem Faraj

***Abstract*—Polymers are used as drag reducer in a strategic pipeline successfully for the past few decades due to its viscoelastic properties that can suppress the turbulent in pipelines. One of the many issues facing the use of these additives is its resistance to high shear forces during the transportation where it can be easily degraded where they pass them a pump. In the present work, polymer-surfactant complexes of anionic polymer and nonionic surfactant are investigated to prove its capability in enhancing the drag reduction and mechanism degradation performance. The interaction between anionic polymer Poly (acrylamide-co-diallyl-dimethylammonium chloride) and nonionic surfactant tween 20 in aqueous solution has been studied by using rheology, rotating disk apparatus (RDA) and pipe loop techniques. The effect of polymer concentration, surfactant concentration and rotational speed in enhancing the drag reduction were studied. The results showed that almost 35% drag reduction can be obtained. In addition, the effect of the degradation on the mixtures as a function in the time has been discussed also.**

***Index Terms*—Polymer, surfactant, drag reduction, RDA.**

I. INTRODUCTION

Drag reduction (DR) has wide applications in industry such as; transportation of oil, wastewater treatment, firefighting, transport of solids in water, heating and cooling rings, hydraulic and jet machinery, and also biomedical applications [1]-[4].

A lot of research work has been done to enhance the DR efficiency of fluids by using Polymer additives (PAs) after Dodge and Metzner studies [5]. Lumley [6] suggested that there is a serious value of wall shear stress at which the macromolecules become stretched due to the fluctuating strain rate. Though, in the viscous sub-layer close to the wall, polymer coils are not greatly twisted and viscosity does not rise greatly above solvent viscosity. Lumley [7] concluded that the stretching of randomly coiled polymers due to robust turbulent flow is pertinent for DR. Difference in turbulent construction in the buffer layer was also investigated by Tiederman [8]. Virk [9] based on experimental results suggested that DR is incomplete by an asymptotic value. Warholic *et al.* [10] lead experiments with polymer solutions and concluded that the Reynolds shear stress becomes insignificant near the maximum DR asymptote. Polymer DR was also clarified by viscoelastic effects of the polymer chains in the solution [11], [12]. Tesauro *et al.* [13] proposed that energy is transported by the velocity fluctuations to the polymer chain; which is kept in the form of stretching of the polymer chain (which in turn wastes the energy into heat), and by easing of the polymer chain from extended to an equilibrium state. But these DR additives are found to be exposed to mechanical and thermal degradation [14] leading to a damage in the drag reduction effectiveness at strong shear forces or a high temperature. Especially it has been well reported that polymer chains are degraded by severe mechanical force in a turbulent flow field.

Several studies [15]-[18] found that the addition of surfactant into a polymer solution could be an active technique in decreasing the mechanical degradation of polymer particularly in high temperature flow systems. The precise mechanism of DR by surfactant solutions is still indistinct; though, certain researchers have proposed that viscoelastic effects of surfactant solution could be accountable for turbulent DR [19]. Polymer and surfactants interact in two ways. First, the interaction is possible for polymers with negative or positive charge with oppositely charged ionic surfactant. The electrostatic interactions play a deep role here. Critical aggregation concentration (CAC) has been reported to be some orders of magnitudes lower than the critical micelle concentration in this case. The interaction between non-ionic polymer and ionic surfactant or (similar charge) polymer-surfactant complex is the second conceivable interaction type, where the CAC can be near to the critical micelle concentration (CMC) of surfactant. A hydrophobic interaction between the hydrophobic portions of both polymer and surfactant is the driving force for the interaction with this type [20]-[23].

The interaction between ionic polymer and ionic surfactant complex (similar charge) has studied by Kim *et al*. [23]. They found that the % DR has been increased by adding a little of surfactant to the mixture. That increasing in the % DR was happened as a result of the hydrophopic interaction between polymer and surfactant.

One aim of this work is to investigate the drag reduction capability of polymer-surfactant complexes. The interaction between anionic polymer Poly (acrylamide-co-diallyl-dimethylammonium chloride) and nonionic surfactant tween 20 in aqueous solution has been studied by using rheology and RDA techniques. The effect of polymer, surfactant and rotational speed has been discussed. In addition, the effect of the degradation on the pressure drop also has been studied as a function of the time by using flow pipe loop.

II. MATERIAL AND METHODS

A. Material

The Poly (acrylamide-co-diallyl-dimethylammonium

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chloride) (P (AAm-*co* DADMAC)) 10 wt. % in H_2O and Tween 20 were purchased from Sigma Aldrich, they were used without further purification. Double deionized water was used to prepare samples and make dilutions, accordingly.

B. Method

1) Rheology test

In this research, the samples from polymer-surfactant mixture were prepared in different concentrations 50,500,700 and 1000 ppm by using 200 ml of DI water. The samples were left 24 hours until dissolved exactly. The pure water has examined in the Brookfield Viscometer, and then the samples were also examined at the same apparatus to check the viscosity, shear rate and shear stress at (20, 40, 60, 100, 120, 180 and 200 RPM). The temperature was kept at 25°C ±0.05°C.

2) Rotating disk apparatus

After step of rheology test another samples were prepared also by the same method but by using 1200 ml of the water. The pure water was examined at the rotating disk apparatus (RDA) to check the torque by changing the RPM from 50 to 3000 and these samples also were examined at the rotating disk apparatuses to check the torque for all samples at different RPM. The Fig. 1 is shown the image of rotating disk apparatus.

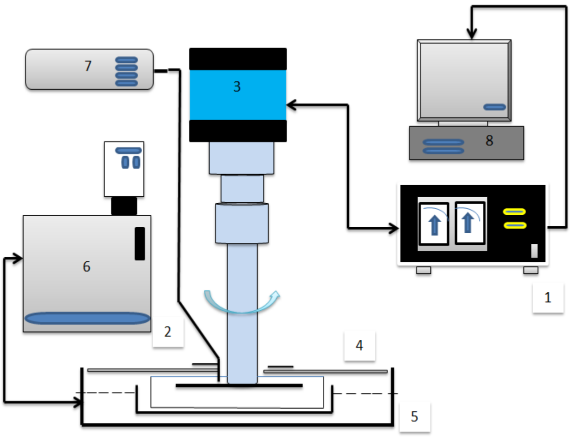

Fig. 1. Graphical image of a rotating disk apparatus for drag reduction measurement: (1) speed controller, (2) thermocouple, (3) motor, (4) solution container, (5) water bath, (6) water-circulating system, (7) thermometer, and (8) PC.

3) Pipe loop

In this study, the pipe loop was also employed to simulate the pressure drop versus the time. Samples were prepared as previously, with the same concentration parameters (50, 200, 500,700 and 1000) ppm, respectively in the tap water but with cylinder capacity (100 L). The samples and the reference were examined at the pipe loop apparatus to measure pressure drop versus the time to compare between pressure drop of water and the samples.

III. RESULT AND DISCUSSION

Fig. 2 shows the effect of increasing the concentration of PAMC on the torque comparing the torque of reference (pure water). It can be seen that the torque of PAMC declined dramatically by increasing the concentration compared the torque of the reference. The torque of the water at 3000 rpm was 33 while the torque of PAMC at 50 ppm was 30 at the same rpm. On the other hand, by increasing the concentration of PAMC till 700, 1000 ppm the torque has been decreased to achieve 24, 22 respectively.

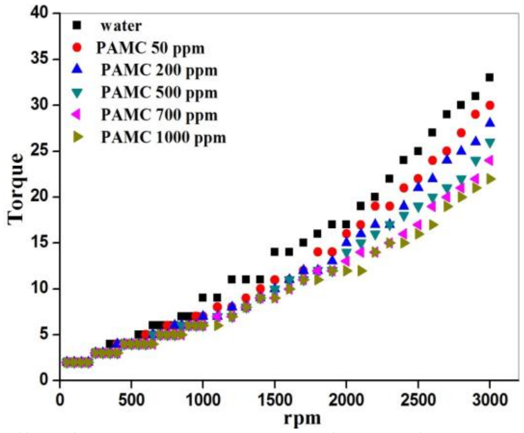

Fig. 2. Effect of concentration on torque as a function of rotational speed of Poly (acrylamide-co-diallyl-dimethylammonium chloride.

Fig. 3. illustrates the relationship between the torque and the rotational speed at different concentration of the Tween 20. It's obvious that the torque of The tween 20 was not affected by increasing the concentration. By increasing the concentration of the tween 20 from 50 to 1000 ppm the torque was exactly same.

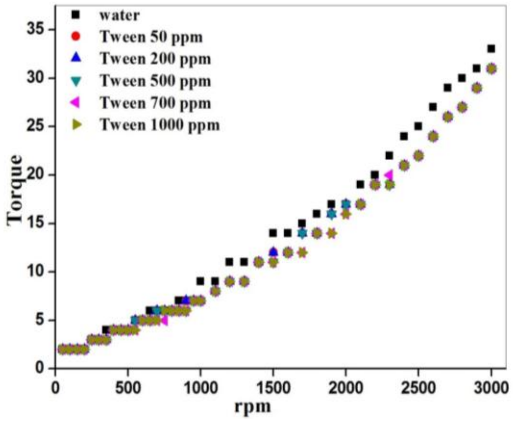

Fig. 3. Effect of concentration on the torque as a function of rotational speed of Tween 20.

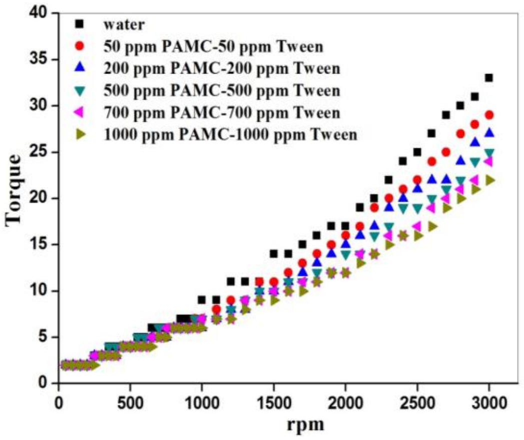

Fig. 4. Effect of concentration on torque as a function of rotational speed of Poly (acrylamide-co-diallyl-dimethylammonium chloride - Tween 20 mixture in water solution.

The relationship between the torque of the reference and mixtures of PAMC-Tween 20 in water solution as a function in rpm is shown in Fig. 4. It is obvious that the torque of mixtures has been declined by increasing the concentration. The torque of PAMC-Tween 20 mixture at 3000 rpm and 500 ppm was 25 while the torque of PAMC was 26 at same conditions. This decreasing in the torque was happened as a result of hydrophobic interaction between polymer surfactant mixtures [24]. We can see this interaction as a result of TEM test in Fig. 5.

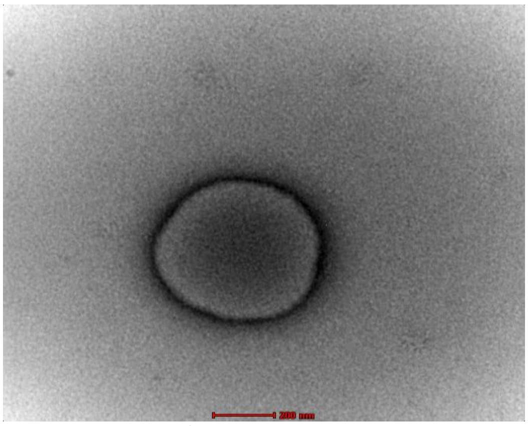

Fig. 5. TEM image of PAMC - Tween mixture at 1000 ppm.

Fig. 6 shows the comparison between pressure drop values of reference and polymer surfactant mixtures as a function of time. It can be seen that the Δ P decreased by increasing the concentration of the mixtures. The pressure drop of reference was around 101 Pa, while Δ P of the mixture 50 ppm PAMC- 50 ppm Tween was almost 99 Pa during the first 10 S, after that it was decreased slightly until 97 Pa. By increasing the mixture concentration to 1000 ppm the Δ P has been declined to around 90 Pa. This decreasing in the pressure drop of the mixture may be happened because the hydrophobic interaction between polymer and surfactant.

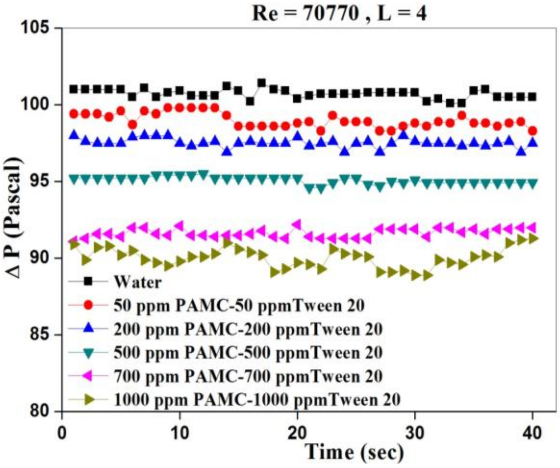

Fig. 6. Compare the values of the pressure drop of reference (tap water) and PAMC - Tween 20 mixtures as a function of time.

IV. CONCLUSION

In summary, by using a rotating disk apparatus, the effect of surfactant, concentration and rotating speed for ionic polymer of the PAMC on the drag reduction was investigated. The DR efficacy induced by the PAMC–Tween mixture is found to be obvious higher than that of pure PAMC. In addition, the effect of the degradation on the pressure drop as a function of time was also investigated.

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