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Drag Reduction of Crude Oil Flow in Pipelines Using Sodium Dodecyl Benzene Sulfonate Surfactant

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Abstract

In the present work, a closed loop circulation system consist of three testing sections was designed and constructed. The testing sections made from (3m) of commercial carbon steel pipe of diameters(5.08, 2.54 and 1.91 cm). Anionic surfactant (SDBS)with concentrations of (50, 100, 150, 200 and 250 ppm) was tested as a drag reducing agent. The additive(SDBS)studied using crude oil from south of Iraq. The flow rates of crude oil were used in 5.08 and 2.54 cm I.D. pipes are (1 – 12) m3/hr while (1-6) m^3/hr were used in 1.91 cm I.D. pipe. Percentage drag reduction (%Dr) was found to increase by increasing solution velocity, pipe diameter and additives concentration (i.e. increasing Renolds number). Also it was found that there is no change in apparent physical properties (viscosity) of crude oil after the addition of SDBS. The higher value of drag reduction of 54% in 5.08 cm I.D. was observed using 250 ppm SDBS surfactant dissolved in the used crude oil at flow rate of 12 m^3/hr. Friction factor was calculated from experimental data. The friction factors values for pure solvent lies near or at Blasius asymptote suggested for flow of Newtonian fluids. After the addition of small amount of SDBS, the friction factor values were positioned below Blasius asymptote toward Virk maximum drag reduction asymptote, which was never reached.

Keywords: drag reduction, surfactants.

Introduction

Drag reduction is a phenomenon in which the friction of a liquid flowing in a pipe in turbulent flow is decreases by using small amount of an additive (Drag reduction agents DRA). This is beneficial because it can decrease pumping energy requirements (or HP). Some current application, where drag reduction has been applied include oil transmissions pipelines. The used drag reducing additives are effective because they reduced the turbulent friction of the solution. These results in a decrease in the pressure drop across a length of pipe and likewise reduced the energy required to transport the liquid [1].

Surfactants are drag reduction agents, which have the ability to form a certain structure called micelles. The important aspect of surfactant which impacts their performance is their ability to self repair [2].

The phenomenon of drag reduction firstly was observed by Mysels [3–5]. Mysels compared the pressure drop of gasoline and of gasoline thickened with aluminum disoaps flow through the same pipe. Tom's phenomenon was the first description of drag reduction gave by Tom [6], who studied the effect of flow rate with various concentration of poly methyl methacrylate in monochlorobenzene.

Since the first reports of drag reduction, a large number of researchers have worked in this area. White [7] concluded that the drag reduction increases with increasing pipe diameter, and it terminates at a limiting value of the flow of Reynolds number because of the degradation that occurred as a result of oxidation after a period of several days. In the experimental work, a dilute solution of 508 ppm of cetyl tri methyl ammonium bromide (CTAB) used in water in order to increase its flow rate. Zakin [8] used non–ionic surfactant in aqueous solution to study the effect of surfactant structure, concentration, temperature and mechanical degradation on drag reduction. The used surfactant had the ability to self repair when it reaches a region of lower shear forces. Finally, he showed that drag reduction increases with decreasing pipe diameter. Mansour et al. [9] used a soapy industrial cleaner drag reducing agents in turbulent flow of Jordanian crude oil in different pipes sizes to study the effect of additives on reducing skin friction. A concentration of only 2 ppm of the chemical additive injected into the crude oil line causes an appreciable amount of drag reduction in different pipes. The researchers concluded that drag reduction increases with increasing pipe diameter. Mansour et al. [10] used new drag reducing chemical additive to minimize skin friction in turbulent flow of Iraqi crude oil. Large scale pipes of 2.5, 5.1, 7.6 and 10 cm were used in their experiments. About 63% maximum drag reduction was obtained with 9 ppm of additive. The results concluded that the drag reduction increases with increasing pipe diameter, flow rate of crude oil and additive concentration up to a certain limit 9 ppm.

Abdul–Hakeem [11] used three types of anionic surfactants (SDBS, SLES and GEM) with one non–ionic surfactant (NPH) as drag reducers in turbulent flow of Iraqi crude oil at flow rate range (10.76 – 14.16) m^3/hr in three pipe inside diameter of 1.3, 2.5 and 7.6 cm.. The percentage drag reduction (%Dr) increases with increasing the surfactant concentration within a certain limits, with increasing solution flow rate and pipe diameter.

The goal of the present work to investigate the effectiveness of the used drag reducing agent (SDBS) with Iraqi crude oil from south of Iraq flowing through circulating system. Also study the effects of additive concentration, pipe diameter, solution flow rate on the percentage of drag reduction. Another aim of the present work is to compare the drag reduction percent (%Dr) calculated from the experimental data with other asymptote suggested in the literature.

Experimental Work

The circulating flow loop system used in the present work is presented in Figure1, which consist of reservoir tank of solution, pumps, flow meter, pipes, valves and pressure gauges. The accuracy of measuring devices is around 95 % by calibration with flowing liquid.

The physical properties of crude oil from south Iraq were 32.7 API (SG=0.8644), viscosity at 50°C=3.208 cst and negligible amount of water content. The south Iraq crude oil is blend consisting of Zubair main pay, Mushrif pay in Rumaila field, Nahr Umer oil field in Qurna and Luhais oil field. The high percentage of oil which is about 85 % of the belnd comes from Zubair main pay in Rumaila field.

The preparation of additive solution by mixing small amount of SDBS surfactant taken in weight part per million (ppm) with a sample of crude oil is the first step in the experimental procedure, then the solution is added into the reservoir tank of crude oil so as to used in the recirculation closed system. The operation is starts when the pump begins delivering the solution through the testing section for the same pipe diameter, and additive concentration. For each run the flow rate of solution was controlled by bypass section to a certain value, while pressure drop readings were taken. Readings of pressure drop were taken again when the flow rate of solution was changed to another fixed value. This procedure was repeated for each pipe diameter, and for different additive concentrations.

Experimental calculations

Reynolds number can be calculated using the following equation [12]:

$$\mathrm{Re} = \frac{\rho . v . D}{\mu}$$

Percentage drag reduction can be calculated after the pressure drop readings through sections of test are taken. The %Dr was calculated as follow [13]:

$$\%Dr = \frac{\Delta p_b - \Delta p_a}{\Delta p_b}$$

Friction factor in term of fanning friction factor can be calculated from [12]:

$$f = \frac{\Delta p . D / 4L}{\rho . v^2 / 2}$$

Results and Discussion

Effect of fluid velocity

Figures (2 to 4) show the effect of solution velocity (v) on the percentage drag reduction (%Dr) in term of dimensionless group (Re) for the SDBS surfactant concentration (50, 100, 150, 200 and 250 ppm) in crude oil from south of Iraq flowing in different pipes diameters (5.08, 2.54 and 1.91 cm). The results show that, the drag reduction percentage increases with increasing fluid velocity.Increasing the fluid velocity means increasing the degree of turbulence inside the pipe .This will provided a better media to the drag reducer to be more effective .The behaviour of icreasing (%Dr) with velocity of fluid may be explained due to realation between degree of turbulence controlled by the solution and the additive effectiveness.

Effect of additives concentration

Figures (5 to 7) indicated influence of concentration of the additive SDBS on the drag reduction percentage (%Dr) for different pipe diameters and fluid

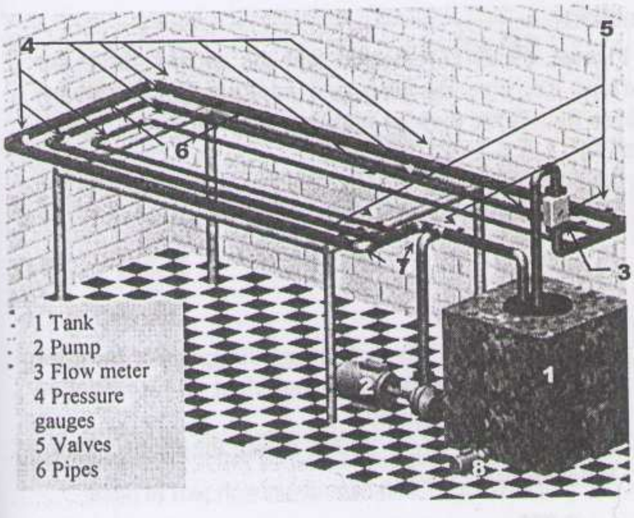

Fig. 1 A 3D-schematic diagram of the close loop circulation system

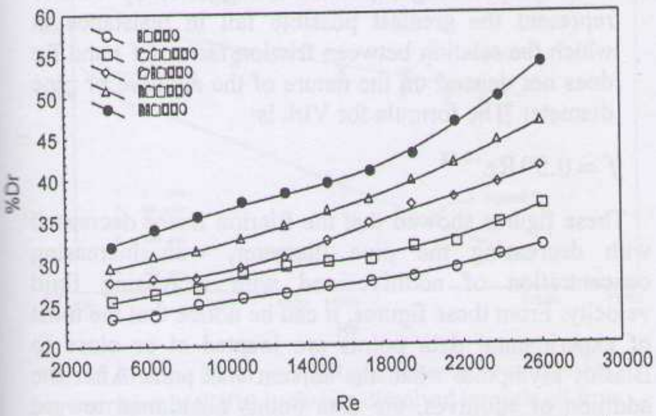

Fig. 2 Effect of Reynolds number on percentage drag reduction for SDBS within different concentration dissolved in the crude oil from south of Iraq flowing through 0.0508 m I.D. pipe

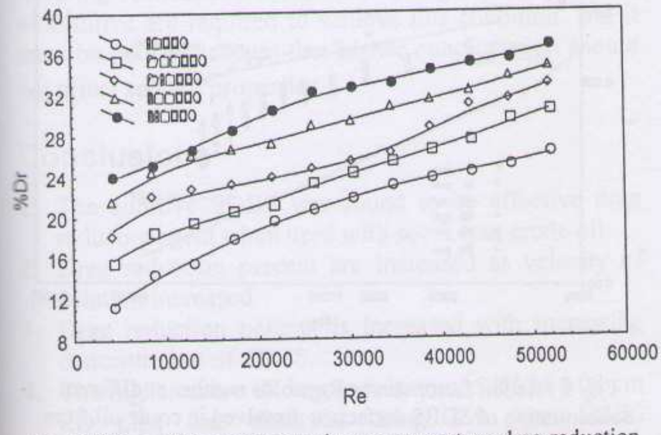

Fig. 3 Effect of Reynolds number on percentage drag reduction for SDBS within different concentration dissolved in the crude oil fromsouth of Iraq flowing through 0.0254 m I.D. pipe

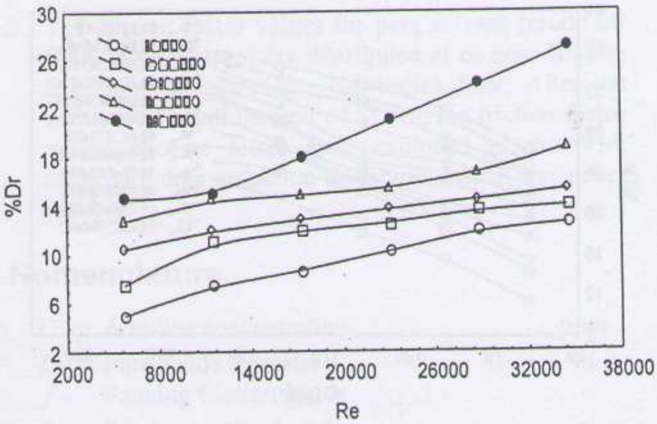

Fig. 4 Effect of Reynolds number on percentage drag reduction for SDBS within different concentration dissolved in the crude oil from south of Iraq flowing through 0.0191 m I.D. pipe

velocities.These Figures show, that the (%Dr) increases with increasing the additive concentration at certain value of Reynolds number. The increment in %Dr is ascribed to increases of associated additive molecules in the process of drag reduction.This means increasing the number of formed micelles which are responsible for increasing drag reduction percentage.

Effect of pipe diameter

Figure (8) shows the effect of pipe diameters on %Dr for the crude oil, concentration of additive and volumetric flow rate. The comparison of %Dr between the three pipes achieved at constant flow rate and certain additive concentration. The results show that, the %Dr increases with pipe diameter within certain additive concentration. This increase in %Dr is attributed to large eddies exist in the pipe of large diameter, which absorb large amount of energy from the main flow.

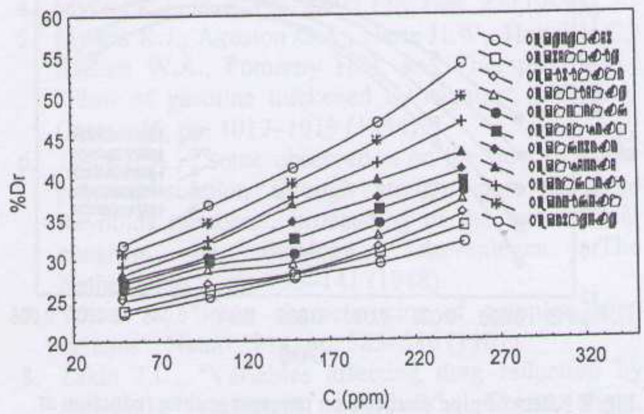

Fig.5 Effect of concentration on percentage drag reduction for SDBS dissolved in the crude oil from south of Iraq flowing through 0.0508 m I.D. pipe

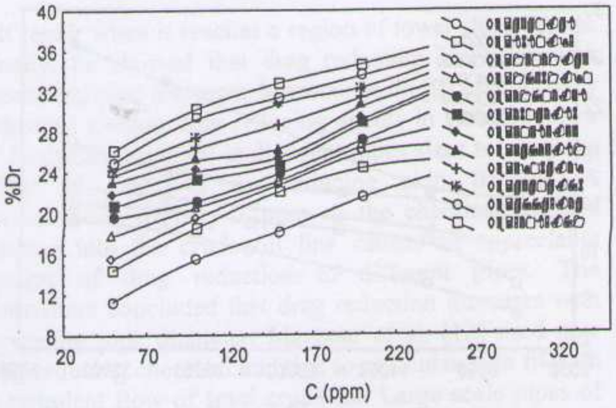

Fig. 6 Effect of concentration on percentage drag reduction for SDBS dissolved in the crude oil from south of Iraq flowing through 0.0254 m I.D. pipe

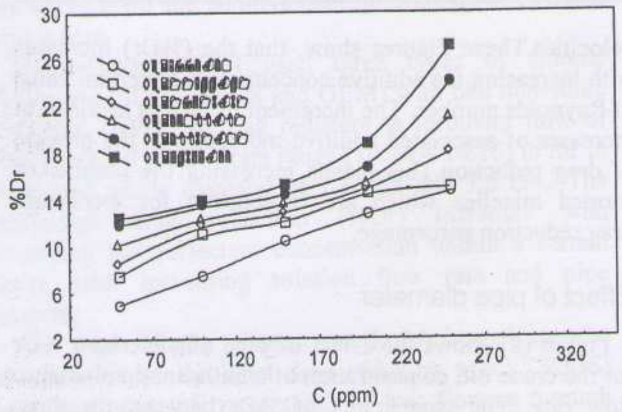

Fig. 7 Effect of concentration on percentage drag reduction for SDBS dissolved in the crude oil from south of Iraq flowing through 0.0191 m I.D. pipe

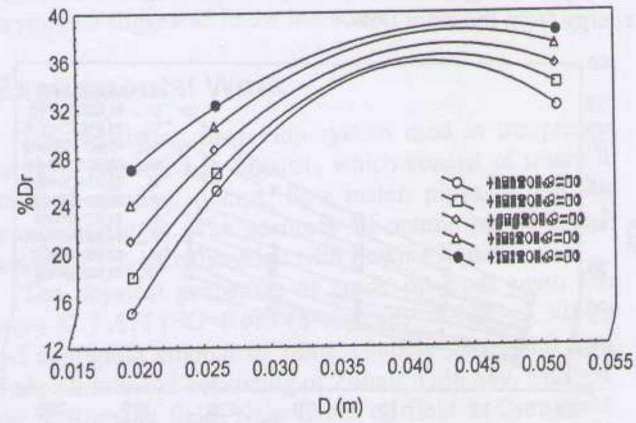

Fig. 8 Effect of pipe diameter on percentage drag reduction at different volumetric flow rates with 250 ppm concentration of SDBS dissolved in the crude oil from south of Iraq.

Friction

Figures, (9 to 11) showed that the friction factor for various Re, pipe diameter and additive concentrations. These figures are divided into four regions. These regions are [14]:

1. Laminar flow region (Re<2300), where the friction factor follows Poisuell's law as follow:

$$Re = \frac{\rho . v . D}{\mu}$$

2. Transition region (Re = 2300 – 3000), where the flow change from laminar to turbulent flow. Friction coefficient rises rapidly.
3. Turblent region (Re > 3000), where the friction factor follow Blasius law:

$$f = \frac{0.079}{Re^{0.25}}$$

4. Virk asymptote region, which is suggested by Virk to represent the greatest possible fall in resistance in which the relation between friction factor (f) and Re does not depend on the nature of the additive or pipe diameter. The formula for Virk is:

$$f = 0.59\,Re^{-0.58}$$

These figures showed that the friction factor decreased with decreasing the pipe diameter, with increasing concentration of additive and with increasing fluid velocity. From these figures, it can be notice that the most of experimental data points are located at or close to Blasius asymptote when the solvent was pure. After the addition of additives, the data points positioned toward Virk asymptote which represent the maximum limits of

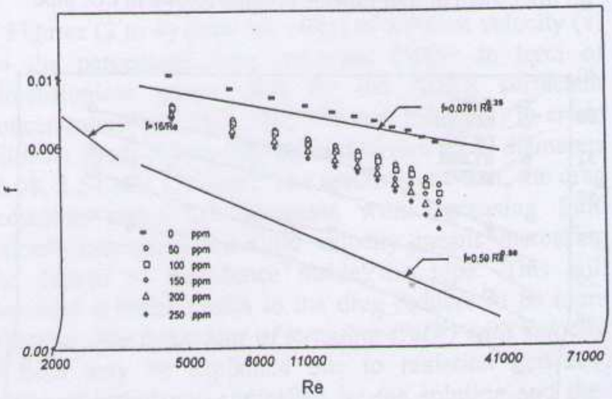

Fig. 9 Friction factor versus Reynolds number at different concentration of SDBS surfactant dissolved in crude oil from South of Iraq flowing through 0.0508 m I.D. pipe

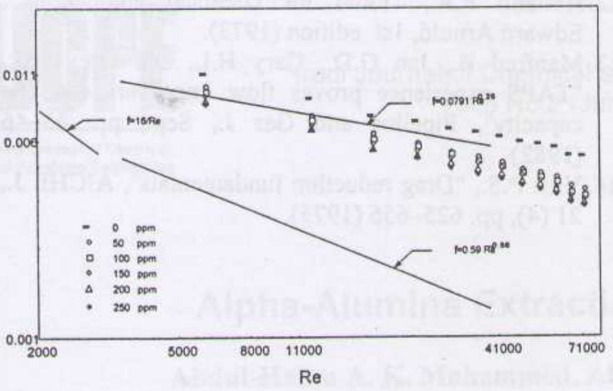

Fig. 10 Friction factor versus Reynolds number at different concentration of SDBS surfactant dissolved in crude oil from south of Iraq flowing through 0.0254 m I.D. pipe

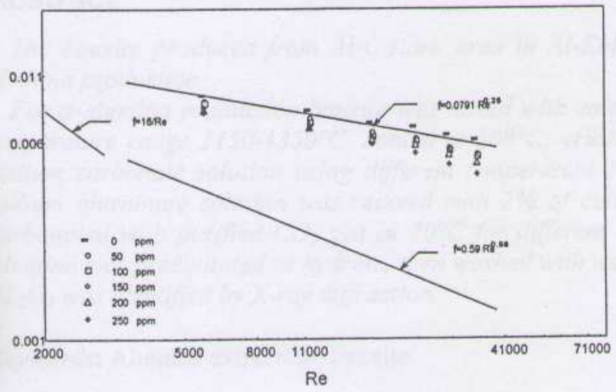

Fig. 11 Friction factor versus Reynolds number at different concentration of SDBS surfactant dissolved in crude oil from South of Iraq flowing through 0.0191 m I.D. pipe

drag reduction. It was difficult to reach these limits of lowering resistance because of the higher concentration of additive are required to achieve this condition. But it must be take in account that higher concentration should not affect solvent properties.

Conclusions

1. The additive SDBS was found to be effective drag reducing agent when used with south Iraq crude oil.
2. Drag reduction percent are increased as velocity of solution increased.
3. Drag reduction percent is increased with increasing concentration of SDBS.
4. The higher value of drag reduction of 54% in 5.08 cm I.D pipe was observed using 250 ppm SDBS surfactant dissolved in crude oil from south of Iraq at flow rate of 12 m3/hr.
5. The drag reduction occurs because of the interaction of the additive with crude oil due to suppressing the turbulence.
6. The friction factor values for pure solvent (crude oil from south of Iraq) are distributed at or near Blasius asymptote suggested for Newtonian flow. After the addition of small amount of SDBS, the friction factor values become lower and positioned toward Virk maximum drag reduction asymptote, which was never reached.

Nomenclature

C	Additive concentration	ppm
D	Pipe inside diameter	m
f	Fanning friction factor	-
L	Testing section length	m
Re	Reynolds number	-
v	Solution velocity	m/sec
$\%Dr$	Percentage drag reduction	-
NPH	Nonyl phenol	
ΔP_b	Pressure drop before addition of SDBS	N/m^2
ΔP_a	Pressure drop after addition of SDBS	N/m^2

Greek letters

ρ	Fluid density	Kg/m^3
υ	Kinematic viscosity	C. st
μ	Solution viscosity	Pa. s

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