DRAG REDUCTION BY USING ANIONIC SURFACTANTS

Sameera M. Hamad-Allah **Hussein H. Hussein**

University of Baghdad
College of Engineering
Petroleum Engineering Department

ABSTRACT

The aim of reducing drag is to increase the flow efficiency by using the same pipes and pumps. As a result the amount of crude oil transported will increase without using new pipes and pumps.

In the present work, the effectiveness of two surfactants (Sodium dodecyl benzene sulfonate (SDBS) and Sodium lauryl sulfate (SLS)) are studied by using a closed loop system. This system consists of three pipes made from commercial steel, each one with different diameter (0.75, 1 and 1.5 inch). The length of each individual test section of the pipe is two meters. The experimental work is achieved under three different temperatures (30º, 40º and 50°C). The concentrations of both surfactants used are ranging between 50 to 300 weight ppm.

Laboratory tests showed that there is a direct proportionality between the percentage of drag reduction (%DR) on one hand and in Reynolds number and pipe diameter on the other hand. Inverse proportionality is observed between %DR and temperature. The %DR increases as concentration increases, but at a certain higher concentration, this relation will reverse.

The final results showed that the highest drag reduction (%DR) was 23.67%. This value is obtained when 200 ppm SDBS is added at 30°C.

The calculated values of friction factor were found to be situated between Blasius and Virk asymptote adjacent.

الخلاصة:

إن الهدف من تقليل الإعاقة هو زيادة كفاءة الجريان باستخدام نفس الأنابيب والمضخات. بالنتيجة تزداد كمية النفط الخام المضخوخ بدون استخدام مضخات وأنابيب جديدة.

في هذا العمل تم دراسة فعالية نوعين من معاملات التوتر السطحي(المنظفات) وهي:

(SDBS, SLS) باستخدام منظومة جريان مغلقة. هذه المنظومة تتألف من ثلاثة أنابيب مصنوعة من مادة الستيل الصناعي ذات أقطار مختلفة وهي (0.75 و 1 و 1.5 أنج). طول كل مقطع اختبار يبلغ (2 متر). تم إجراء العمل ألمختبري تحت ثلاث درجات حرارية مختلفة وهي (30 ,40 ,50 درجة مؤية). تركيز المنظفين المستخدمين تروح بين (50-300 جزء لكل مليون جزء وزني).

الفحوص المختبرية بينت وجود تناسب طردي بين نسبة تقليل الاعاقة (DR%) من جهة وعدد رينولد وقطر الأنبوب من جهة أخرى. يلاحظ وجود تناسب عكسي بين نسبة تقليل الاعاقة ودرجة الحرارة. إن زيادة تركيز معاملات التوتر السطحي يساعد على زيادة نسبة تقليل الاعاقة ولكن هذه الزيادة تعطي مفعول عكسي عند التراكيز العالية.

أظهرت النتائج النهائية إن أعلى نسبة لتقليل الاعاقة بلغت 23.76 % .نحصل على هذه القيمة بإضافة 200 جزء لكل مليون جزء من مادة SDBS وبدرجة حرارة 30 درجة مؤية.
تقع القيم المحسوبة لمعامل الاحتكاك بين محاذي Blasius ومحاذي Virk.

INTRODUCTION

Drag is a term used to refer to pressure drop per unit length of pipe which resulted from friction. Many techniques for drag reducing were suggested by many researches. One of these techniques depends on suppressing turbulent eddies by using baffles with different heights, other techniques used layers of greasy materials or bubble layers to reduce friction. The modern techniques use small amounts of an additive in a fluid which cause a reduction in the turbulent friction compared with that of the pure fluid at the same flow rate (Jiri Myska 1997). The word “drag” may also be defined as the resistance force parallel to the direction of fluid flowing over a solid surface. Drag force may be expressed by two components: “friction component” which is equal to the stream wise component of all shearing stresses over the surface and “pressure drag component” which is equal to the stream wise component of all normal stresses (Mansour 1998).

There are many applications of drag reduction such as increasing flow rate in drilling operations, fire fighting and irrigation. In petroleum industry, drag reduction is of great importance in hydraulic fracturing of oil wells and transportation of liquid petroleum (Thomas R. 1981).

White (1967) examined flowing of a dilute solution of cetyl trimentol ammonium bromide (CTAB) at concentration 508 ppm. He concluded that the drag reduction increases by increasing pipe diameter. Hershy, Mcmillan and Boxter (1971) used aluminum dioctoate in toluene as drag reducer. Zakin (1983) used large number of non–ionic surfactants to study the effect of surfactant structure, concentration, temperature and mechanical degradation on drag reduction. Abdul–Hakeem(2000) used one type of non–ionic surfactant (nonyl phenol) and two types of anionic surfactants (sodium dodecyle benzene sulfonate, SDBS and sodium lauryl sulfate , SLES) as drag reducers in turbulent flow of Iraqi crude oil.

EXPERIMENTAL WORK AND TEST PROCEDURE

The flow system used in this work consists of reservoir tank, pump, flow meter, pipes, valves, pressure transmitters, chiller, digital thermometers and computer interface. A schematic diagram of flow system is given in figure (1). The diameters of pipes are 0.75, 1 and 1.5 inch while the length used is two meters. These dimensions are considered suitable for laboratory work.

The following experimental procedure is carried out :

1. The crude oil is permitted to flow in only one pipe. The flow rate of solution was controlled by bypass section until this rate reaches a specific value.
2. The pressure drop is measured by transmitter which is connected with the computer.
3. Steps 1 and 2 are repeated with different flow rates, keeping in mind that this operation is carried out at constant temperature.
4. The above steps are redone but with the addition of a solution of different additives to the crude oil.
5. Steps 1 to 4 are repeated for the other two pipes.
6. Using different surfactant types, concentrations and temperatures, the above procedure is redone for the sake of observing the effect of these parameters on pressure drop.

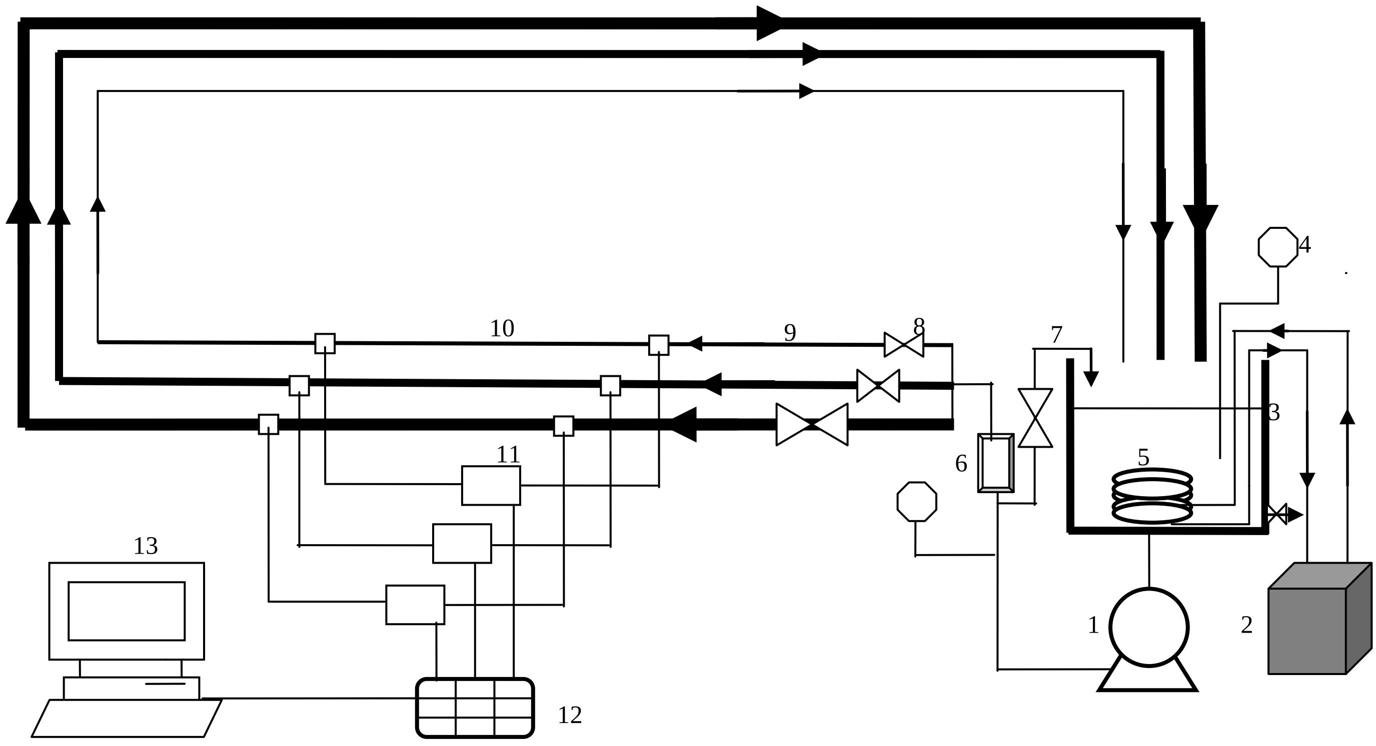
The main properties of crude oil before and after adding are given in table (1)

Table (1) Physical properties of crude oil

Temperature °C	Specific gravity before adding	Kinematic viscosity csc before adding	Specific gravity after adding	Kinematic viscosity csc after adding
30	0.879	15.314	0.876	15.315
40	0.873	10.152	0.874	10.152
50	0.867	4.233	0.869	4.232

The velocities used are 1.7 to 5.3 m/sec. The choice of the velocities is controlled by the pump capacity.

The concentration of available surfactants are first chosen to be very small (50 ppm). As this concentration gave small drag reduction the concentration is continuously increased. At specific concentration (300 ppm), the drag reduction decreased hence the concentration increase is stopped.



1. Centrifugal pump, 2. Chiller, 3. Tank, 4. Digital thermometer, 5. Cooling coil, 6. Flow meter, 7. By pass line, 8. Valve, 9.Entrance length, 10. Test section, 11. Pressure transducer, 12. Parallel port, 13.P/C interface.

Figure (1) schematic diagram of flow system

Experimental Calculations

The following equations are used to calculate velocity(V), drag reduction percentage(%DR) and Reynolds number(Re) respectively.

$$V = Q/\ A \tag{1}$$

$$\%Dr = \frac{\Delta P_b - \Delta P_a}{\Delta P_b} \tag{2}$$

$$\mathrm{Re} = \frac{\rho \cdot V \cdot D}{\mu} \tag{3}$$

RESULTS

Several runs (108) were carried out in this work to study the influence of the following variables on drag reduction:

1- Reynolds number and Pipe diameter.
2- Surfactants concentration.
3-Tempreature.

Effect of Reynolds Number and Pipe Diameter

Figures (2a-2d) shows the effect of Reynolds number and pipe diameter on %DR for concentrations (50-300) ppm for SDBS at 30°C at different pipe diameters (0.75, 1 and 1.5 inch). Figures (3a-3d) show the same effect but for SLS.

It is noticed that for a certain pipe diameter the %DR increases by increasing Reynolds number. This result is expected since the degree of turbulence inside the pipe increases as Reynolds number increases and this will provide a better media to the drag reducer (surfactant) to be more effective.

It is obvious that at the same Reynolds number, high %DR is obtained for larger pipe I.D This is because the increase in pipe diameter will give a large area for interaction between the aqueous solution of surfactant and crude oil. At temperature 40° and 50°C the same effects were observed.

Effect of Concentration

Figures (4a-4c) are plotted for SDBS at 30°C for different diameters and figures (5a-5c) for SLS at 30°C.

From figures (4 and 5), it is noticed that %DR increases as concentration increases to a certain value (about 200 ppm). This may be attributed to the formation of rod-like micelles which increases as concentration increases to some extent.

When the concentration became greater than 200 ppm, the rate of %DR increase will be less. Such behavior may be explained by the change of micelles structure from rod-like to spherical shape as explained by Virk(1967).

Effect of Temperature

The temperature of crude oil is reduced and controlled by a chiller. Figures (6a-6d) show the effect of temperature on %DR for concentrations (50-300) ppm for SDBS in pipe of 0.75 inside diameter at different temperatures, and figures (7a-7d) show similar plot but for SLS.

It is noticed that %DR decreases as the temperature increases for both additives used. This may be caused by the transformation of rod-like (or thread like) to spherical micelles these behavior noticed by Takashi(1993).

Friction Factor

The friction factor is calculated by the following equation(Bottural 1999):

$$f = \frac{\Delta P d / 4L}{\rho v^2 / 2} \tag{4}$$

The calculated value of friction factor is plotted versus Reynolds number on log-log scale as shown in figures 8 and 9. The friction factor is also calculated by using Blasius and Virk equations.

$$f = 0.0791(\mathrm{Re})^{-0.25} \qquad \text{Blasius} \qquad (5)$$

$$f = 0.59(\mathrm{Re})^{-0.58} \qquad \text{Virk} \qquad (6)$$

As can be seen from figures 8 and 9, the values of friction factor obtained by equation (4) lie between Blasius and Virk .

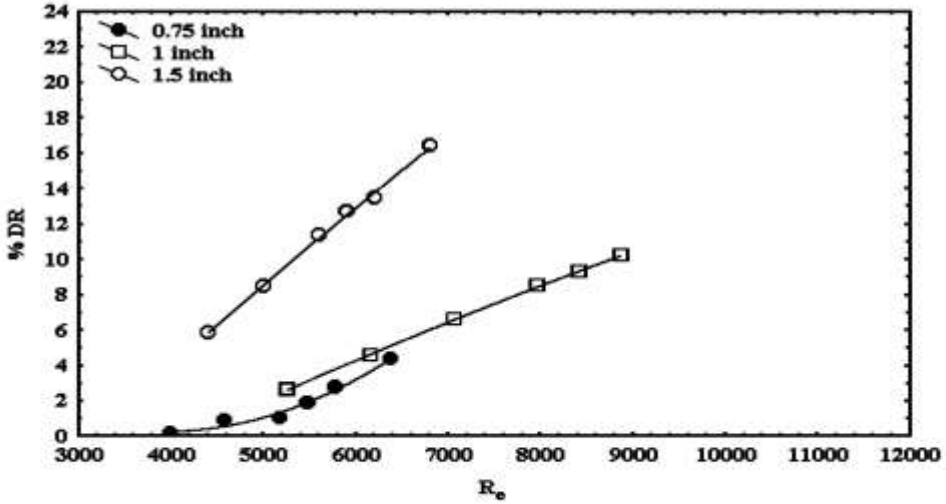


Figure (2a)

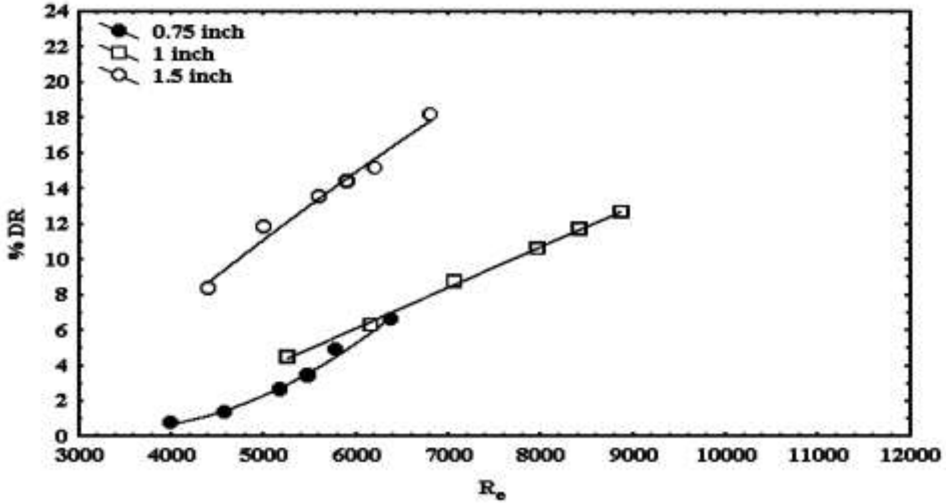


Figure (2b)

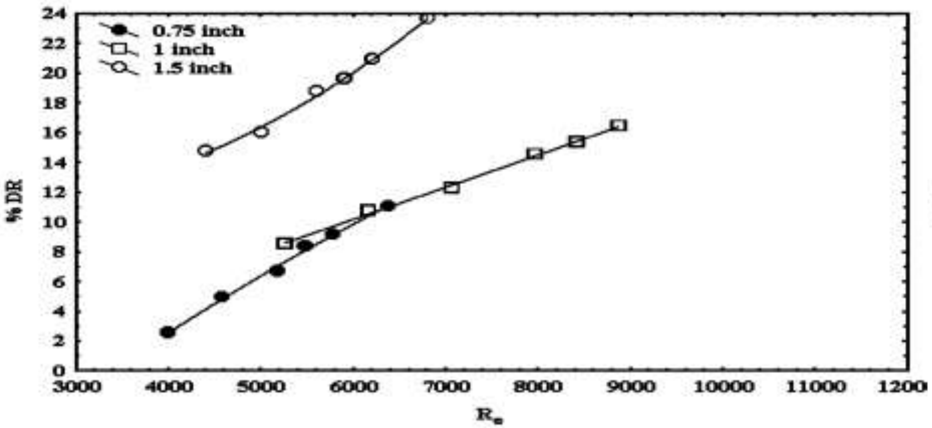


Figure (2c)

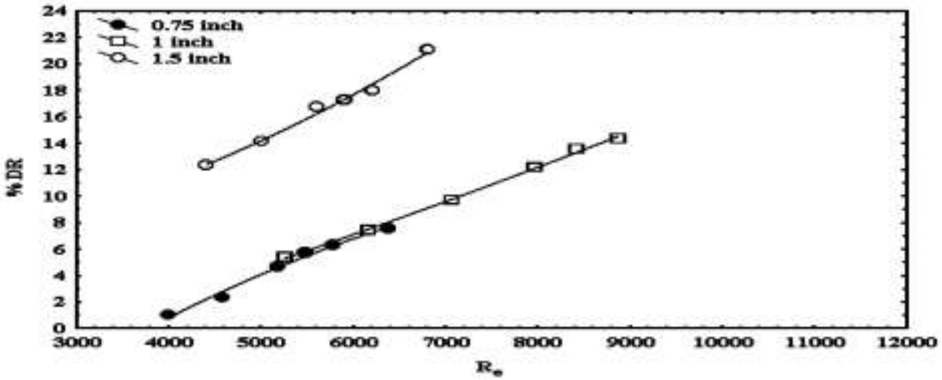


Figure (2d)

Figure (2) effect of Reynolds number and pipe diameter on %DR for SDBS at 30°C; (a): 50 ppm, (b): 100 ppm, (c): 200 ppm and (d): 300 ppm

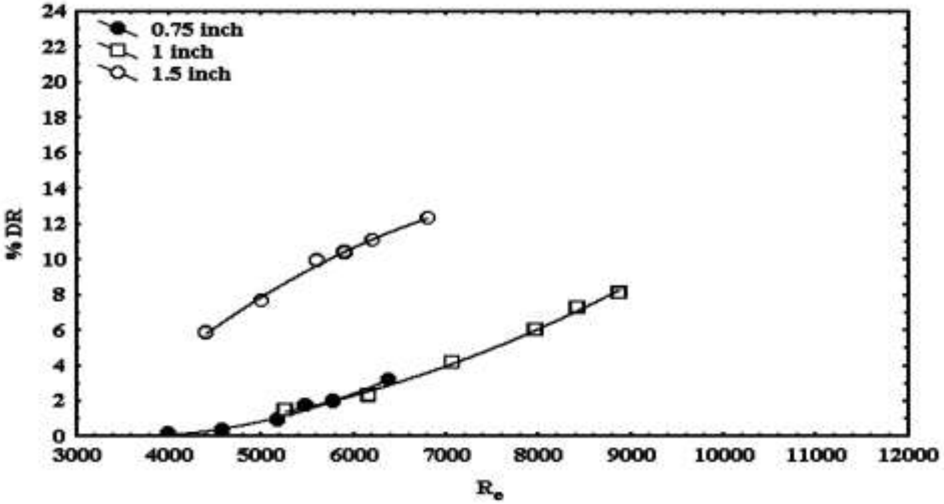


Figure (3a)

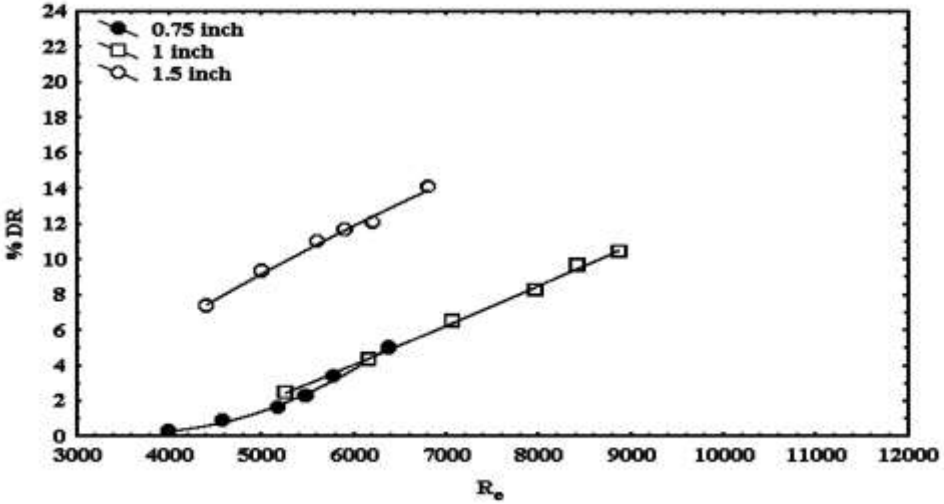


Figure (3b)

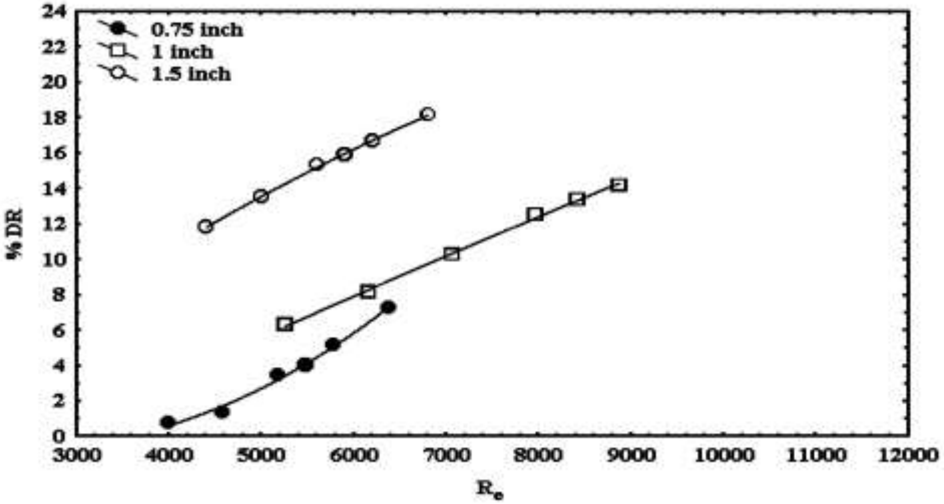


Figure (3c)

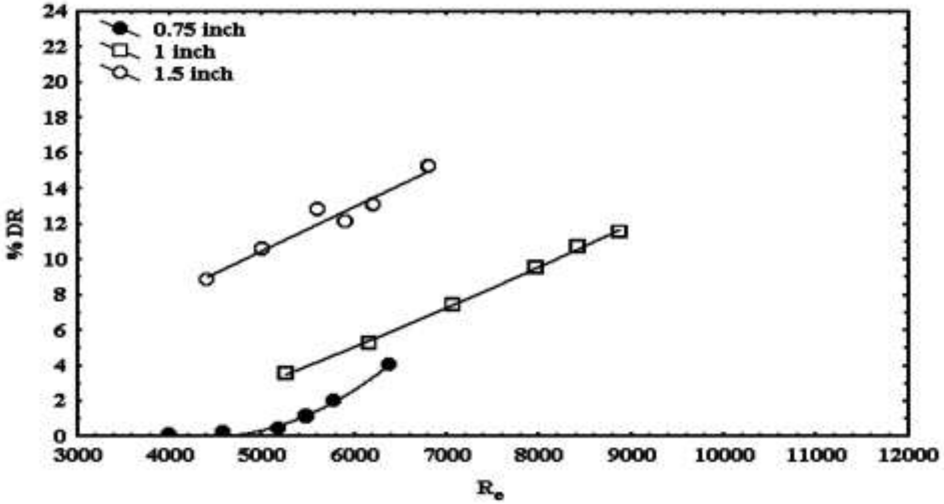


Figure (3d)

Figure (3) effect of Reynolds number and pipe diameter on %DR for SLS at 30°C; (a): 50 ppm, (b): 100 ppm, (c): 200 ppm and (d): 300 ppm

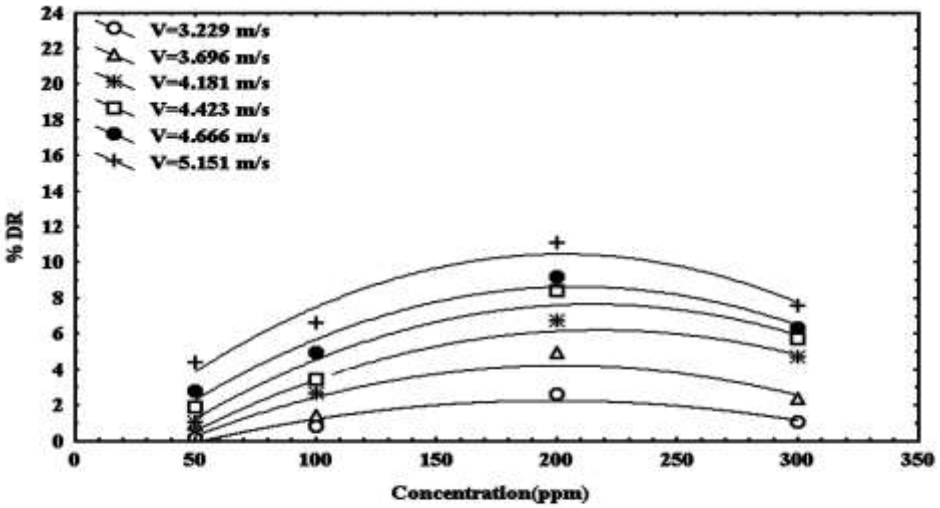


Figure (4a)

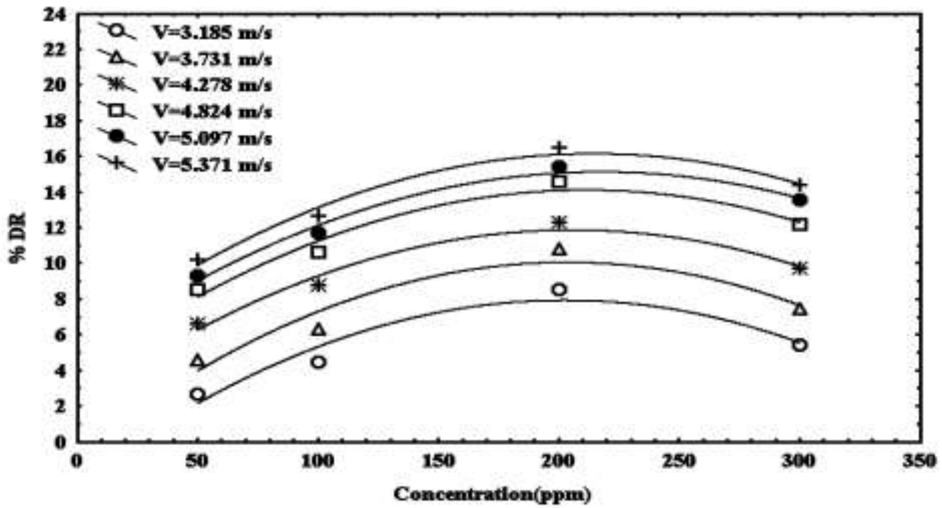


Figure (4b)

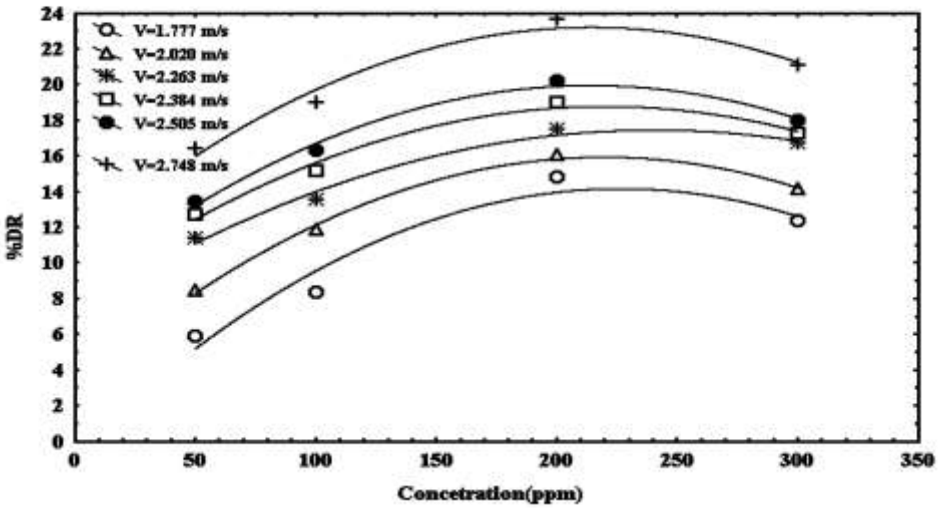


Figure (4c)

Figure (4) effect of concentration on %DR for SDBS at 30°C; (a): 0.75 inch ID, (b): 1 inch ID and (c): 1.5 inch ID

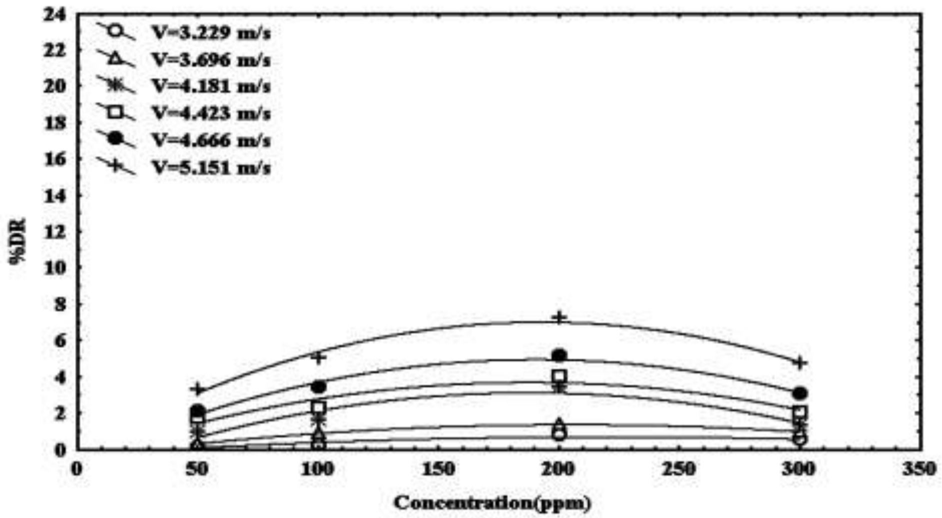


Figure (5a)

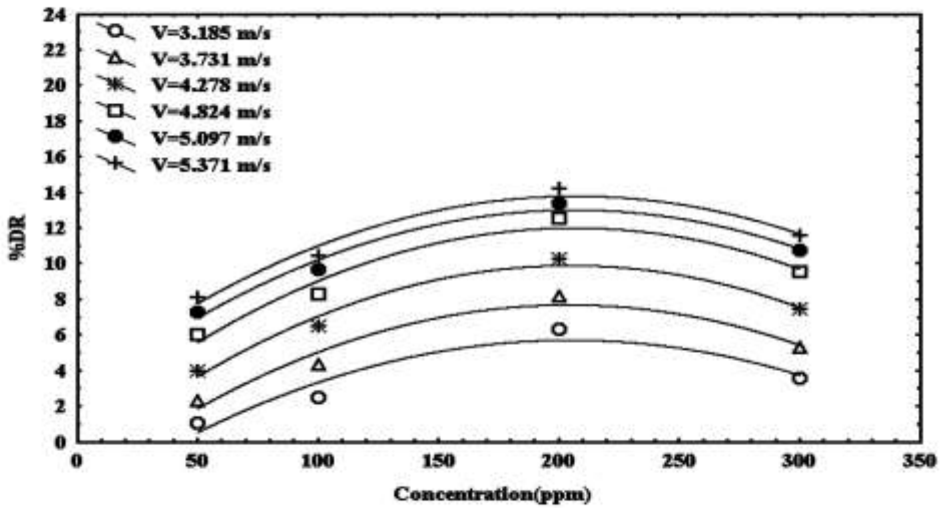


Figure (5b)

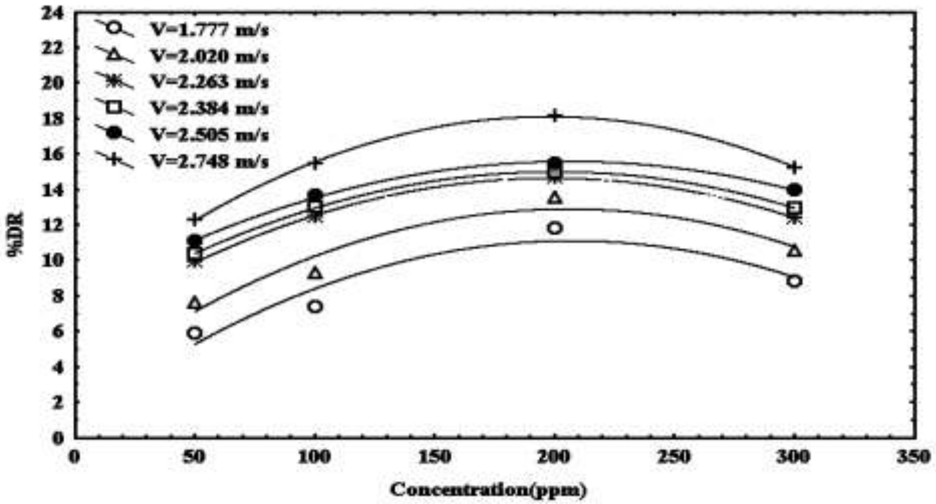
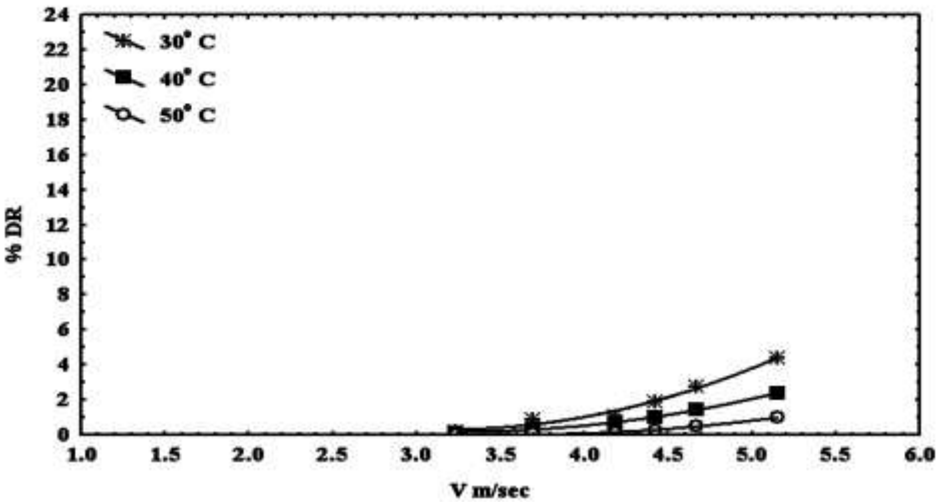
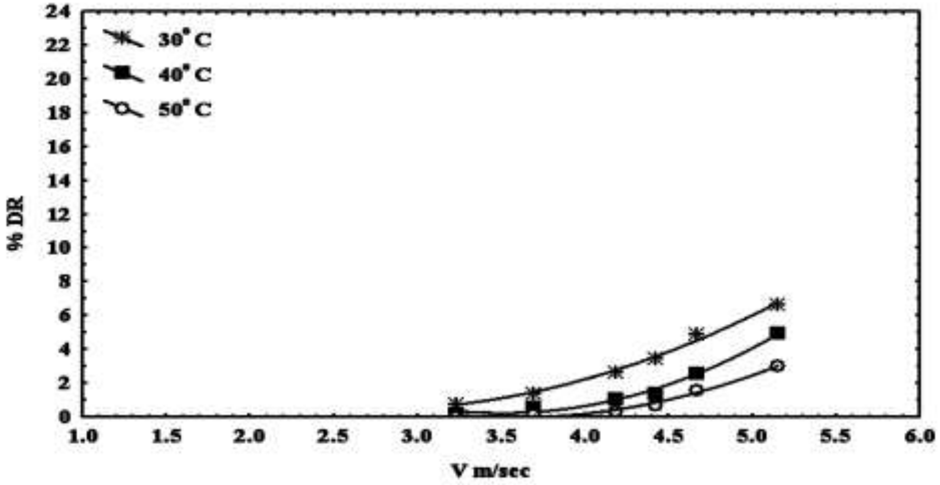


Figure (5a)

Figure (5) effect of concentration on %DR for SLS at 30°C; (a): 0.75 inch ID, (b): 1 inch ID and (c): 1.5 inch ID





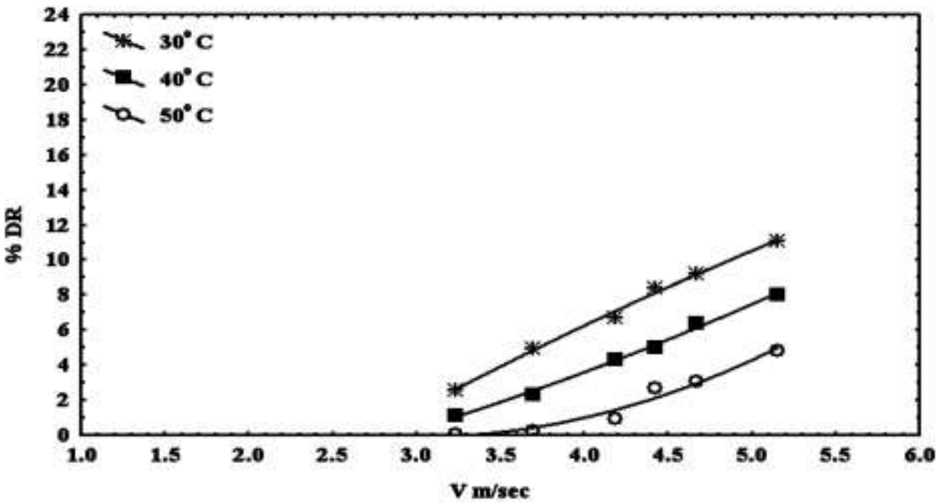


Figure (6c)

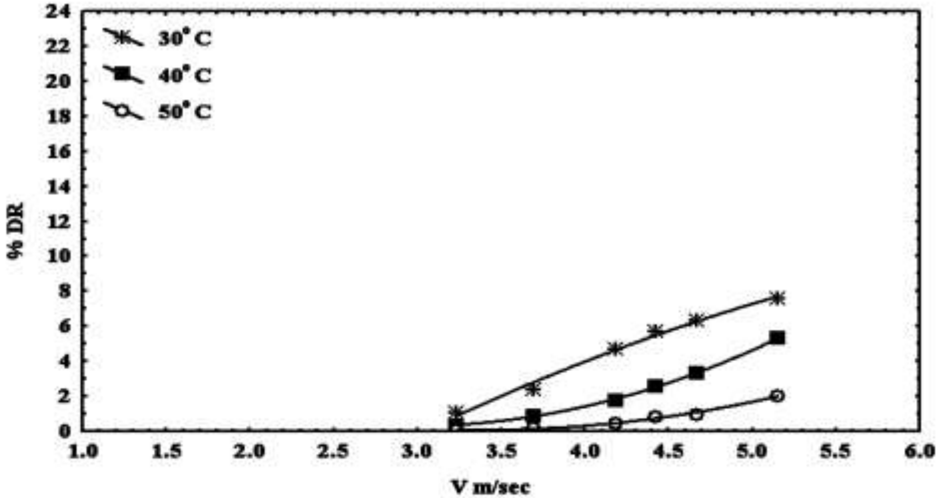


Figure (6c)

Figure (6) effect of temperature on %DR for SDBS at 0.75 inch I.D.; (a): 50 ppm, (b): 100 ppm, (c): 200 ppm and (d): 300 ppm

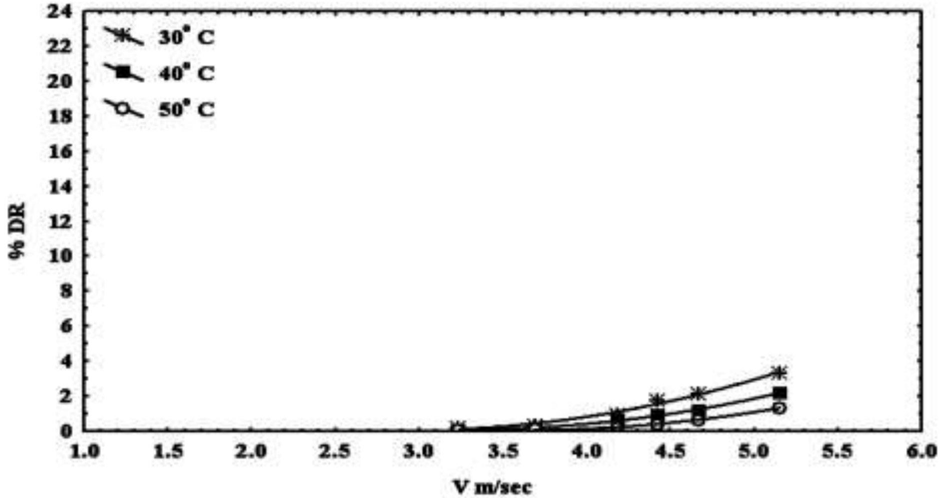


Figure (7a)

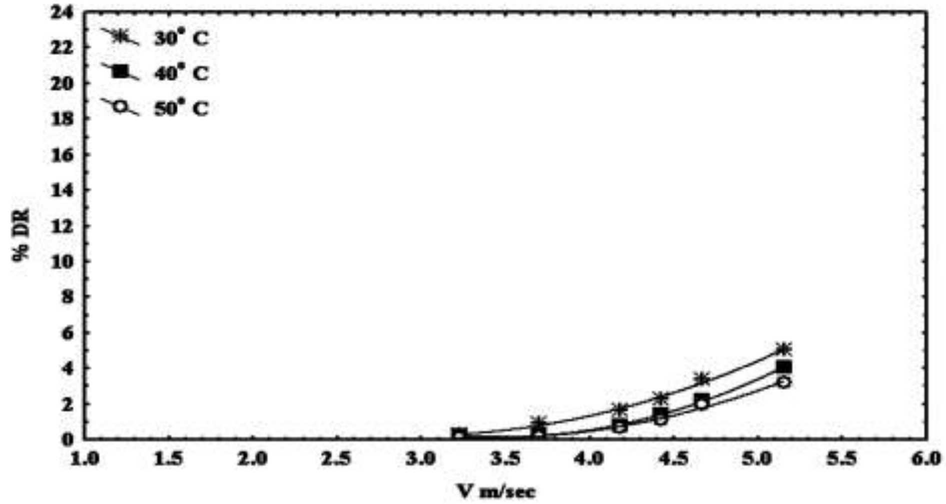


Figure (7b)

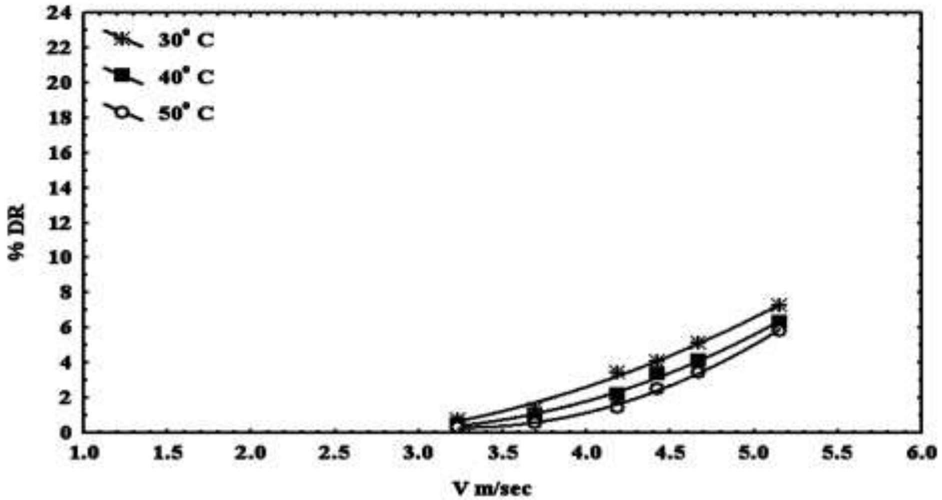


Figure (7c)

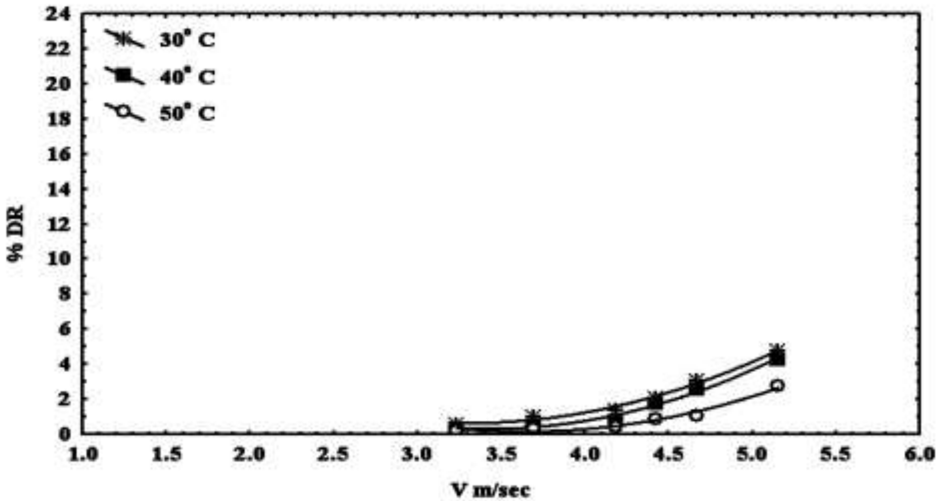


Figure (7d)

Figure (7) effect of temperature on %DR for SLS at 0.75 inch I.D.; (a): 50 ppm, (b): 100 ppm, (c): 200 ppm and (d): 300 ppm

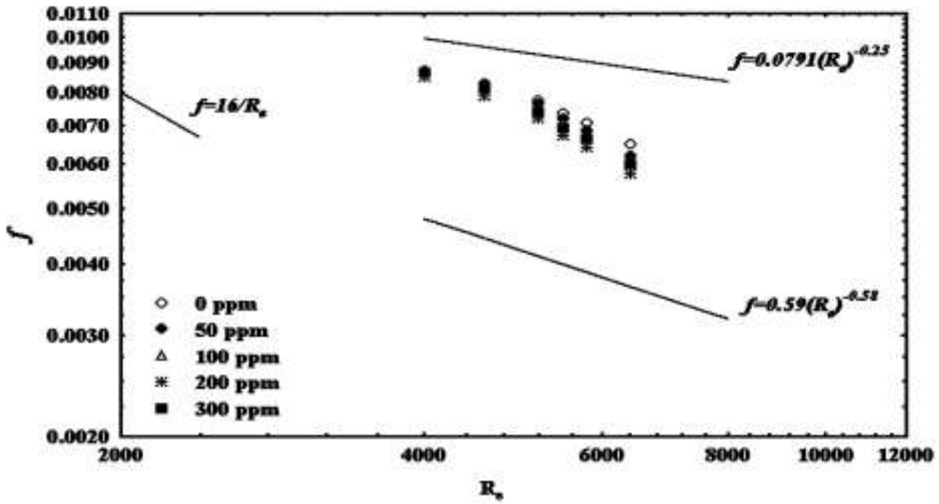
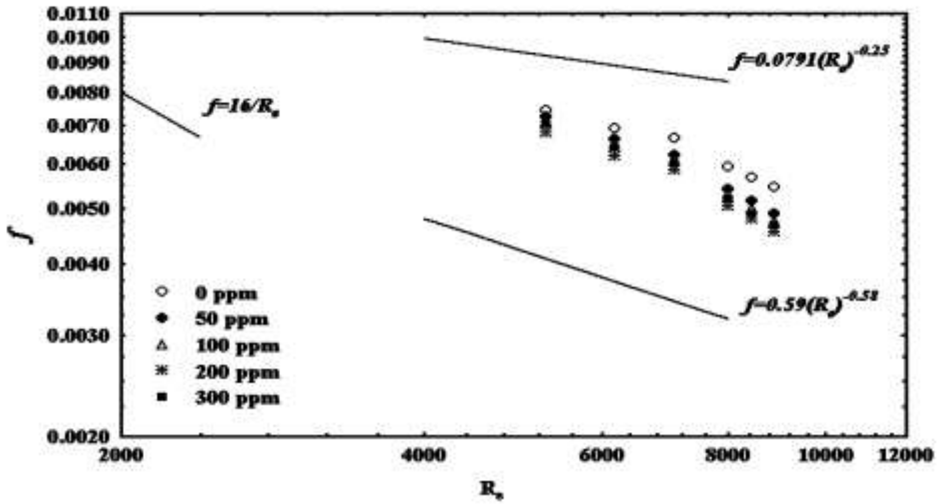


Figure (8a)



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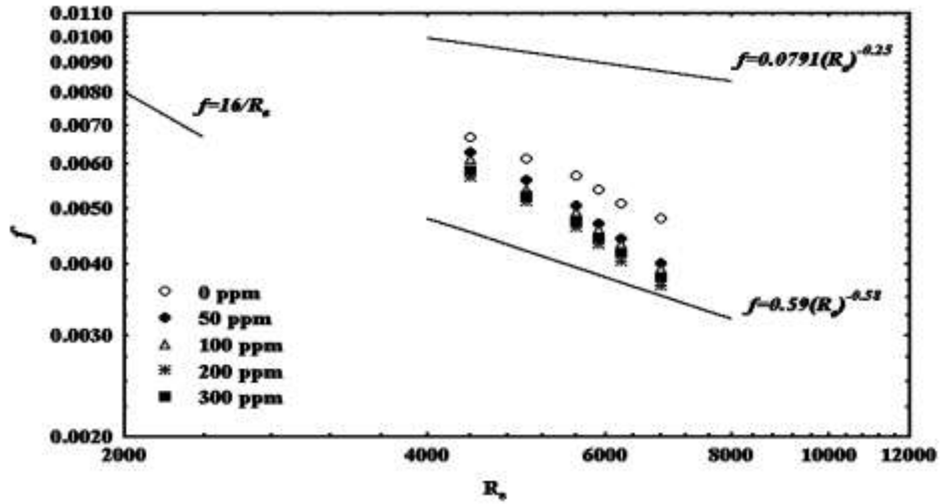

Figure (8c)

Figure (8) calculated friction factor versus Reynolds number at different concentration of SDBS at 30°C; (a): 0.75 inch ID, (b): 1 inch ID and (c): 1.5 inch ID

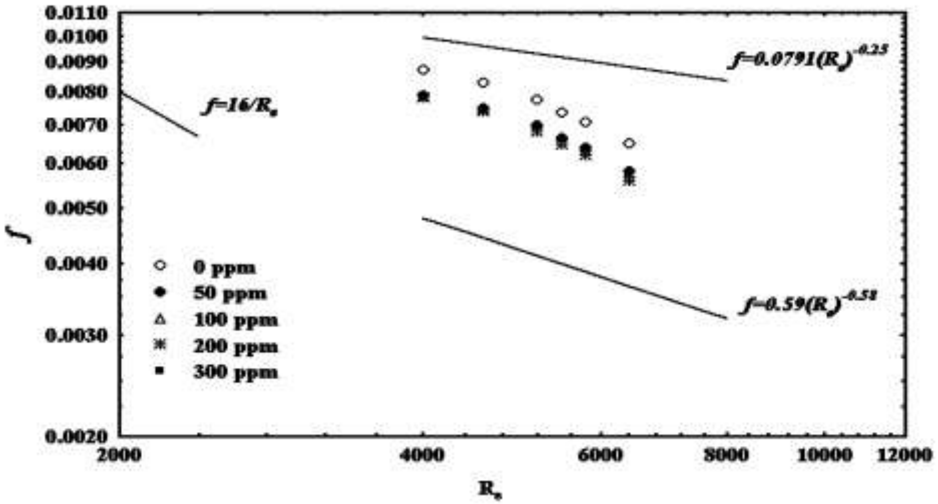

Figure (9a)

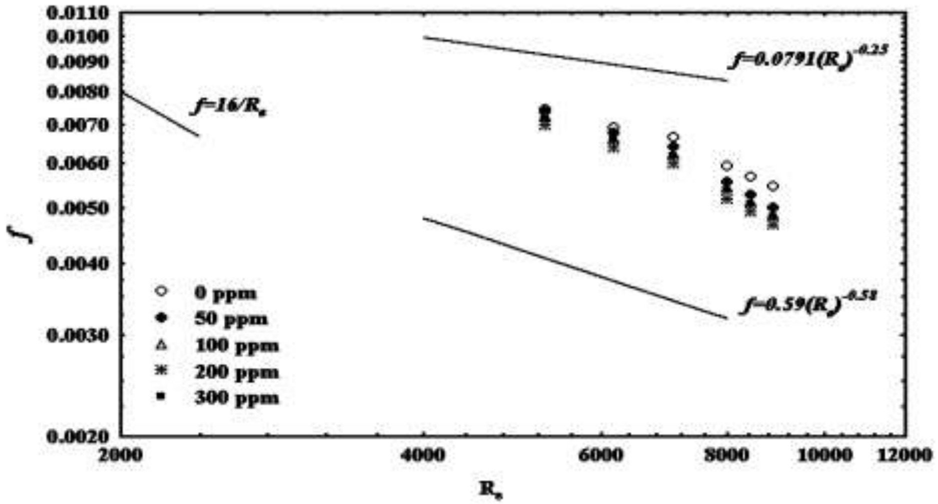

Figure (9b)

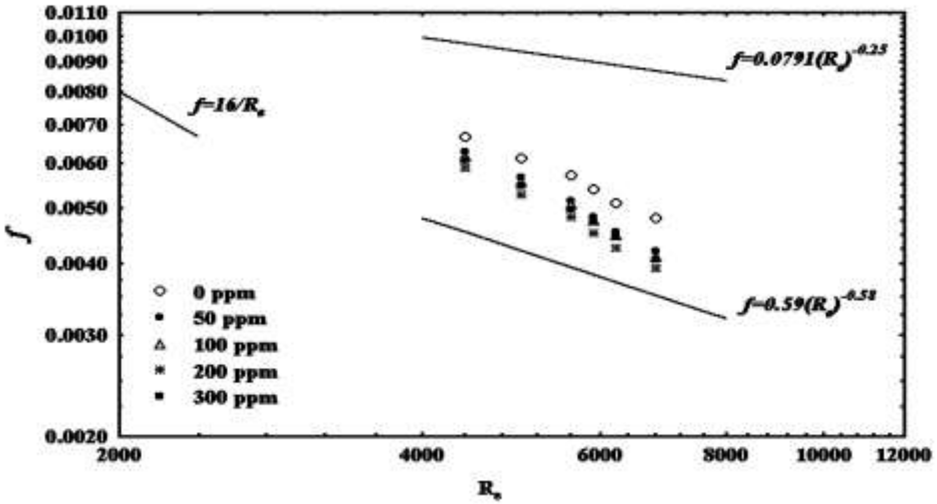

Figure (9c)

Figure (9) calculated friction factor versus Reynolds number at different concentration of SLS at 30°C; (a): 0.75 inch ID, (b): 1 inch ID and (c): 1.5 inch ID

CONCLUSIONS

1-Maximum % DR obtained in the present work was 23.67% by using SDBS surfactant at 30°C in 1.5 inch pipe diameter. This indicates that both surfactants used are effectiveness of moderate as drag reducer with the crude oil under study.

2-The drag reduction percent increases when :

- Increasing Reynolds number.
- Increasing surfactant concentration to a certain limit.
- Decreasing temperature.

3-The values of friction factor calculated lie between Blasius and Virk lines.

SYMMOLS AND ABBREVIATIONS

Symbol	Description	Unit
%DR	drag reduction percentage	-
d	Pipe inside diameter	[in]
L	Testing section length	[m]
Re	Reynolds number ($\rho VD/\mu$)	-
V	velocity	[m/s]
P	Pressure	[psi]

Abbreviations	Definition
CTAB	Cetyl tri-methyl ammonium bromide
NPH	Nonyl phenol
ppm	part per million
SDBS	Sodium dodecyle benzene sulfonate
SLES	Sodium lauryl ether sulfate
SLS	Sodium lauryl sulfate

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