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Problems of Heavy Oil Transportation in Pipelines And Reduction of High Viscosity

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Abstract

Drag has long been identified as the main reason for the loss of energy in fluid transmission like pipelines and other similar transportation channels. The main contributor to this drag is the viscosity as well as friction against the pipe walls, which will results in more pumping power consumption.

The aim in this study was first to understand the role of additives in the viscosity reduction and secondly to evaluate the drag reduction efficiency when blending with different solvents.

This research investigated flow increase (%FI) in heavy oil at different flow rates (2 to 10 m^3/hr) in two pipes (0.0381 m & 0.0508 m) ID By using different additives (toluene and naphtha) with different concentrations (2, 4, 6, 8 and 10) wt. % at 35^{o} C.
The results of this study showed the following:

- Increasing values of Dr% and FI% for all drag reducing agents with heavy oil. Increasing values of Dr% with increasing of Reynolds number, fluid velocity and additive concentration.
- With the larger pipe diameter, performances of drag reduction occur is much better than smaller pipe diameter.
- The additives (toluene and naphtha) reduce the high viscosity of used heavy oil.
- Naphtha is more efficient as viscosity reducer than toluene. Finally, all these results help the understanding of the flow properties of heavy oils and aim to contribute to the improvement of their transport.

Key Words: Heavy oil, drag reduction.

Introduction

Cost saving is one of the most essential concerns in any industry. One of the key to the present concern is by cutting down on the power consumption. Fluids transportation in pipelines and other similar transportation channels tends to consume loads of power for the reason that in moving fluid, energy will be dissipated due to mainly frictional drag. Drag reduction is a flow phenomenon in which a reduction in turbulent friction occurs. Since the early forties, drag reduction has become an increasing interest in science and technical applications. Power saving, is the major headline for many investigations that deals with drag reduction [1].

One of the modern techniques in drag reduction is by the addition of different quantities of chemical additives (such as polymer, surfactant or fiber) to liquids transported in pipelines. That in some cases, it is necessary to increase the transported liquid flow rate in built pipelines to avoid any extra costs and time spend on building new pipelines to have the same flow improvement needed.

Another types of chemical additives are solvent, which have the ability to dilute heavy oil transported in pipelines, but requires a large investment for the installation of an additional return pipeline.

The objectives of this study are:

1- To study the effect of additive, quantity and type of solvent on the flow in pipelines.
2- To study the effect of fluid flow rate on transportation in pipeline
3- To study the influence of solvents that reduced the viscosity of heavy oil with significance to their functions in the drag reduction in pipelines.

Literature Review

Drag reduction is a phenomenon in which the friction of a liquid flowing in a duct in turbulent flow is decreased by using small amount of additives. This is beneficial because it can decrease pumping energy requirements. Some current applications where drag reduction has been applied include oil transmission pipelines, district heating and cooling systems. Different types of additives can be used in these systems and include surfactants, fibers, aluminium disoaps, and polymers. Drag reducing additives are effective because they reduce the turbulent friction of a solution. These results will decrease the pressure drop across a length of conduit and likewise reduce the energy required to transport the liquid [2].

1- Drag Reduction by Using Surfactants

Davis et. al. investigated experimentally the effects of mixtures of cationic surfactant on their drag reduction and rheological behaviour. Cationic alkyl tri methyl quaternary ammonium surfactants with alky chain length of C12 to C22 were mixed at different molar ratios. The drag reduction tests showed that by adding 10% mole of C12, the effective drag reduction temperature range expands to 40-120ºC, compared with 80-130ºC with only C22 surfactant. Thus mixing cationic surfactants with different alkyl chain lengths is an effective way of tuning the drag reduction temperature range. The experimental results showed in micrographs a thread-like miceller network for surfactant solutions in the drag reducing temperature range while vesicles were the dominant microstructures at non-drag reducing temperatures and this supports the widely believed hypothesis that thread-like micelle network are necessary for the surfactant solution to be drag reducing[3].

Abdul-Hakeem tested different types of surfactants, three anionic surfactants plus one non-ionic surfactant as drag reducers in turbulent pipe flow of Iraqi crude oil within three pipe diameters of 0.5, 1, and 3 inch I.D. The investigator concluded that the percentage drag reduction (%DR) increasesby increasing the surfactant concentration (within certain limits), solution flow rate and pipe diameter. Maximum percentage drag reduction of 56.5% was achieved at concentration of 200 ppm SDBS surfactant.

Finally, the drag reducing mechanism was explained by the interaction of surfactant micelles with the crude oil, which allows the turbulence to be suppressed [4].

Hussein, H. studied the effectiveness of two surfactants (Sodium dodecyl benzene sulfonate (SDBS) and Sodium lauryl sulfate (SLS)) in crude oil by using a closed loop system for three pipes of different diameter (0.75, 1 and 1.5 inch) with length 2m for each and he used three different temperatures (30º, 40º and 50°C). The concentrations of both surfactants used are ranging between 50 to 300 ppm. He found that the final results showed that the highest drag reduction (%DR) was 23.67% (flow increase percentage was 16%). This value is obtained when 200 ppm SDBS is added at 30°C [5].

2- Drag Reduction by Using Polymers

Motier used polymeric drag reducing agents to facilitate the pipeline transportation of crude oil and some refinery products (reducing the frictional loss associated with turbulent flow of liquids). Motier obtained the best performance with gasoline and fuel oil in his experiments. The great effectiveness has been found in the low viscosity Kirkuk crude oil. The variability in performance was a function of the viscosity of crude [6].

Shao and Lin studied the mechanism of drag reduction by polymer (polyacrylamide) additives. The researchers concluded that the visualization of mixing layer shows that the addition of polymer will enhance coherent structure. The measurements of the turbulent intensities and Reynolds stresses by LDA show that polymer additives do not simply suppress the turbulent fluctuation as they expected. In pipe flow, the axial turbulence intensity is increased while the radial turbulence intensity is decreased. This means that the turbulence structure is changed rather than suppressed [7].

Taegg et al. studied the maximum drag reduction (MDR) in a turbulent channel flow by polymer additives using numerical simulation in aqueous solution [8, 9].

Ma 'aly S. Asaad studied the effectiveness of two polymers (polyisobutylene(PIB)) and (styrene styrenebutediene rubber (SBR)) and in kerosene by using a closed loop system for four pipes; 1,1.5 inch I.D. made of carbon steel and 1, 1.5 inch I.D. made of galvanized iron. A gradual increase of 4 percentage drag-reduction was observed with increasing the polymer concentration and velocity. The 1.5 inch I.D. carbon steel pipeline at 3m long (test section) shows higher drag reduction compared to other pipes at constant velocities [10].

3- Viscosity Reduction

Blending with a less-viscous hydrocarbon such as condensate, naphtha, kerosene or light crudes it's called dilution. However, in order to attain acceptable limits for transport, a fraction as high as 30% of diluents by volume is necessary and implies large pipeline capacity. Problems may also arise with regard to diluents availability [11].

Dilution could be a solution for heavy oil, but requires a large investment for the installation of an additional return pipeline.

Anhorn et al. studied Methyl Tert-Buty Ether (MTBE) and Tert-Amyl Methyl Ether (TAME) in laboratory experiments as alternative thinners for heavy oils [12].

Henaut,I. et al. used simple organic solvents (toluene, heptane…) which are not representative of complex heavy crude oils(from 0 to 20% in weight). All results help the understanding of the flow properties of heavy crude oils and aim to contribute to the improvement of their transport [13].

Argillier,J.F. et al. used different low viscosity hydrocarbons as diluents, in particular naphtha, kerosene. In a second part of the study different alcohols are used also for blending with heavy oil. Concerning tests with diluents, 4 dilution rates (5, 10, 15 and 20% in weight) and 5 temperatures (3, 20, 40, 60 and 80°C) have been tested for each diluent [14].

Finally, in this work Flow with Reynold's number lower than 4000 is regarded as laminar flow. With heavy oil viscosity in the range of 100-10000 cP, it can readily be shown that pipe flow will be laminar using any economically viable pipe diameter. The Reynold's numbers for pipe diameters ranging between 1-30 inches, using common heavy oil values for density, viscosity and flow velocity as shown in figure(1)[15].

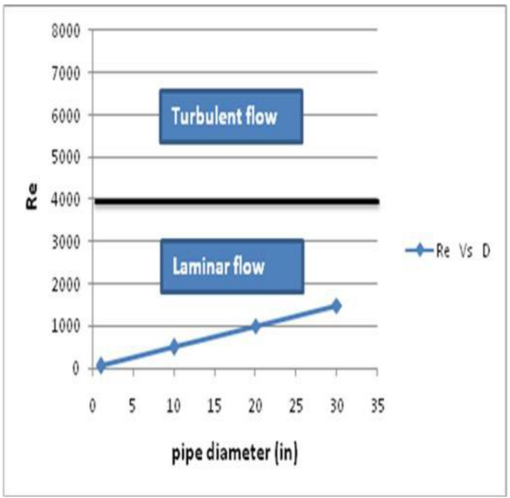
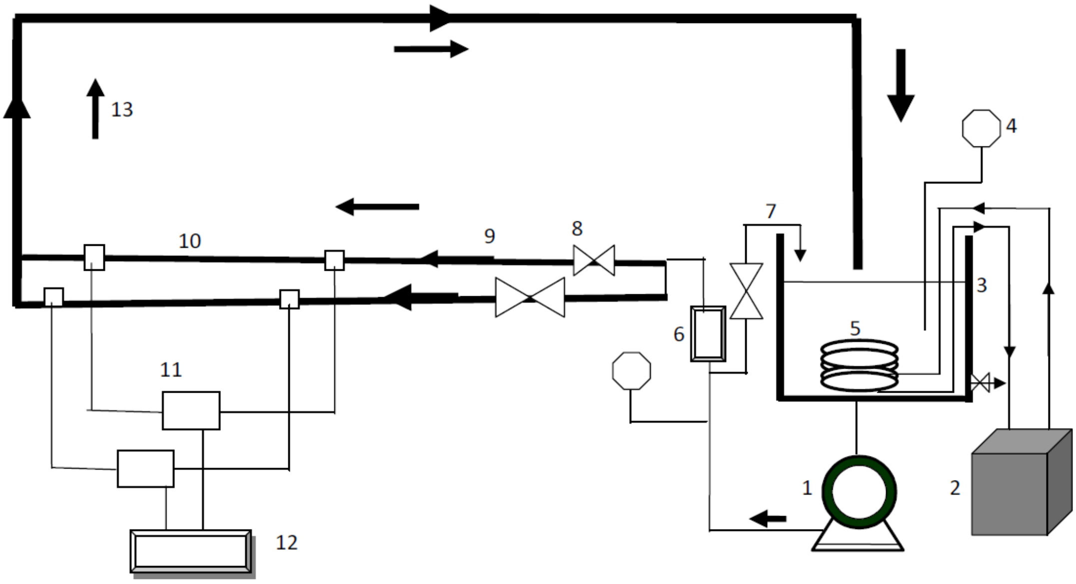


Fig. 1, Reynolds Number vs. Pipe Diameter [15] (ρ = 975 kg/m3, u = 1 m/s, μ = 500 cP)

Description of Circulating Flow Loop System

The description of main parts of the flow system as shown in figure (2). It represents the flow system apparatus used in the present work, which consist of reservoir tank of solution, pump, flow meter, pipes, valves, pressure transmitter, digital screen, chiller and digital thermometers.



1. Gear 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 transmitter, 12.Digital screen, 13.Return pipe.

Fig. 2, Schematic Diagram of Flow System

Material Used

1- Liquid

The used heavy oil was taken from Al-Doura refinery with physical properties as given in table (1).

Table 1, Physical Properties of Heavy Oil

Temperature °C	Specific gravity	Kinematic viscosity c.st
35	0.965	394.00

2- Solvents

Toluene and naphtha were used as drag reducing agents and to dilute the viscosity with concentration 2, 4, 6, 8 and 10 % by weight. Solvents were provided by Al-Doura refinery.

Experimental Procedure

1- The reservoir was filled with 75 liter of corresponding fluid heavy oil.
2- The heavy oil is permitted to flow in only one pipe. The flow rate of solution was controlled by bypass section until this rate reached a specific value.
3- The pressure drop is read by transmitter which is connected with the digital screen.
4- Steps 2 and 3 are repeated with different flow rates. Keeping in mind that this operation is carried out at constant temperature.
5- The above steps are redone but with the different additives of solvents to the heavy oil.
6- Steps 2 to 5 are repeated for the other pipe.
7- Using different solvent types and concentrations, the above procedure is redone for the sake of observing the effect of these parameters on pressure drop.

Results and Discussion

- Maximum Dr% of 38.78% and 31.85 % were obtained using heavy oil containing 10% wt of naphtha flowing in pipes of 0.0508m and 0.0381 m I.D. at 35°C respectively.
- The maximum volumetric flow rates in (0.0508 and 0.0381) m I.D. pipes were 10 m3/hr.

The Naphtha has a large stability than Toluene. This may be attributed to the chemical structure and its resistance to the shear forces which governs the effectiveness of the solvent used as drag reducer.

The effect of the used additives (toluene and naphtha) on drag reduction as shown in figures (3-4).

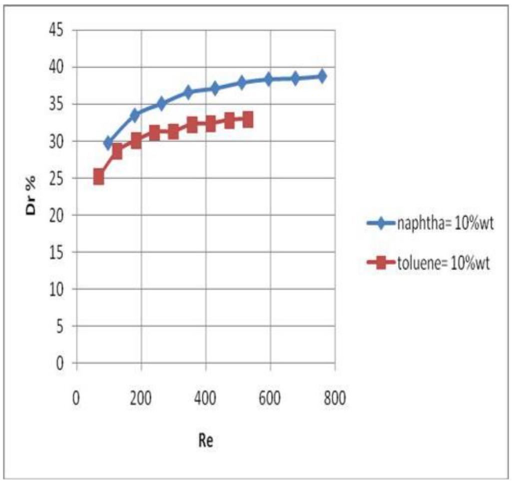


Fig. 3, Effect of Re on %Dr in Heavy Oil Flowing Through 0.0508 M I.D. Pipe

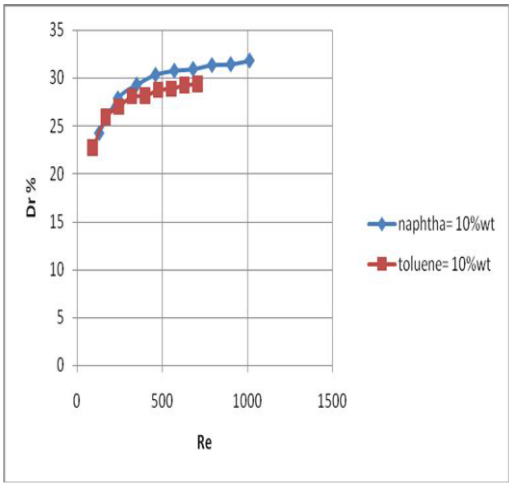


Fig. 4, Effect Of Re on %Dr in Heavy Oil Flowing Through 0.0381 M I.D. Pipe

The effect of solution of velocity (v) on the percentage drag reduction (%Dr) in term of dimensionless group (Re) was done which showed the drag reduction percentage increases with increasing fluid velocity. Increasing the fluid velocity means increasing the Reynolds number inside the pipe, this will provide a better media to the drag reducer to be more effective.

The behaviour of increasing %Dr with velocity of fluid may be explained due to relation between degree of Reynolds number controlled by the solution velocity and the additive effectiveness as shown in figures (5-8).

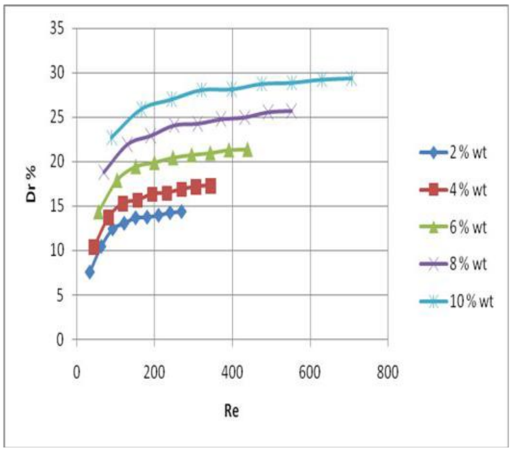


Fig. 5, Effect of Reynolds Number on Percentage Drag reduction for Toluene in Heavy Oil Flowing Through 0.0381 m I.D. Pipe

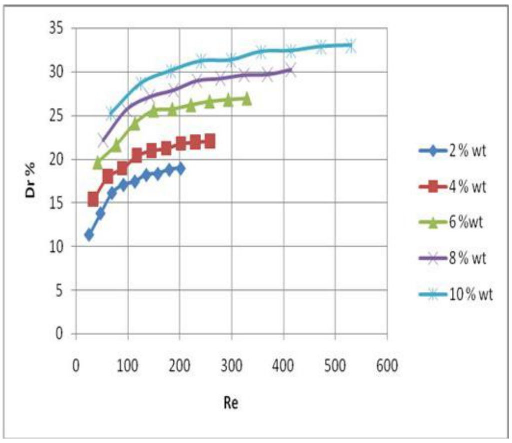


Fig. 6, Effect of Reynolds Number on Percentage Drag Reduction for Toluene in Heavy Oil Flowing Through 0.0508 M I.D. Pipe

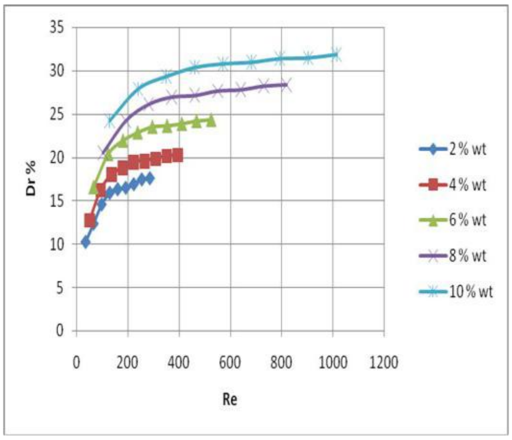


Fig. 7, Effect of Reynolds Number on Percentage Drag Reduction for Naphtha in Heavy Oil Flowing Through 0.0381 M I.D. Pipe

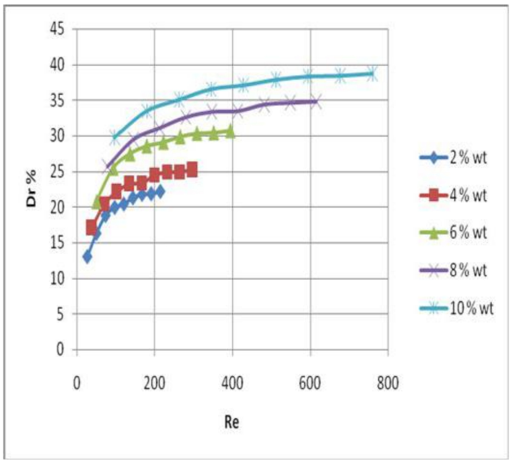


Fig. 8, Effect of Reynolds Number on Percentage Drag Reduction for Naphtha in Heavy Oil Flowing Through 0.0508 M I.D. Pipe

%Dr and %FI increase with increasing the additive concentration for toluene or naphtha at certain value of Reynolds number. The increment in %Dr is ascribed to increases of associated additive molecules in the process of drag reduction. Also, it show that there is not a limit value of concentration after which no further drag reduction occurs within additives concentration (2–10 %wt) for toluene and naphtha as shown in figures(9-12).

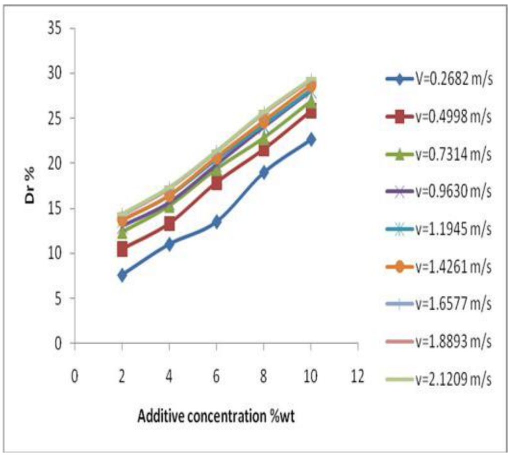


Fig.9, Effect of Concentration on Percentage Drag Reduction for Toluene in Heavy Oil Flowing Through 0.0381 M I.D. Pipe

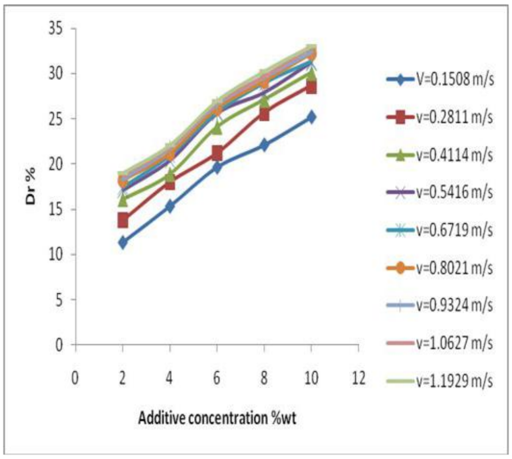


Fig. 10, Effect of Concentration on Percentage Drag Reduction for Toluene in Heavy Oil Flowing Through 0.0508 M I.D. Pipe

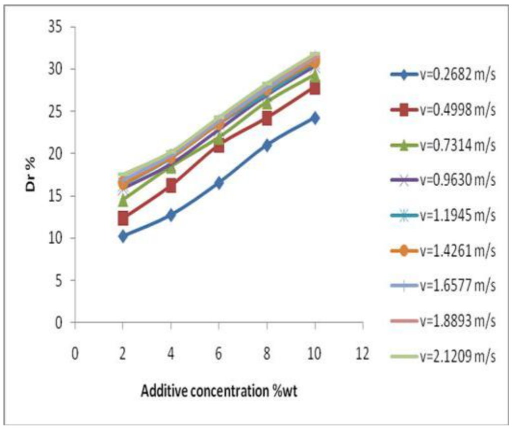


Fig.11, Effect of Concentration on Percentage Drag Reduction for Naphtha in Heavy Oil Flowing Through 0.0381 M I.D. Pipe

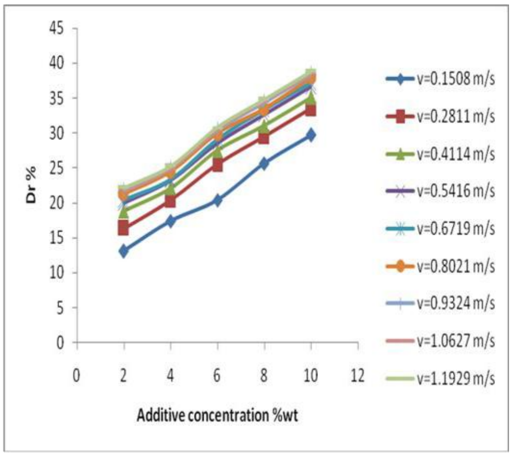


Fig. 12, Effect of Concentration on Percentage Drag Reduction for Naphtha in Heavy Oil Flowing Through 0.0508 M I.D. Pipe

The Effect of Concentration of the Additive Types on the Viscosity Reduction

The used additives affect the physical properties of present used heavy oil, while the viscosity was reduced which indicated that we treated high viscosity and diluted heavy oil after addition as shown in figure(13)

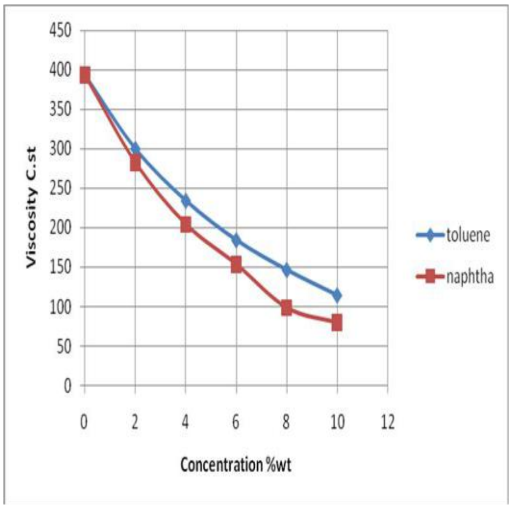


Fig. 13, Effect of Different Concentration on Viscosity for Naphtha and Toluene In Heavy Oil

Conclusions

1- The additives (Toluene and Naphtha) were found to be effective drag reducing agents when used with heavy oil.
2- Drag reduction percent or flow increase percent are increased with increasing velocity of solution, increasing concentration of additives and decreased temperature.
3- Maximum %Dr of 38.78% was obtained using heavy oil containing 10% wt of naphtha flowing in pipes of 0.0508 m I.D. at 35°C at flow rate 10 m3/hr.
4- The additives (toluene and naphtha) diluted the high viscosity of used heavy oil.
5- The drag reduction occurs because of the interaction of the additives with heavy oil due to increasing the intermolecular distance within the oil and decreases the viscosity and density.
6- The used additives affect the physical properties of present used heavy oil, while the viscosity was reduced which indicated that we treated high viscosity.

Nomenclature

C: Solvent concentration
%Dr: Percentage drag reduction
%FI: Percentage flow increase
Re: Reynolds number ($\rho VD/\mu$)
T: Temperature
%Wt.: Percentage weight

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