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Experimental Study of Friction Factor for Iraqi Crude Oil by Using Nano-Al_2O_3 as Drag Reduction Agent (DRA)

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Abstract

Objectives: The aim of the present work is to study the effect of adding Nano-Al_2O_3 on the experimental friction factor and pressure drop for Iraqi crude oil. **Methods/Statistical Analysis:** The effect of three pipe diameters (0.5, 0.75 and 1 inch), five values of Reynolds number and Nano-Al_2O_3 concentration (0.002–0.01 wt %) on the friction factor were studied. **Findings:** The results illustrated that the friction factor is generally decreased with increasing of Nano-Al_2O_3 concentration and crude oil flow rate. **Application/Improvements:** There is very low available literature on the drag reduction process by using Nano-Al_2O_3 as drag reduction agent for Iraqi crude oil.

Keywords: Friction Factor, Iraqi Crude Oil, Nano-Al_2O_3

1. Introduction

With a rise in the combination in world energy source and the decline of classic oils, crude oils have been acquired as hydrocarbons source for future usage[1]. Hydrocarbon resources are very important and present approximately 65% of the world's overall energy resources[2]. Besides crude oil, is the main resource of hydrocarbon in the world, and heavy ore is a large part of the world's recoverable oil reserves[2,3]. Crude oils represent only account for a small part of the world's oil production due of their high viscosities, which cause difficulties in the transportation of these oils in pipelines[4]. So, crude oils with high viscosity and composition complexity make them difficult and expensive to produce, transport and refine[5]. A comprehensive study was published on the drag reduction for the distilled water flow. In the experimental work,a pipe with an inside diameter of 8.46 mm was used, containing 300 weight parts per million of a polyethylene oxide of molecular weight 0.57×10^6 dissolved in water during the friction factor escalating. The performance of different polymer solutions was described, and a trend to maximum drag reduction asymptotical cases was found.

Based on some experimental results[6] obtained, the friction factor was placed for the drag reducing agents in crude oil pipelines. The relationship predicts the drag reduction under different parameters, such as flow rate and temperature reduction agents[7] developed friction pressure model for tubes wrapped and directly based on the energy dissipation of the vortices in high Reynolds number and shear-rate-dependent relaxation time. It was found that their correlation in straight tubing was better than previous correlations.

Also[8] new models were developed for predicting the friction factor value as the same as a function of the solvent's Reynolds number for two straight tubes and coiled tubing using the data for an optimum concentration of polymer.

Based on the elastic properties of polymers[9], experiments were suggested. And, based on the experimental results obtained at different operating conditions[10], a mathematical model was proposed to predict the drag

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reduction by a given polymeric solution for a two-stage flow. The model can be used to calculate friction and maximum drag as a function of drag reduction agent concentration.

Very few studies have been done on pressure drop reduction by using nanoparticles compared to polymers and surfactants. Therefore, in this study, Nano-Al_2O_3 at different operating conditions was injected through the process. The parameters effecting on the pressure drop reduction and friction factor were investigated. They are different pipe diameters (0.5, 0.75, and 1 inch) by varying the concentration of Nano-Al_2O_3 and Reynolds number.

2. Materials and Methodology

Nano-Al_2O_3 properties were examined by the Atomic Force Microscope (AFM) and the X-ray Diffraction (XRD) spectra, the results of measurements showed spherical particles morphology and analyses of structure as show in Figure 1. These measurements were carried out in the Presidency of Nanotechnology and Advanced Materials Research Center, University of Technology, and Baghdad, Iraq. A sample of Iraqi crude oil was taken from the Al-Daura Refinery. The experimental work was done in the Research Laboratory of Petroleum Research and Development Center, Baghdad, Iraq.

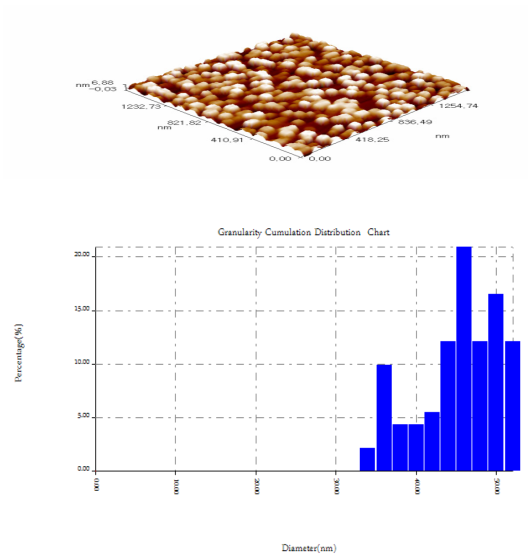

Figure 1. ASM test for Nano-Al_2O_3.

2.1 Experimental Arrangement

The schematic diagram of the experimental is illustrated in Figure 2 which is in Petroleum Research and Development Center (PRDC). In this paper, 25 kg of crude oil were placed in the container and then pumped through a gear pump. After 30 minutes, the value of pressure gauge was taken to find the pressure drop along the pipe. In order to prepare the nanocrude oil, 0.5 gm of nano-Al_2O_3 was added to 10 ml of crude oil and mixed for 10 minutes using stirrer. This step was repeated by increasing 0.5 gm for each run and for five used concentrations. The effect of variable flow rates (10, 20, 30, 40, and 50 L/min) was investigated by taking readings every 10 minutes. More than three different diameters were selected for the pipe (0.5, 0.75 and 1 inch) for each of the five flow meters for crude oil. The above experimental process was repeated to study the effect of concentration and type of nano materials on the pressure drop in reducing the drag. The Brookfield Viscometer (DV 3T) and its rheological properties could be determined by two indexes n and k, indicating the flow behavior and the consistency index of the crude oil.

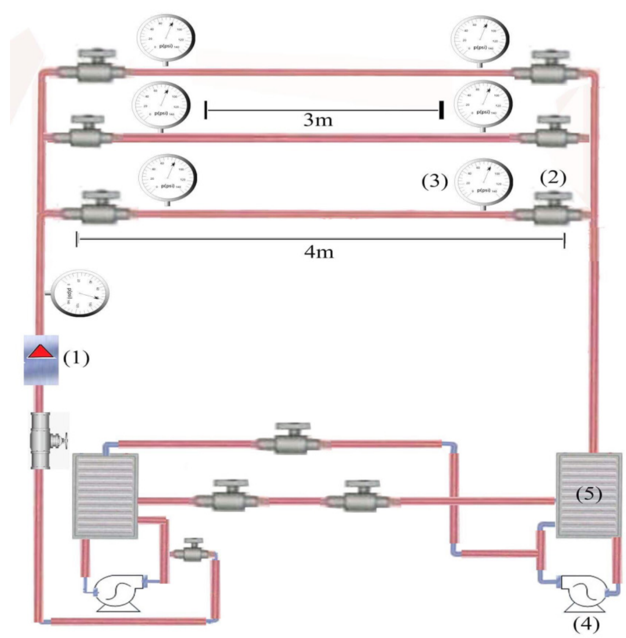

Figure 2. Schematic diagram for process.
1-Rotarmeter. 2-Valve. 3-Pressure gaug. 4-Pump. 5-Tank

3. Results and Discussion

Liquids are classified according to their rheological behavior. All liquids are classified as either Newtonian or Non-Newtonian Reynolds number that can be interpreted as the ratio of inertial forces to viscous forces. Since crude oil is a non-Newtonian fluid of power-law type, its Reynolds number would be defined by the equation bellow:

$$Re = d^n v^{2-n} \rho / (8^{n-1} k ((3n+1)/4n)^n) \quad (1)$$

The rheological properties of crude oil could be determined by two indexes n and k, indicating the flow behavior and the consistency index of the crude oil. The measured flow performanceindex (n) of crude oil was 0.83 at a temperature of 30°C, and the measured consistence coefficient (k) was 9×10^{-5} kg/m s^{2-n}.

To calculate the amount of friction factor, the pressure difference between the two specified points of each pipe was simply measured and then converted into friction factor using Darcy–Weisbach equation.

$$f = 4\tau_w / \rho V^2 = d\, \Delta P / 2 L \rho V^2 \quad (2)$$

Where, τ_w is the shear stress of wall, ρ is the density of the crude oil, Vis the velocity of crude oil, d is the diameter of inside pipe, ΔP is the drop pressure of the flow and L is the distance between the two points that measures the pressure drop.

Figure 3 shows the effect of adding Nano-Al_2O_3 with different crude oil flow values at three different diameters on the pressure drop. It is shown that the lower pressure drop is at Nano-Al_2O_3 concentration = 0.006, 0.01 and 0.002 wt% for (0.5, 0.75 and 1 in), respectively.

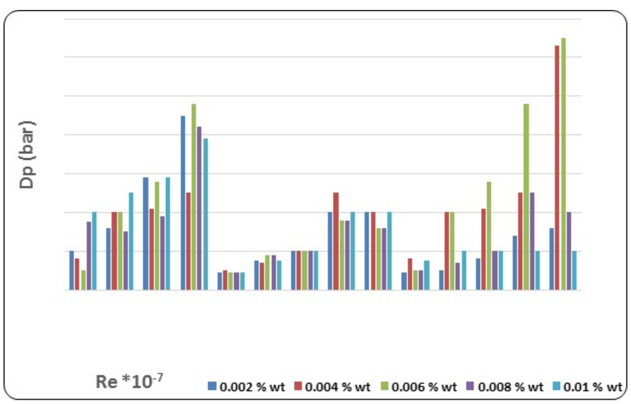

Figure 3. Pressure drop (Bar) for Reynolds No. for different Nano-Al_2O_3 concentrations (0.002 to 0.01 wt %).

Figures 4 to 6 manifest the effect of adding Nano-Al_2O_3 with different crude oil flow values at three different diameters. It is shown that the higher decreasing friction factor is at nanoparticle concentration = 0.006, 0.01 and 0.01 wt % for (0.5, 0.75 and 1 inch), respectively at 0.5", and the fraction factor gives the same performance as for (0.002, 0.004 wt %). For 0.75", the result illustrated the same performance for all nanoparticle concentrations. Finally, 1" in behaves like as 0.75".

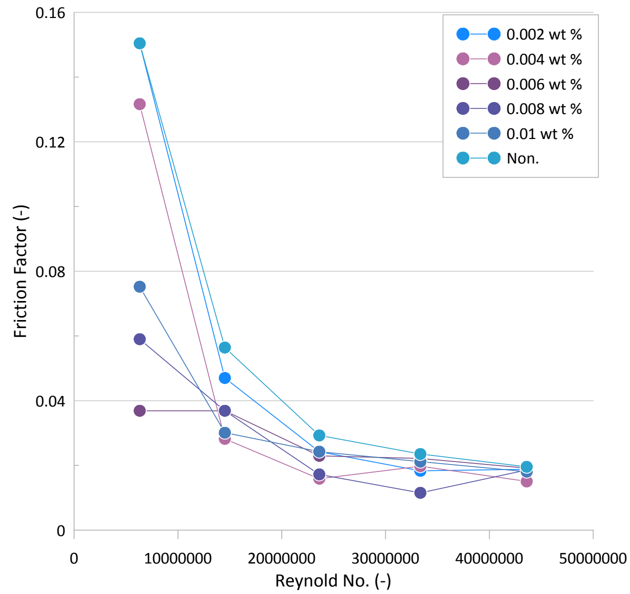

Figure 4. Effect of Nano-Al_2O_3 concentration on the friction factor at pipe diameter (d) = 0.5".

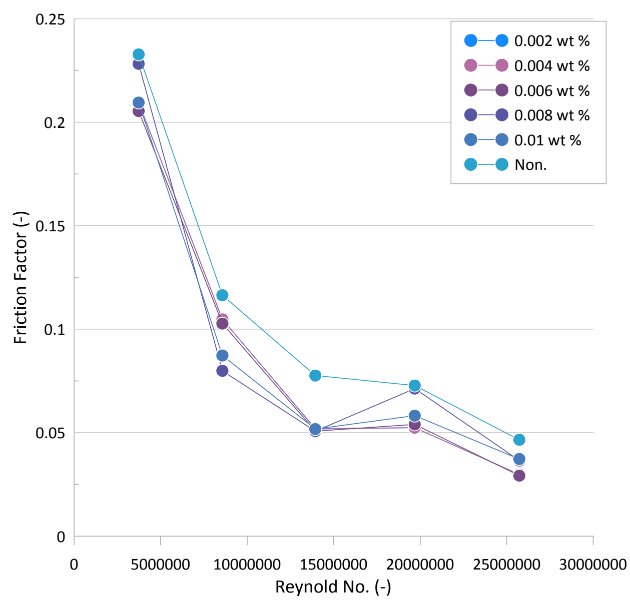

Figure 5. Effect of Nano-Al_2O_3 concentration on the friction factor at pipe diameter (d) = 0.75".

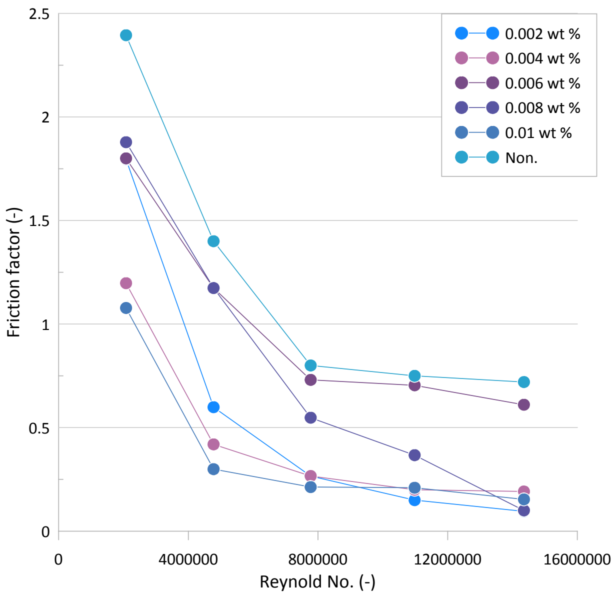

Figure 6. Effect of Nano-Al_2O_3 concentration on the friction factor at pipe diameter (d) = 1".

The fraction (f) of Nano or colloidal particles leads to a reduction of drag or viscosity by direct reduction of free asphaltene in crude oil, which in principle contributes to a stiffer viscoelastic network in fluid. The adsorption of asphaltene and its consequent reduced concentration as the result of the availability of surface area on the nanoparticles prevents the formation of large drag-causing networks in the bulk of the fluid counter-acting the viscosity-inducing soft asphaltene colloids (aggregates)[11].

The efficiency of nanoparticle under consideration was measured by calculating the drag reduction related to the addition of nanoparticles compared to the pipeline drag reduction with the nanoparticles.

4. Conclusions

The experimental study on the drag reduction system for Iraqi crude oil has given some basic data. In real, the following conclusions are extracted from the present study:

- The drag reduction was revealed high at high nanoparticles concentration.
- Nano-Al_2O_3 used as an additive in crude oil elucidateda good friction reduction (pressure drop reduction).

5. Acknowledgements

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