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Experimental Investigation of Major Dynamic Parameters of Nano Crude Oil

Ramin Osanloo[1, 2], Farshad Farahbod[3, *]

[1]Department of Chemical Engineering, Science and Research Branch, Islamic Azad University, Sirjan, Iran
[2]Department of Chemical Engineering, Sirjan Branch, Islamic Azad University, Sirjan, Iran
[3]Department of Chemical Engineering, Firoozabad Branch, Islamic Azad University, Firoozabad, Iran

Abstract

Undoubtedly, crude oil is one of the powerful sources of energy provision in the world. Knowing of the dynamic properties of crude oil is very important for engineering. It seems the dynamic properties of fuels can be improved by linking with nanotechnology. Nano particles which are prepared by a method of ultrasonic are applied in crude. Experiments are held in heated tube section for both simple oil and nano oil, which contains nano zinc oxide. The effect of temperature changes, addition of nano particle and length of the tube on values of friction factor, velocity, thermal conductivity, overall heat transfer coefficient, thermal diffusivity, and cinematic viscosity are investigated.

Keywords

Rheology, Environmental Problems, Crude Oil, Ultrasonic, Nano Particles

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1. Introduction

1.1. Crude Oil

The top three oil producing countries are Russia, Saudi Arabia and the United States. About 80 percent of the world's readily accessible reserves are located in the Middle East, with 62.5 percent coming from the Arab 5: Saudi Arabia, UAE, Iraq, Qatar and Kuwait [1, 2 and 4]. A large portion of the world's total oil exists as unconventional sources, such as bitumen in Canada and extra heavy oil in Venezuela [4 and 5]. While significant volumes of oil are extracted from oil sands, particularly in Canada, logistical and technical hurdles remain, as oil extraction requires large amounts of heat and water, making its net energy content quite low relative to conventional crude oil [6 and 7]. Thus, Canada's oil sands are not expected to provide more than a few million barrels per day in the foreseeable future [8 and 9].

In its strictest sense, petroleum includes only crude oil, but in common usage it includes all liquid, gaseous, and solid hydrocarbons [10]. Under surface pressure and temperature conditions, lighter hydrocarbons methane, ethane, propane and butane occur as gases, while pentane and heavier ones are in the form of liquids or solids [11]. However, in an underground oil reservoir the proportions of gas, liquid, and solid depend on subsurface conditions and on the phase diagram of the petroleum mixture [12].

An oil well produces predominantly crude oil, with some natural gas dissolved in it. Because the pressure is lower at the surface than underground, some of the gas will come out of solution and be recovered (or burned) as associated gas or solution gas. A gas well produces predominantly natural gas [13]. However, because the underground temperature and pressure are higher than at the surface, the gas may contain heavier hydrocarbons such as pentane, hexane, and heptane in the gaseous state. At surface conditions these will

* Corresponding author
E-mail address: mf_fche@iauf.ac.ir (F. Farahbod)

condense out of the gas to form natural gas condensate, often shortened to condensate [14]. Condensate resembles petrol in appearance and is similar in composition to some volatile light crude oils.

The proportion of light hydrocarbons in the petroleum mixture varies greatly among different oil fields, ranging from as much as 97 percent by weight in the lighter oils to as little as 50 percent in the heavier oils and bitumens [15].

The hydrocarbons in crude oil are mostly alkanes, cycloalkanes and various aromatic hydrocarbons while the other organic compounds contain nitrogen, oxygen and sulfur, and trace amounts of metals such as iron, nickel, copper and vanadium [16]. The exact molecular composition varies widely from formation to formation but the proportion of chemical elements varies over fairly narrow limits as follows [17].

1.2. Nanotechnology

In recent years, development in the miniaturization technologies results in the fabrication of micro-scale electronic devices which is used in various industries such as aerospace and automotive. For maximum performance of these micro devices which is known as MEMS (Micro Electromechanical Systems), the temperatures should be in a certain range. Micro channel as Compact and efficient cooling devices have been developed for the thermal control of MEMS [18]. Utilizing nano fluid as working fluid could improve the cooling and heating performance. Because of the more stable nature of nano fluid compared with its pioneer generation (including micro and millimeter particles) and exceptional thermal conductivity of nanoparticles, it could considerably enhance the convective heat transfer coefficient in micro channel. During the last decade, many studies on convective heat transfer with nano fluids have been considered [19].

1.3. Friction Factor

The Darcy friction is an important parameter that predicts the frictional energy loss of drilling fluid in a pipe based on the velocity of the fluid and the resistance due to friction. It is used almost exclusively to calculate head loss due to friction in the flow [48].

$$h_f = \frac{fLV^2}{2Dg} \tag{1}$$

2. Materials and Method

2.1. API of Crude Oil

The API of crude oil is classified according to the Table 1.

Table 1. Composition of drilling fluid.

component	API
Crude oil	29

2.2. Preparing Nano-Sized ZnO

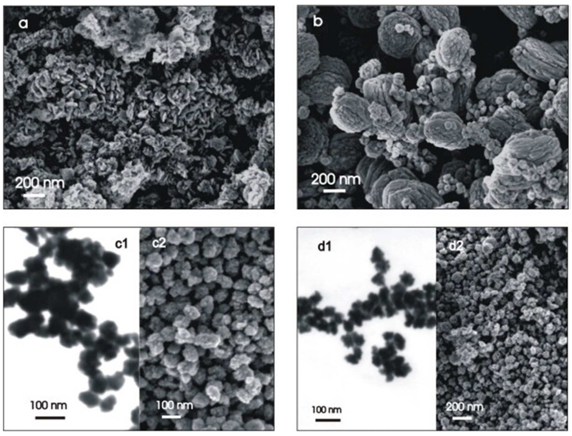

Figure 1. SEM and TEM picture of synthesized nano paticles.

Zinc dioxide (ZnO) is a transition metal oxide that has long been known to be active for hydrocarbon decomposition and has more recently shown to display high reforming activity for various long-chain Hydrocarbons. Researches showed that ZnO is highly active in reforming isooctane via partial oxidation. This process is exothermic (ΔH°= −659.9 kJ/mol) and in the presence of ZnO proceeds to full conversion at 700°C and 1 atm. The catalytic activity shown by ZnO can be explained in terms of the Mars-van Krevelen mechanism, which involves the consumption of nuclear philic oxygen ions provided by the oxygen sub-lattice with the purpose of sustaining the redox cycles taking place on the catalyst surface. Despite its interesting catalytic properties, a very limited number of studies have been conducted examining the potential of ZnO as a catalyst for reforming processes. Such studies were carried out using commercial ZnO, with particle sizes in the range of a few micrometres and Brunauer, Emmett, and Teller (BET) surface areas <10 m2/g. By utilizing nanoparticles we have shown that it is possible to significantly increase the total reactive surface area and thus achieve reforming processes with much higher efficiency levels than those of commercial ZnO. Nanoparticle ZnO was synthesized by reduction of zinc trioxide (MoO3) powder in a 1:3 volume ratio of ethylene glycol to distilled water16. The mixture was combined in a 45 ml Teflon-lined general-purpose vessel, which was subsequently sealed and heated to 180°C for 12h. After cooling, the dark colored ZnO was filtered and air dried at 100°C. Figure 2 shows scanning electron microscope (SEM) and transmission electron microscope (TEM) images of nanoparticle ZnO. These images indicate that the agglomerates consist of nanoparticle ZnO with sizes ranging from 54-83 nm. The BET surface area of the nanoparticle ZnO was determined to be 48 square meter per gram, which is about an order of magnitude greater than that of the commercially available material. Figure 1 shows the SEM and TEM photos of zinc oxide nano particles. In addition, Table 2 illustrates the values of XRD.

The pictures of synthesized nano particles are stated in different scales. It seems that the morphology of synthesized nano particles is spherical.

Table 2. The amount of XRD of zinc oxide nano particles.

XRD	2teta
100	33
101	34
102	36
110	47
103	57
112	63
100	64
103	68

The physical property of synthesized aluminum oxide nano particles is mentioned in the Table 3.

Table 3. Physical properties of zinc nano particles.

Aluminum oxide nano properties	
Zinc	80.34%
Oxygen	19.6%
Resistivity	$1.2\times10^6\Omega$.cm at 20C
Average size	68 - 87nm

2.3. Experimental Set up

The experimental set up includes mixing tank, adiabatic tube test section and electrical heater is used to survey the behavior of nano crude oil. At the beginning, the crude oil is mixed by zinc oxide nano particles in an ultrasonic (With 400Watt, for 3hour), then the nano crude oil is mixed in mixing tank, passing through an electrical heater to reach the desired temperature in the range of, 20 C to 95 C and 18 C to 91 C. Vertical adiabatic test tube with 0.3 m and 0.025 m in length and diameter, respectively is used. Digital sensors transmit the obtaining parameters to the control box.

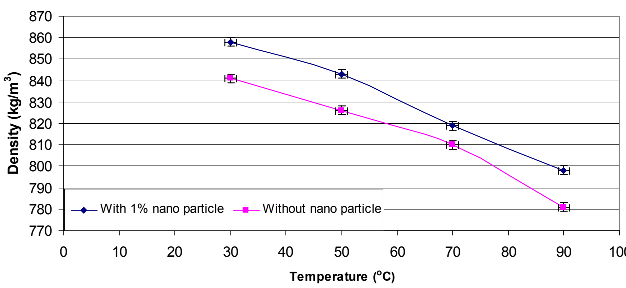

Figure 2. Density versus temperature.

Figure 2 shows the decrease trend of density of both simple and nano oil (1 wt%) with temperature enhancement. Temperature changes in range of (30, 50, 70 and 90 C) changes values of density for simple oil from 841 kg/m^3 to 781 kg/m^3 and for nano oil from 858 kg/m^3 to 798 kg/m^3. Higher values of density are obtained for nano oil than simple oil at the same temperature. This is obviously related to the higher value of nano oil mass than the simple oil mass at per unit volume of each oil. The decrease trend of density with temperature is also described by the increase in the amount of kinetic energy, the increase in volume of both simple and nano oil which decreases the value of density for two types of oil.

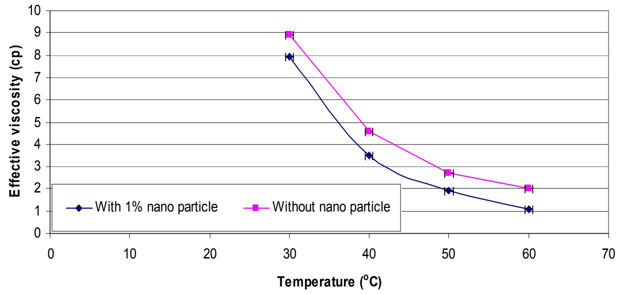

Figure 3. Effective viscosity versus temperature.

The effective viscosity versus temperature is shown in Figure 3 for nano oil and for simple nano oil. The increase in temperature decreases the amount of effective viscosity of both simple and nano oil which contains 1% nano particle. The increase in temperature in ranges of (30, 40, 50 and 60 C) decreases the amount of effective viscosity from 7.91 cp to 1.1 cp for nano oil and from 8.9 cp to 2.01 cp for simple oil.

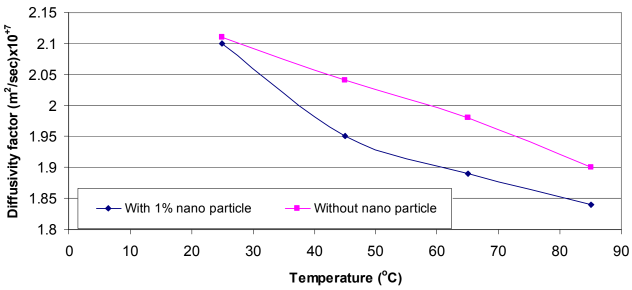

Figure 4. Thermal Diffusivity factor versus temperature.

Thermal diffusivity is a material-specific property for characterizing unsteady heat conduction. This value describes how quickly a crude oil reacts to a change in temperature. In order to predict cooling processes or to simulate temperature fields, the thermal diffusivity must be known; it is a requisite for solving the Fourier differential equation for unsteady heat conduction. Figure 4 shows the effect of temperature on the diffusivity factor. Diffusivity factor shows the diffusion ability of heat inside the fluid. The increase in temperature decreases the amount of the diffusivity factor of nano oil and increases the values of the diffusivity factor for simple oil. The competitive role of thermal conductivity and also density of fluid (positive effect of temperature on two mentioned values) final result the decrease trend of diffusivity factor for nano oil and the increase trend for simple oil. The lower amounts of diffusivity factor in nano oil are obtained were compered with the obtained values for simple oil. The values of simple oil are 1.03 times of values of nano oil.

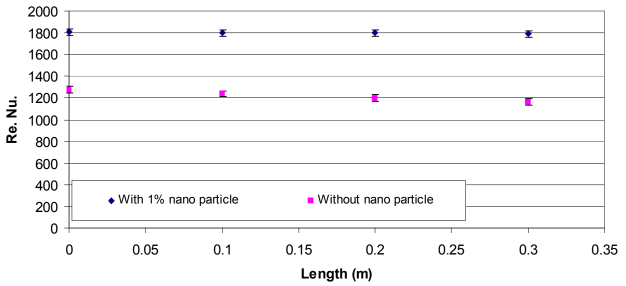

Figure 5. Values of Reynolds number through the length.

The Reynolds number is one of the important dimensionless numbers which is used extensively in hydrodynamic field. The total effect of nano zinc oxide on the velocity, viscosity and density of oil through the length is shown in Figure 5. The decrease trend in Reynolds number is obtained from simple oil through the 0.3 m length of pipe from 1276 to 1164. For nano oil the decrease trend of Reynolds number is somehow slightly from 1807 to 1789.

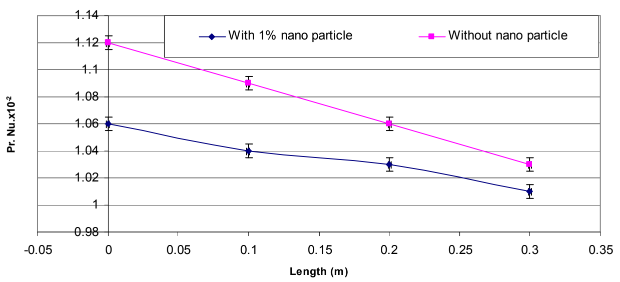

Figure 6. Prandtle number versus length.

Evaluation of thermo-physical properties of the fluid is easier with a prandtle number to calculate heat transfer properties. Figure 6 shows the changes of prandtle number versus length. The decrease trend of prandtle number is obtained from both types of nano oil and simple oil. The values of prandtle of nano oil changes from 106 to 101 and for simple oil changes from 112 to 103.

3. Conclusions

Application of nano zinc oxide in oil is studied in this manuscript. The effect of addition of different weight percentage of nano particle in the oil, which flows vertically under different temperatures (ranges from 30-70 C, 25- 85 C, 30- 90 C) in a tube section is investigated, experimentally. Test tube with 0.025 m in diameter and 0.3 m in length is used in the study. Some important thermo-physical properties are measured. Besides, some applicable dimensionless groups in hydrodynamic calculations and heat transfer are presented. The temperature changes from 25 C to 85 C decreases the value of thermal diffusivity factor for nano oil (1 wt%) about 0.9 time of initial value but increases the value of thermal diffusivity for simple oil to 1 time of the initial value. Through the length of tube section the decrease in values of cinematic viscosity, velocity, Reynolds number. Peclet number and Prandtle number are obtained for both simple oil and nano oil contain 1 wt% nano zinc oxide.

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