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Experimental investigation of the kinetics properties of the nano crude oil in a vertical line

Abstract

In this study, experiments are designed to investigate the effects of ultrasonic zinc oxide nanoparticles on the properties of crude oil flow. The rheological and thermal properties of the crude oil containing nanoparticles were investigated *in vitro*. The nanoparticles were prepared by ultrasonic method in crude oil. Experiments were carried out in a hot tube for plain oil and nanoparticles containing zinc oxide. The effect of temperature changes, addition of nanoparticles and tube length on the values of friction coefficient, velocity, conductivity coefficient, overall heat transfer coefficient, thermal diffusion coefficient and kinematic viscosity were investigated. For nano oil (containing 1wt.% Zinc oxide) Reynolds number decreased to 0.99 initial value, Prandtl number decreased to 0.951 initial value, Peclet number increased to 0.94 initial value.

Keywords: rheology crude oil, heat properties, ultra-sonic, nano particles

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Introduction

Definition of nanotechnology

Nanotechnology has been able to dramatically revolutionize the various sciences by working across the range of atoms and the ability to modify their arrangement and optimize the efficiency and efficiency of systems with less raw materials and higher quality production.[1] In addition, nanotechnology, with its interdisciplinary nature, has broken the boundaries of different sciences and created a context in which the results, capabilities and tools of all disciplines and sciences can be used to enhance the quality of life.[2] The oil and gas industry in Iran is very old and has been able to exploit these huge resources to create a special place in this regard for the country.[3] Trying to access technology and improve the status quo in these industries is something that has been paying particular attention to it for years.[4] For this reason, the oil, gas and petrochemical industries have been relatively far from the nanotechnology sphere, and to some extent nanotechnology has entered the area.[5] What this study is looking at are areas of nanotechnology in the industry.[6]

Crude oil as a fossil fuel

Crude oil, on the other hand, is a hydrocarbon liquid that accumulates in various porous rocks in the Earth's crust and is either burnt as fuel or converted to chemicals by processes.[7] Although it is often known as black gold, it has a wide range of viscosity due to its different hydrocarbons and various colors of dark, black and yellow. This fossil fuel is formed under conditions of high pressure and heat on the buried bodies of zooplankton and algae.[8]

Nanofluids

Nowadays, a new generation of fluids has been the focus of researchers in the oil and gas industry, called nanofluids or smart fluids, resulting from the addition of low volumes of nanoparticles to fluids to enhance and improve their properties.[9] One of the most important properties of nanofluids is that their properties strongly depend on the size of the nanoparticles present. Such as smart fluids can improve the process of overloading the tanks by changing the wettability, reducing the tensile strength and also the sand strength.[10] For example, Salimeno and his colleagues were able to show that the use of nanoparticles increases the rheological properties as well as the effect of surfactant solution on the oil extraction process and, in the first place, causes a change in the surface tension coefficient of the oil-surfactant mixture.[11] On the other hand, nano particles can play a significant role in the enhanced oil recovery. Important applications of nanoparticles in this field include the use of nanomaterials to facilitate the separation of oil and gas inside the reservoir and the use of nanoseconds within the reservoir rock.[12] The nanoparticles drop off their cargoes when they come in contact with rocks containing crude oil and recycle the crude oil.

Relation between nano and oil reservoirs

One of the basic applications of nanoparticles is to change the wettability of the reservoir rock. The wettability of a fluid-reservoir rock system is defined as the ability of one fluid to diffuse over the rock surface in the presence of another fluid. Wetting not only determines the initial distribution of fluid but is a major factor in how fluid flows into the reservoir and plays an important role in oil and gas production. In general, hydrophilic reservoir rock is preferable to oil. Because, in the case of oil-friendly bunker oil, oil tends to stick to it and reduce production. When the well is exploited, damage to the formation may result in oil-like reservoir damage, which may well modify reservoir wettability using nanoparticles. Despite the increased heat transfer by the micrometer particles added to the base fluid, the use of solid particles of these dimensions also poses problems such as deposition or particle deposition, wear, pipe blockage, and increased condensation pressure drop in the duct. Fluid pointed out. Advances in materials technology have made it possible to overcome the above problems using solid nanoparticles. In fact, nano-fluids can be defined as: fluids containing solid suspended particles that cause a leap in the heat transfer phenomenon. These nanoparticles can alter the thermal and thermal properties of the base fluid.[13]

Present study

The literatures about dynamic and thermal properties of nano oil are rare. The nano metal oxide is used in this research. The conductivity coefficient in the nano metal oxide is high rather than the non-metal oxides. So, the metal oxide is selected for this study. The composition of nano metal oxide and crude oil can produce the nano fluid with novel properties. This new fluid can be used in different wells. Since that, the literatures about the mixing of nano metal oxide and crude oil and also, the physical properties of made nano fluid is so rare. Therefore, these items are the novelty of this research. Especially, the research about the mechanical and thermal characteristics of nano crude oil is very limited. So, in this research, the application of zinc oxide nanoparticles on crude oil is investigated. The effect of adding different weight percentages of zinc oxide nanoparticles to oil at different operating temperatures while crossing the adiabatic vertical tube has been studied and evaluated. In this research, the temperature ranges of 30 to 70, 25 to 85, 30 to 90 degrees Celsius is evaluated to evaluate the temperature range. In fact, the nanoparticles were integrated with oil and then kinetic parameters such as Reynolds number were calculated. Also, some thermal parameters such as Peclet number and Prandtl number have been evaluated and discussed in this research.

Materials and methods

The laboratory apparatus consists of mixing tanks, adiabatic tube sections and heaters to finally investigate the behavior of crude nanoparticles. Before the crude oil enters the mixing tank, the crude oil is first mixed with ZnO nanoparticles in ultrasonic conditions (at 400 watts for 180 minutes). This mixing is done microscopically and it makes the zinc oxide nanoparticles stable within the oil then the crude nano oil is mixed in the mixing tank. An electric heater is also used to achieve nano crude oil at the desired temperature in the range of 30°C to 90°C and 25°C to 85°C. In addition, there are various methods and devices for measuring the rheological properties of the fluid. The best way to use crude oil is to use a 35 Fan viscometer. A viscometer is a type of rotational rheometer and performs only one measurement at a time.

Description of experimental target

On the other hand, laboratory measurements usually measure the relationship of heat transfer between a fluid stream and a solid surface. These measurements, whether in natural or forced convection, are usually expressed as dimensionless parameters such as Nusselt number or Stanton number. The nanoparticles are first integrated into the oil and then inserted into a vertical insulated tube. As the various temperature sensors are mounted on the surface of the tube, the physical properties of the nano-oil are studied. Finally, some physical and thermal parameters can be measured and studied using physical properties obtained. The Figure 1 shows this process. In addition, the temperature profile in show, schematically in this Figure.

Statistical analysis

Experiments analysis is performed by design of experiment (DoE) tool (Design Expert 7.0) to evaluate the effect of controllable variables on the amount of sulfur removal. This statistical evaluation helps to understand the quantity of the effect of each variable on the response. The authors use the historical data as an initial design in study type of response surface. This type of design is applicable with the limited database of experiments and also is appropriate when the controllable variables are more than three. Moreover, this design supports the existed experimental data. The Figure 2 shows normal plot residuals.

Hardware system

The system processor is Intel (R), Core (TM), i3 CPU, M 370 @2.40GHz, in addition system type is 64 bit and windows type is 7. Also, installed memory (RAM) is 4 GB.

Figure 1 Schematic of pilot plant.

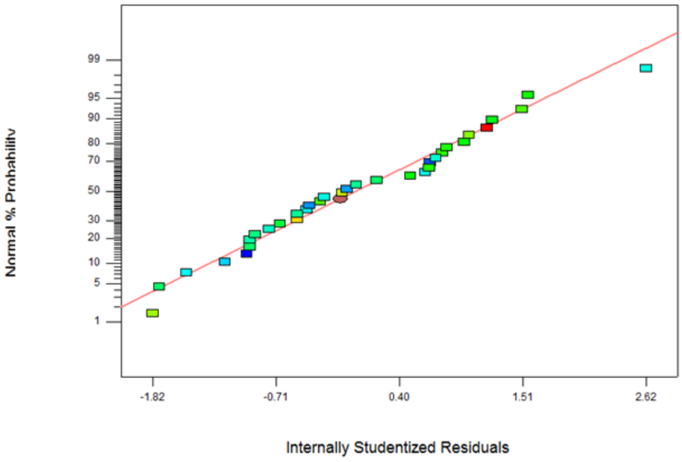

Figure 2 Normal plot of Residuals.

Results and discussion

The literatures about experimental evaluation of thermal and dynamic properties of nano oil is rare. So, the basic parameters in thermal and dynamic subjects are evaluated in this part. The Figures 3, 4 and 5 illustrate the rheology of the nano crude oil in the vertical tube.

Investigation of reynolds number as a dynamic property

Experimental results in the Figure 3 shows, increasing of the weight percentage of nanoparticles increases the coefficient of friction. Since the effect of adding nano on hydrodynamics on properties such as viscosity, velocity, density. In addition, Reynolds number is one of the most important non-dimensional numbers widely used in hydrodynamic fields. The overall effect of zinc nano oxide on velocity, viscosity and density of oil in the tube is shown in the Figure 3. The Reynolds number decreases for plain oil in the 0.3 m length from 1276 to 1164. For Nano fluid, the Reynolds number has a slight decreasing trend from 1807 to 1789. The experimental results show the viscosity will increase through the line. So, the Reynolds number will decrease, slowly.

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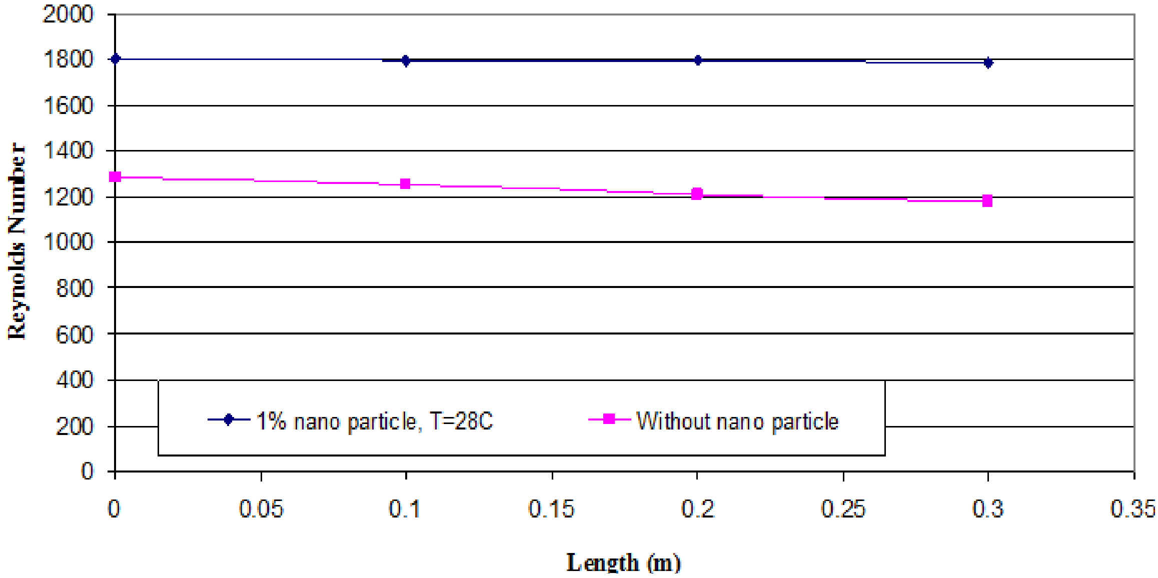

Figure 3 Values of the Reynolds number through the length.

Investigation of prandtl number as a thermal property

It is easier to evaluate the thermo-physical properties of a Prandtl fluid because it results in the calculation of heat transfer properties. The Figure 4 shows the variations of the Prandtl number by length. The downward trend of the Prandtl number was obtained for the two types of nanotube and plain oil. Prandtl number values for nano-oil vary from 106 to 101 and for plain oil vary from 112 to 103. The experimental results show the thermal diffusivity coefficient will decrease through the line. In fact, the conductivity factor and density values will change through the line. So, the Prandtl number will decrease with increasing of the length the line.

Investigation of peclet number as a thermal property

The Figure 5 shows the numerical values for nano-oil and plain oil along the tube. The values of the number of pellets for the nano oil varied from 188431 to 177781 and for the plain oil from 181034 to 166720 along the pipe. Since the Reynolds number is decreased with increasing of length. So, the Peclet number will decrease, finally. Obtained results sow this subject in the Figure 5.

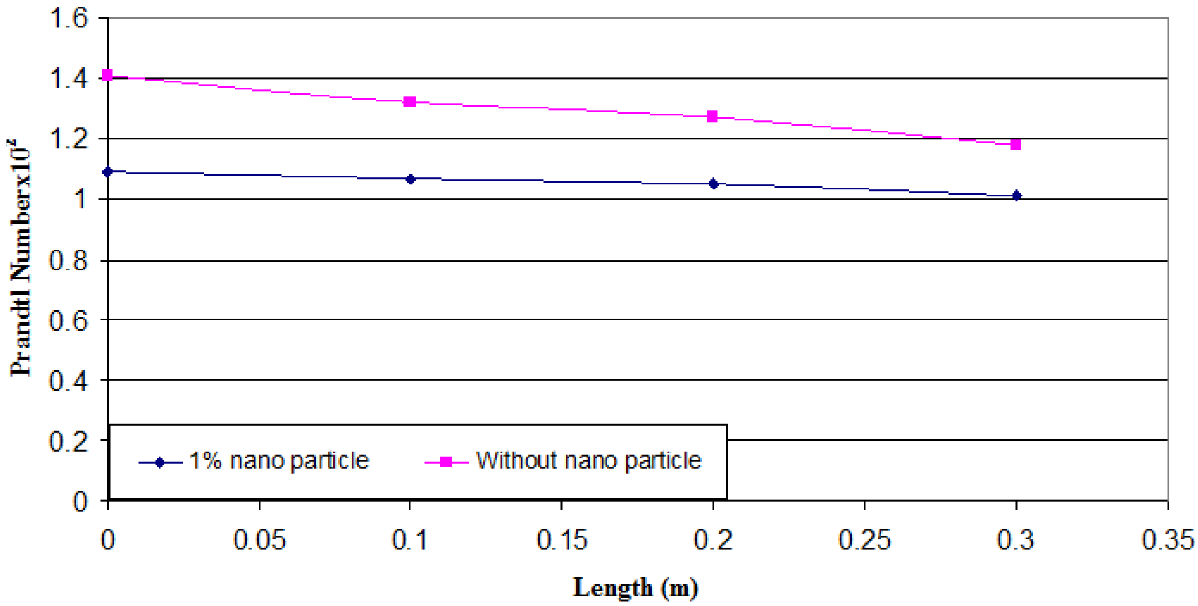

Figure 4 Prandtl number versus length.

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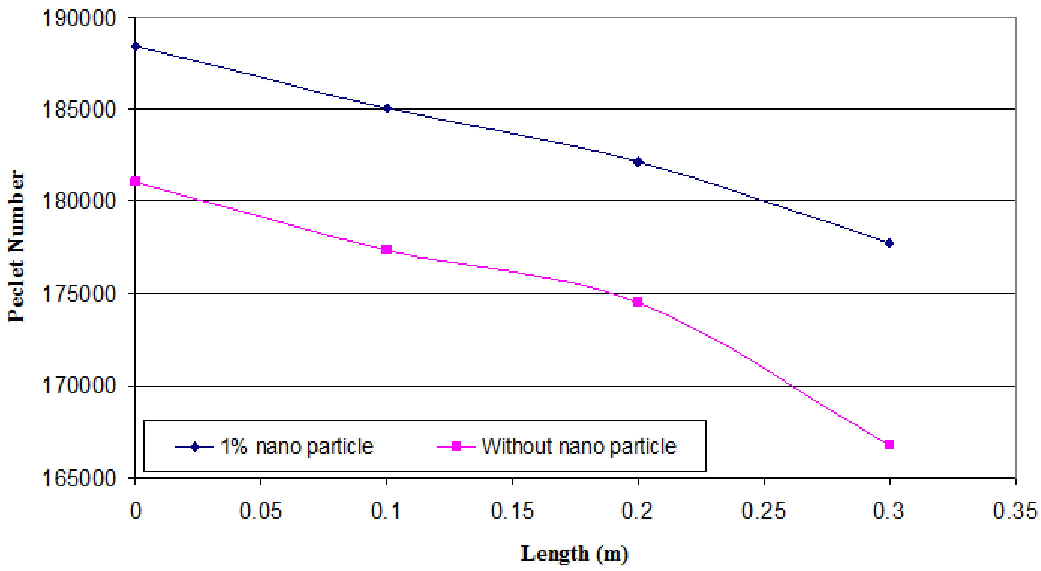

Figure 5 Peclet number versus length.

Conclusion

In this research some important kinetic and thermal variables such as Reynolds number, Peclet number and Prandtl number have been evaluated. Since the physical properties of the nano crude oil must be measured to calculate the kinetic and thermal properties of the nano crude oil, these properties are first measured and then the dimensionless numbers are calculated. Obviously, evaluation of listed numbers is a relatively complete comparison between the important thermal and kinetic oils containing nano-particles and simple oils. The results show that the incorporation of metal oxide nanoparticles in crude oil can improve the kinetic and thermal parameters of petroleum. Therefore, the application of zinc oxide nanoparticles on crude oil is investigated. Moreover, the effect of adding different weight percentages of zinc oxide nanoparticles to oil at different operating temperatures while crossing the adiabatic vertical tube has been studied and evaluated. The temperature ranges are selected as 30-7°C, 25-85°C, 30-9°C. So, the manner of nano fluid is investigated completely. The experiments were carried out in a hot tube for plain oil and nanoparticles containing zinc oxide. The effect of temperature changes, addition of nanoparticles and tube length on the values of dynamic and thermal characteristics of nano oil is evaluated, experimentally. Experimental results show, nano oil (containing 1wt.% Zinc oxide) Reynolds number decreased to 0.99 initial value. In addition, the Prandtl number decreased to 0.951 initial value. Also, the Peclet number increased to 0.94 initial values by changing of operating temperature.

Conflicts of interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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