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Investigation of Physical Properties of Nano Crude Petroleum: Increasing Oil Flow Rate in Reservoirs

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Abstract

The zinc oxide nano-particles have been used in this research. In this work, zinc oxide nanoparticles have been added to light and heavy crude oil. In this research, thermoelectric and physical properties of light and heavy crude petroleum have been measured, experimentally. In addition, dimensionless groups in hydrodynamics and heat transfer calculations are presented. This research illustrates that heat capacity of light and heavy crude petroleum varies from 4256 J/kg·˚C to 4457 J/kg·˚C and 4476 J/kg·˚C to 5002 J/kg·˚C, respectively. Moreover, heat capacity of light and heavy nano-crude petroleum is changing from about 4285 J/kg·˚C to 4496 J/kg·˚C and 4494 J/kg·˚C to 5021 J/kg·˚C, respectively.

Keywords

Crude Petroleum, Thermoelectric, Kinetic Properties, Nano-Metals, Dimensional Numbers

1. Introduction

Today, energy is considered as one of the most basic human needs. Energy is a vital need for industry, food production and agricultural production [1]. This is despite the fact that a large percentage of the world's energy is provided by fossil fuels, the use of which inevitably causes harm to human health, and damages to equipment and the facilities of various industries that use them follow [2]. The fossil fuels are divided into three main types including coal, oil and natural gas. All of three categories began to form a few hundred thousand years ago [3]. Before the appearance of dinosaurs, the period when these fuels began to form is called the "Carboniferous" period, which is a part of the Paleozoic era. "Carboniferous" takes its name from carbon, which is the most important component of coal and other fossil fuels [4]. The reason why they are called fossil fuels is that at that time the earth was full of swamps that were covered with huge trees and ferns and other leafy plants, and as the trees and plants died, they sank into the depths of the oceans and were gradually buried and layered [5]. Finally, a sponge called peat was formed [6]. After hundreds of years, peat was covered with sand, clay, and other minerals, and these minerals turned into a kind of sedimentary rock over time [7]. As more layers are piled up, they weigh more [8]. These types of fossil fuels have been used at different times and according to the level of technical knowledge and human ability to explore, exploit and use them in daily life, work and industry [9]. But it is obvious that nowadays the use of oil and gas is much more and more extensive than coal [10]. Oil is another fossil fuel that was formed more than three hundred million years ago [11]. Some scientists believe that the origin of oil is aquatic organisms, each of which is the size of a needle tip, and they can act just like plants [12]. Finally absorb sunlight and convert the energy stored in themselves. These tiny organisms fall to the bottom of the sea after death and are gradually buried under sedimentary layers and rocks, and the rocks and rocks put pressure on these tiny organisms, and the energy in their bodies cannot be discharged, and the carbon over time, under extreme heat and pressure, it turns into oil [13]. The need for oil has been a major factor in many of the wars of the twentieth century, including World War II. The United Arab Emirates, Saudi Arabia and the United States are the top three oil producers. In recent years, the development and advancement of micro-technologies has led to the manufacture and equipment's production on a micro and nano scale that is used in various industries [14]. The use of nano-metals as a surface enhancer can also improve the performance of cooling and heating systems. Hence fluid flow theory is often well established. While the fully developed slow current is still theoretically achieved, a current with other properties, such as turbulent flow, must rely on laboratory and experimental relationships. It should be noted that all the fluid flow in the pipe has a zero velocity profile in the pipe wall, due to the non-slip condition to the maximum in the center of the pipe. Some research studies the dynamic properties of oil. Some others examine the thermodynamic properties of oil [15]. Also, other researches refer to the investigation of electrical properties of crude oil [16]. Other studies investigate the thermal properties and heat transfer mechanisms of oil passing through the pipeline [17]. However, no study has investigated the thermoelectric and kinetic properties of crude oil mixed with nanoparticles. Therefore, this research is significantly different from other researches. In this research, nanotechnology has been used to investigate the thermoelectric properties of high and low density oils.

2. Materials and Method

2.1. API Grade of Crude Petroleum

The feed stream is two types of light and heavy crude oil. The American standard grade of crude petroleum is according to Table 1.

2.2. Properties of ZnO

The nano-ZnO have been used in this work due to high value of the specific surface. In addition, the ZnO nano particle is a non-toxic in low concentrations. The data show a good relationship between health and appropriate concentrations of ZnO compounds (Table 2).

2.3. Production of Nano-ZnO

The ZnO is used to make a solution 1 molar of Zn^{2+}. At the first, Zn^{2+} solution is purified, then a type of 0.05 M active surfactant, as well as 10% ethanol, is mixed with the Zn^{2+} solution in ultrasonic. The produced solution is shaken at regular intervals. Then, the same reactants are mixed with a molar solution of sodium carbonate under similar conditions. Two produced solutions are mixed, proportionally. The reconstituted solution is shaken under ultrasonic conditions for half an hour. Then, another active surfactant is added to the obtained solution and mixed again for half an hour. The final solution is filtered and rinsed several times with pure water and ethanol under ultrasonic conditions, alternately.

Table 1. Composition of crude petroleum.

Composition	Crude petroleum grade
Heavy crude petroleum	26.2
Light crude petroleum	49.1

Table 2. Physical properties of ZnO.

Characteristics	ZnO
Grid parameters in 300 K	
—a_0 nm	0.31563
—c_0 nm	0.51763
—c_0/a_0	1.71
Density (grams per cubic centimeter)	5.632
Stable phase at 300 degrees K	Wurtzite
melting point (˚C)	1975
Thermal conductivity (W/m·K)	1.14
Static dielectric constant	656/8
Refractive index	2.006
Exciton binding energy (mV)	58
Effective mass of electrons	0.27

2.4. Laboratory Equipment

The laboratory equipment includes a mixer tank, adiabatic test tube, and electric heater, which has been used to investigate the thermoelectric behavior of light and heavy petroleum. At the first, the crude petroleum is mixed with nano-ZnO in an ultrasonic (400 W and 180 min). Then, nano-oil is mixed in a mixing tank and then passed through an electric heater until the temperature reaches to 30˚C to 84˚C.

3. Results and Discussion

3.1. Effect of Nano-ZnO on Oil Density

The effect of adding zinc nano oxide on the density is illustrated in **Figure 1**. Increasing the percentage of nano-ZnO increases oil density.

Changes in the percentages of nano-ZnO from 1% to 5% increase density from 8 lb/gallon to 8.34 lb/gallon for light oil and also from 8.9 lb/gallon to 9.36 lb/gallon for heavy nano-crude petroleum. The experimental results show that average increase in density with addition of nano-ZnO is about 9.6%.

3.2. Viscosity of Nano-Oil

Figure 2 illustrates the dynamic viscosity versus shear rate. Increasing shear rate reduces dynamic viscosity for both types of oil.

The experiments show that increasing shear rate reduces dynamic viscosity about 28%. In addition, decrease in the dynamic viscosity may be related to the interaction between oil and nano-ZnO.

3.3. Initial Tension of Nano-Oil

The initial tension change is 1.1 Pa to 2 Pa for light nano-crude oil and 1.7 Pa to 2.9 Pa for heavy nano-crude oil (**Figure 3**). Two experimental relationships are expressed to predict initial tension in terms of temperature. The regression of the relationships is close to one. Hence, the accuracy of the curves is very good.

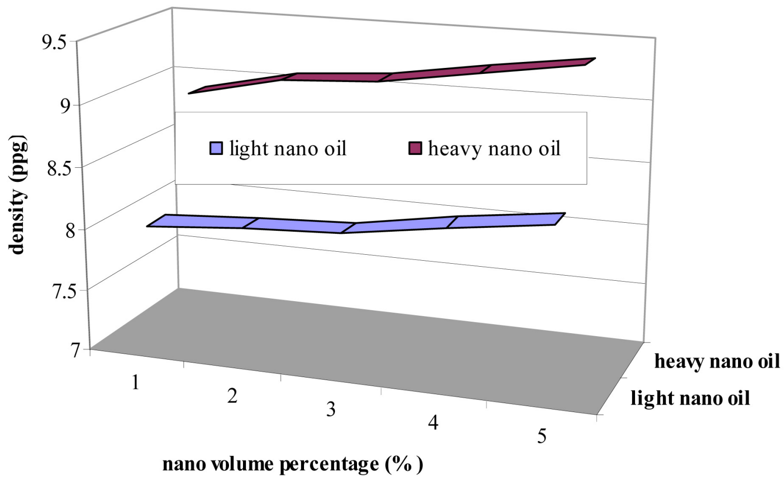

Figure 1. Study of nano-ZnO on density.

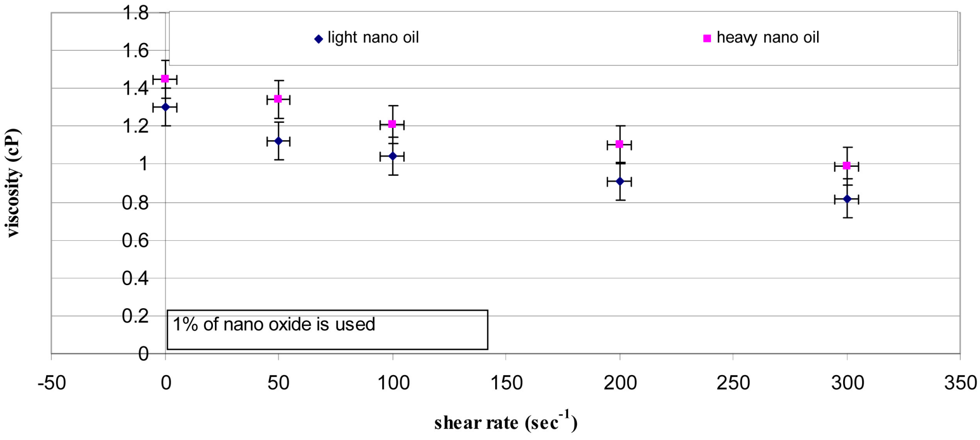

Figure 2. Relationship between shear rate and viscosity.

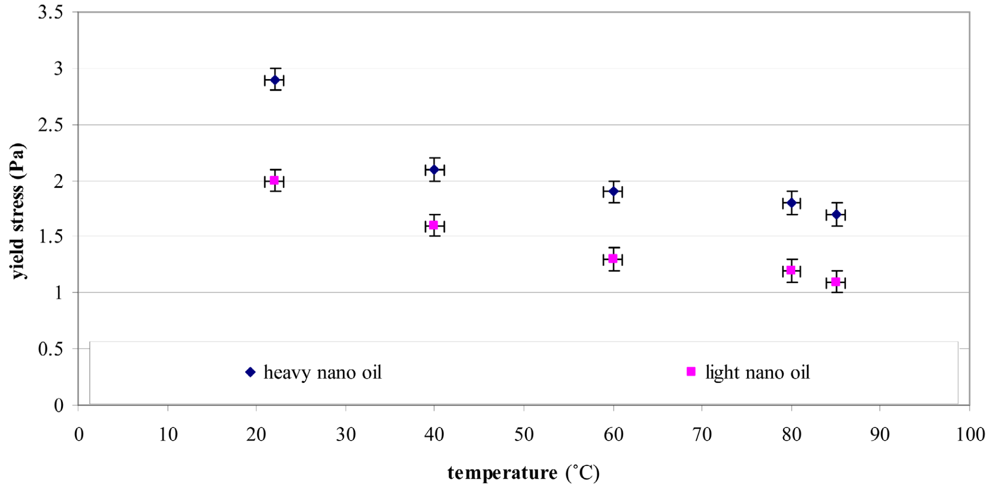

Figure 3. Relation of temperature and initial tension.

The relationship between initial tension and nano-ZnO is illustrated in Figure 4.

3.4. Prandtl Number of Heavy and Light Nano-Oil

The change in Prandtl number in terms of percentage of nano-ZnO is illustrated in Figure 5. The results show that the trend of both curves is decreasing and can be predicted by logarithmic function.

3.5. Investigation of Thermal Conductivity and Thermal Diffusivity

The change in the thermal conductivity ratio of light and heavy nano-oil versus percentage of nano-ZnO is illustrated in Figure 6. The experimental data show that thermal conductivity ratio is greater than one. It means that the ratio of thermal conductivity for light and heavy nano-oil is improved. This ratio is 0.1 to 1.15 for light nano-oil and 1.09 to 1.21 for heavy nano-oil. Results illustrate average difference between values of two curves is 5.2%, approximately.

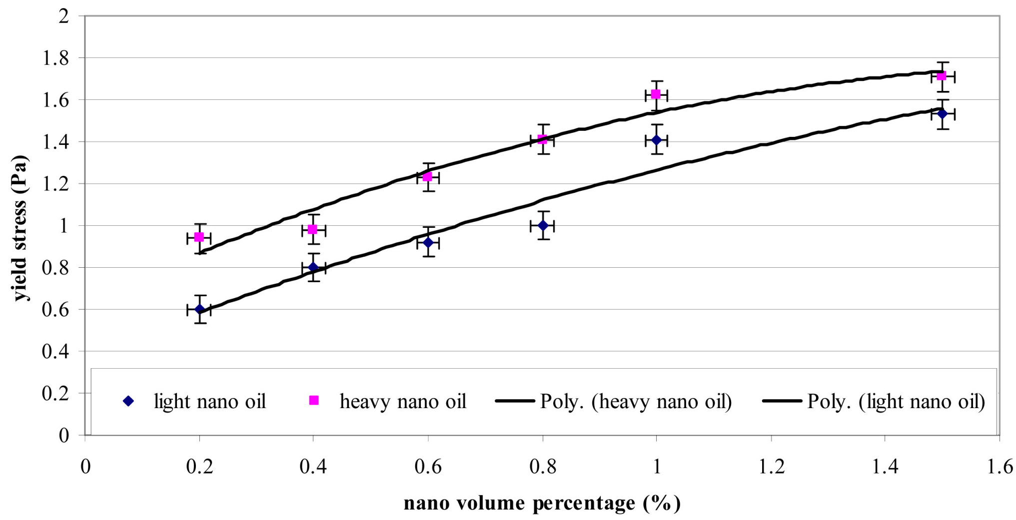

Figure 4. Study of nano-ZnO on initial tension.

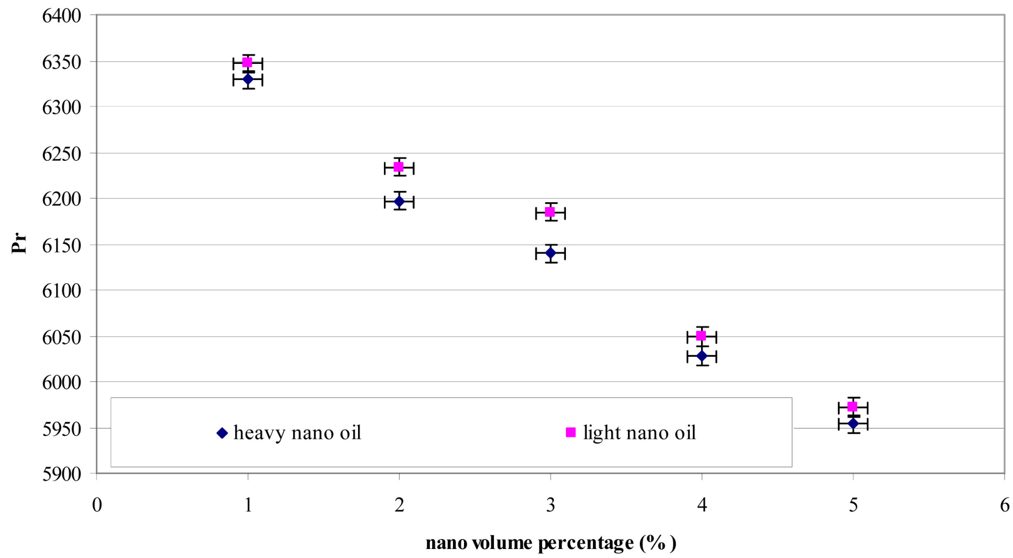

Figure 5. Study of nano-ZnO on Prandtl number.

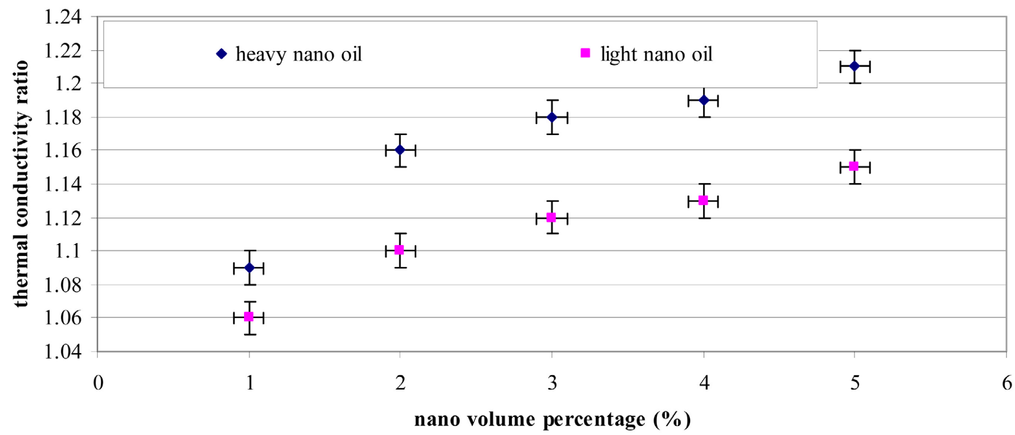

Figure 6. Study of nano-ZnO on thermal conductivity ratio.

Figure 7 illustrates the effect of nano-ZnO on the thermal conductivity with temperature change. In this experiment, the percentage of nano-ZnO varies from 1% to 5%. The studies show that increasing percentage of nano-ZnO usually increases the energy transfer capacity of materials. Therefore, it increases thermal conductivity from 0.15 $W/m^2 \cdot K$ to 0.164 $W/m^2 \cdot K$ for light nano-oil and 0.165 $W/m^2 \cdot K$ to 0.182 $W/m^2 \cdot K$ for heavy nano-oil. The studies show that the use of nano-ZnO increases thermal conductivity about 9%.

3.6. Thermal Diffusivity of Heavy and Light Nano-Oil

The thermal diffusivity ratios for light and heavy nano-oil are 1.07 to 1.25 and 1.03 to 1.16, respectively. The experimental results show that thermal diffusivity ratio in 1% to 2% by volume of nano-ZnO is increasing sharply and this ratio in 2% to 5% by volume of nano-ZnO is almost constant. Figure 8 illustrates relationship between thermal diffusivity ratio and percentage of nano-ZnO.

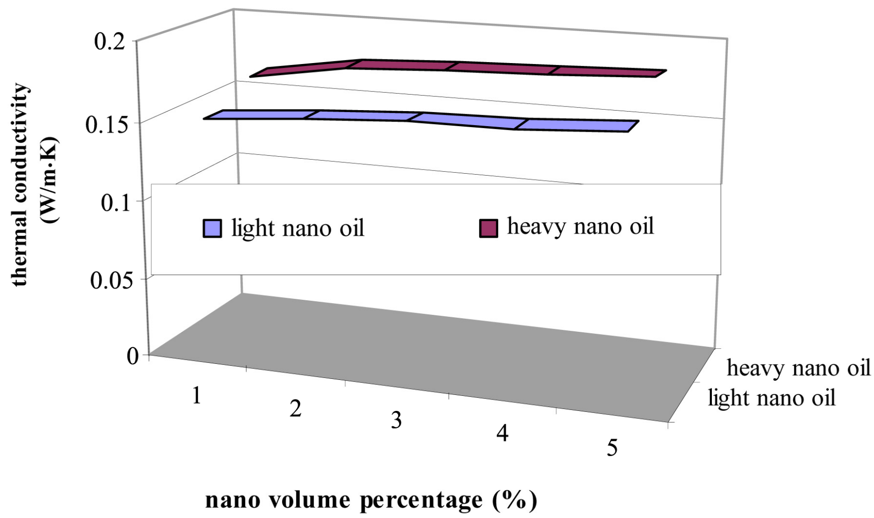

Figure 7. Study of nano-ZnO on thermal conductivity.

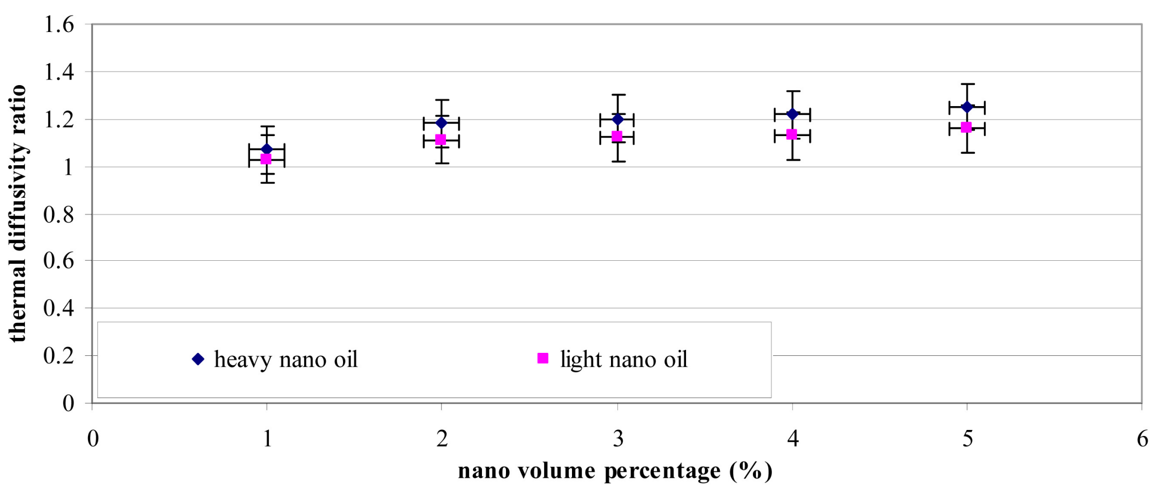

Figure 8. Study of nano-ZnO on thermal diffusivity ratio.

Figure 9 illustrate effect of percentage of nano-ZnO on thermal diffusivity. An increasing has been obtained for both nano-crude petroleum samples. This behavior is predictable according to the definition of the quantity of thermal diffusivity. The results show that changes of percentage of nano-ZO have a positive effect on thermal conductivity and a negative effect on density and heat capacity. Therefore, increasing nano-ZnO has a positive effect on thermal diffusivity.

3.7. Study of Overall Heat Transfer Coefficient

The overall heat transfer coefficient is measured in Figure 10. The regression of curves of light nano-oil and heavy nano-oil is 0.9056 and 0.9248, respectively. Operational data show that the kinetic ability of oil molecules increases with increasing nano-ZnO.

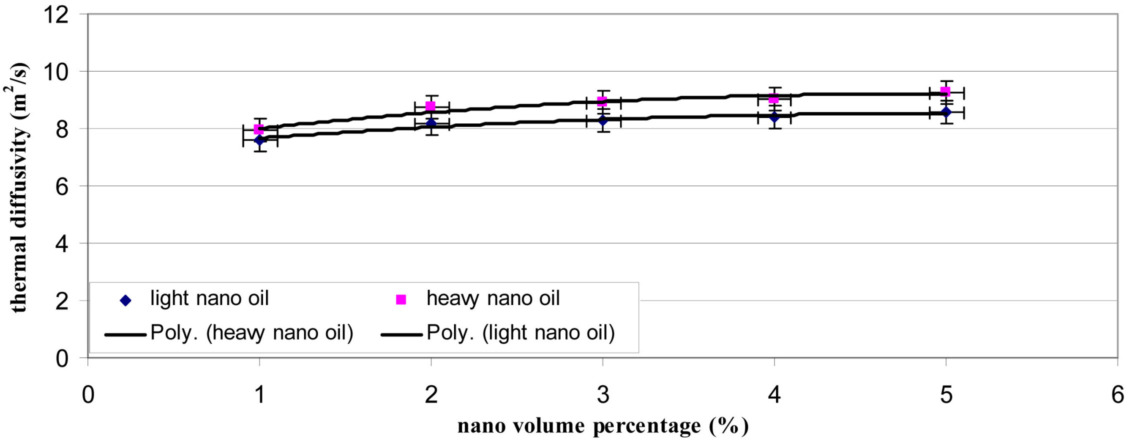

Figure 9. Study of nano-ZnO on thermal diffusivity.

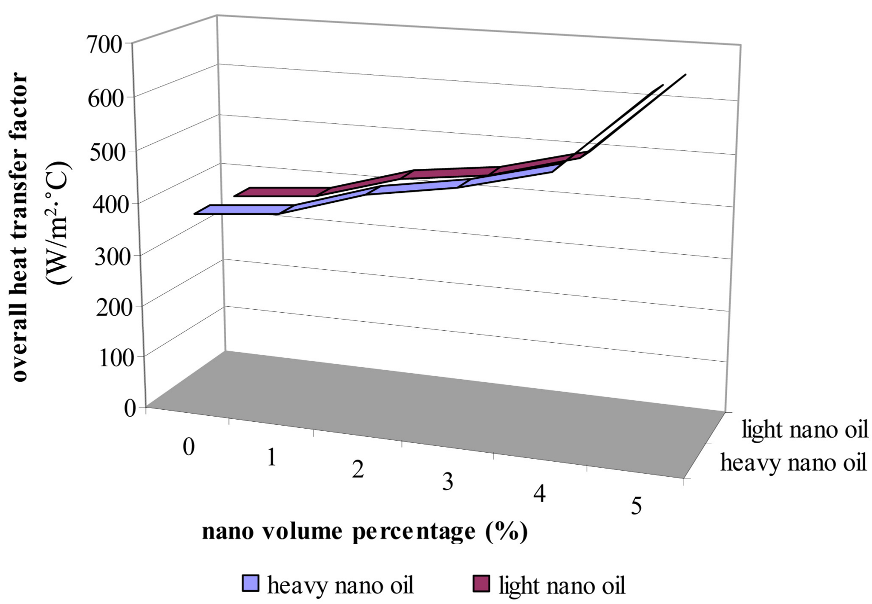

Figure 10. Study of nano-ZnO on overall heat transfer of nano-crude oil.

4. Conclusion

In this work, important thermoelectric and physical properties of light and heavy nano-petroleum have been measured. In addition, dimensionless groups in hydrodynamics and heat transfer calculations are presented. The effect of operating conditions and nano-ZnO on physical thermal properties of crude oil has been investigated. Results show that the heat capacity of light and heavy crude petroleum varies from 4256 J/kg·˚C to 4457 J/kg·˚C and 4476 J/kg·˚C to 5002 J/kg·˚C, respectively. Moreover, the heat capacity of light and heavy nano-crude petroleums is changing from 4285 J/kg·˚C to 4496 J/kg·˚C and 4494 J/kg·˚C to 5021 J/kg·˚C, respectively. Experimental results show that the ratio of thermal diffusion increases when the percentage of nanoparticles added to oil is equal to one to two and is almost constant at higher percentages. This study shows that increasing percentage of nano-ZnO increases energy transfer capacity. Therefore, it increases the thermal conductivity from 0.15 $W/m^2 \cdot K$ to 0.164 $W/m^2 \cdot K$ for light nano-crude oil and 0.165 $W/m^2 \cdot K$ to 0.182 $W/m^2 \cdot K$ for heavy nano-crude oil. Experiments show that increasing shear rate reduces dynamic viscosity about 28%.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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