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Experimental study of the results of adding alumina nanoparticles on viscosity and thermal conductivity of water and ethanol nanofluids

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ABSTRACT

In recent decades, the use of nanofluids has attracted much attention due to its application in various fields such as medical and industries like oil and gas. The combination of nanoparticles with base fluids and its type can produce different results depending on the characteristics of the nanoparticles, one of which is the effect of changes in the viscosity and thermal conductivity of the nanofluids. In this regard, the present study aimed to experimental investigation of alumina nanoparticles composite on the viscosity and thermal conductivity of water and ethanol nanofluids was performed. The nanofluids were prepared by combining of the Al_2O_3 nanoparticles with aluminum triisopropylate and then dispersed in the base fluids using an ultrasonic device. In this study, Al_2O_3 particles and triisopropylate aluminium with a partial thickness of about 2 nm were used with different of volume and concentration ratios in different temperatures. Experimental results of this study about the thermal conductivity and viscosity of water-Al_2O_3 and ethanol-aluminum triisopropylate nanofluids exhibited that the nanofluids have higher thermal conductivity than the base fluids. The concentrations of nanoparticles are very low; however, the thermal conductivity of nano-fluids causes a significant increase in the volume of nanoparticles. The measured thermal conductivity and viscosity of nanofluids showed that these parameters increased with the volumetric concentration of nanoparticles and also the higher temperature, the lower viscosity and the higher thermal conductivity.

Keywords: Nanoparticles; Nanofluids; Alumina; Viscosity; Thermal conductivity

1. INTRODUCTION

In recent years, a new generation of thermal fluids called nanofluids has been studied [1]. Nanofluids are liquids containing of solid particles in nanoscale and fibers, which result in performance of colloidal reactions of nanoparticles in a

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base fluid [2]. Pure base fluids such as water, ethylene glycol (EG), propylene glycol (PEG), and ethanol are commonly used in various medical and non-medical fields in medium and warm heating systems. An important issue should be considered in terms of energy saving is the optimization of the thermophysical properties of the fluid [3]. The thermophysical properties of these nanofluids have significant effects on their heat transfer properties such as viscosity and thermal conductivity of the fluids. Viscosity is one of the most important thermological properties that depends on different parameters [1]. The thermal conductivity in nanofluids is often achieved through experimental studies and investigation of various factors such as concentration, particle type, particle size, particle shape, fluid type and temperature [4]. Base fluids because of different physical properties cause various changes in the thermal conductivity [5]. Since each fluid has its own special conductive properties, therefore induces different conductivities in the nanofluid [6]. Furthermore, the hydrophilicity and hydrophobicity of the nanoparticles in different base fluids are very important. According to this area, some studies based on alumina nanoparticles, triisopropyl aluminum, basic fluids, ethylene glycol, ethanol and oils have been [7]. The thermal properties of nanofluids are influenced by factors such as volume percentage, shape, type, size of the nanoparticles and base fluid. Also the nanofluid heat may be hundreds of times higher than the base fluid thermal conductivity [8]. Temperature is one of the most important parameters affecting thermal conductivity and what makes it very effective is its effect on changing important mechanisms such as Brownian motion in nanofluids [9-10]. The formation of nano-layers around the nanoparticles effects on the mechanism of clustering in nanofluids [11]. As the temperature increases, the nanoparticles begin to move randomly into the fluid, which is due to their smaller size than the micro and milli scale, which these mechanisms lead to an increase in conduction changes [12]. The effect of temperature and concentration changes on the viscosity, density, and heat capacity of non-Newtonian copper oxide fluids and multi-walled carbon nanotubes (MWCNTs) with the help of distilled water-carboxymethyl cellulose base fluid at different volume concentrations were studied [13]. The nanofluidic thermal conductivity coefficient increasing mechanisms included the Brownian motion of the particles, the liquid layer laying at its interface with the solid phase, the heat transfer by photons and the formation of clusters, which can be investigated the effect of each of these mechanisms by molecular simulation [14]. Studies on alumina-water nanofluid showed that viscosity is decreased by increasing temperature and the lower ultrasonic time the lower temperatures require to achieve to the lowest viscosity compared to the higher temperatures [15]. Nanofluidic thermal conductivity increases with the raise of ultrasonic exposure. The thermal conductivity and viscosity of nanofluids grows with the raise of concentration of the nanoparticles. However, with ultrasonic exposure and temperature, it has negative effects on viscosity and positive effects on thermal conductivity [15]. For an ideal heat transfer environment, minimum viscosity and maximum heat conductivity are essential. The conditions for maximum thermal conductivity and minimum viscosity could be gained by multi-response optimization of independent variables [16]. In recent years, the thermal conductivity and viscosity of different nanofluids have been measured and the factors affecting such as temperature, concentration, and ultrasonic time have been studied [17]. But the interactive effect of these parameters on thermophysical properties has rarely been investigated in the literatures [18]. The interactive effect plays an important role in the selection of the optimal nanofluid parameters to show higher heat transfer coefficient. Knowledge of interactive effects which may reduce the number of experiments to obtain the desired heat transfer coefficient [19].

2. PREPARATION OF NANOFLUIDS AND LABORATORY METHODS

2.1. Preparation of ethanol sample

First, 0.1 mol of aluminum isopropylate nanoparticle was added to 50 ml of ethanol and then inserted into the ultrasonic bath to dissolve the nanoparticle. This was performed for (1/2, 0/3, 0/4, 0/5, 0/3) mol of nanoparticles. Then 15 mL of each sample was separated for viscosity and thermal conductivity tests. The viscosity and thermal conductivity in the temperature range (25-45 °C) have been investigated to study the dependence of viscosity and thermal conductivity on temperature in addition to the concentration of nanoparticles. It was found that ethanol responds to the nanoparticles in a constant volume and its physical properties such as thermal conductivity and viscosity changed.

2.2. Preparation of water sample

First, a specific weight/volume percentage of aluminum oxide nanoparticles was added to 50 mL of water and inserted into the ultrasonic bath to dissolve the soluble nanoparticles. This was performed for (1/2, 0.3, 0.4, 0.5, 0.0) mol of the nanoparticles. Then, 15 mL of each sample was separated for the investigation of viscosity and thermal conductivity tests, respectively. It was observed that water responds to the nanoparticles in a constant volume and its physical properties such as thermal conductivity and viscosity changed. The results will be discussed in the following sections.

3. LABORATORY APPARATUS AND METHODS

3.1. Measurement of viscosity

To measure the viscosity of nanofluids, the samples were prepared. The viscometer apparatus of Razi and Tehran University were used. The used viscometer consists of three main parts: a viscometer, an electric control unit and a thermal enclosure that warms the sensors. Figure (1) shows a piston type viscometer. Figure (2) illustrates the sample viscosity based on the flow inside the cylindrical cavity consisting of two magnetic coils located in a sensor with 316 stainless steel body. The temperature of the sample fluid inside the sensor is continuously controlled by RTD platinum mounted inside the bottom of the cavity. Temperature accuracy and reproducibility of RTD are estimated to be ± 0.2 and ± 0.1 °C, respectively. However, the viscometer's accuracy and reproducibility according to the manufacturer's claims are 1% and 8%, for the 0-20 cm interval respectively. The heater chamber (Fig. 1b) is a 70 cm rigid steel cylinder with an outer diameter of 10 cm and an inner diameter of 6 cm, which is exactly equal to the outer diameter of the viscometer sensor hole. The chamber is heated by a 50W rated electric heater located axially inside the chamber.

3.2. Thermal conductivity measurement

This part of our experiments was performed because of the lack of facilities at several sites including. The device used was of Razi and Tehran university, to measure the thermal conductivity digital sensor with a display that was also highly accurate due to up-to-date technology. The important issue of thermal conductivity measurement device is the measurement method. The time required for each measurement was 30 second, which means every second a sample was taken. Then the final minimum squares values were reported by matching the data with exponential integral function and nonlinear least. Therefore, the final report was very accurate. The description of the full features of this device is attached. A constant temperature rotary water system was used to control the temperature at different ranges during the measurement. Each of the reported values in this project was repeated five times for more accuracy.

4. RESULTS AND DISCUSSION

4.1. Description of variables

The variables studied in this paper are concentration and temperature. The effects of these two variables on water and ethanol fluids were investigated and reported.

4.2. Examine Fluid Thermal Conductivity Diagrams

Investigation of thermal conductivity graphs in terms of particle volume fraction in the temperature range of 25-45 °C.

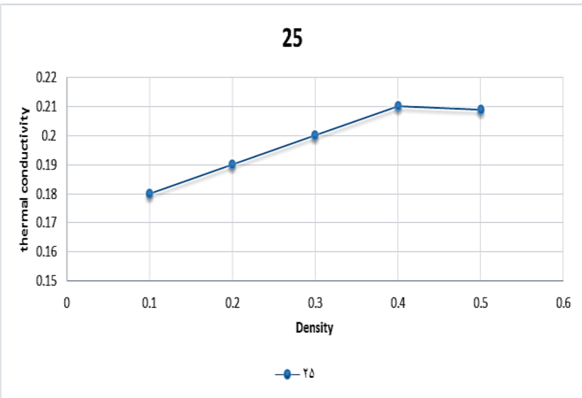

Fig. 4. Thermal conductivity in terms of particle volume fraction for ethanol nano fluid at 25°C.

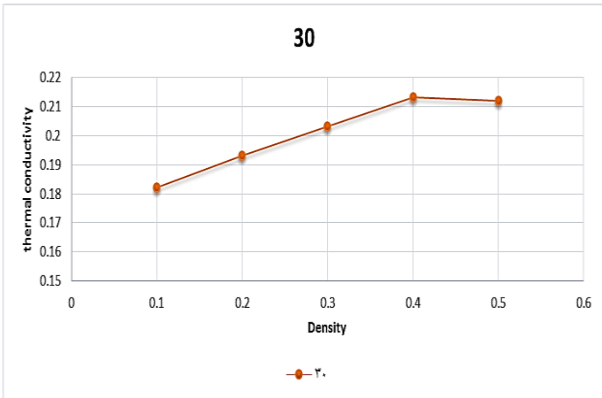

Fig. 5. Thermal conductivity in terms of particle volume fraction for nano-ethanol at 30°C.

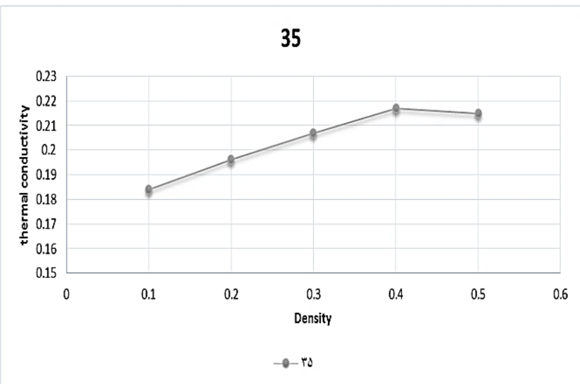

Fig. 6. Thermal conductivity in terms of particle volume fraction for ethanol nano fluid at 35°C.

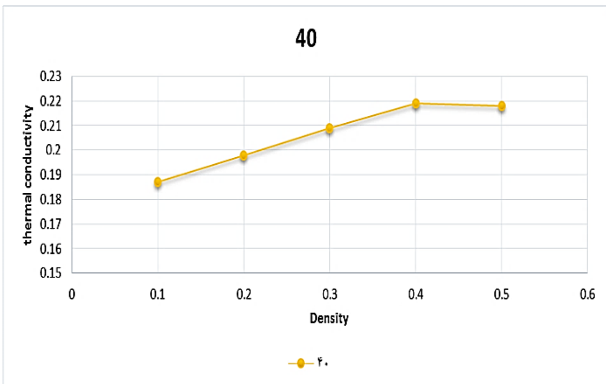

Fig. 7. Thermal conductivity in terms of particle volume fraction for ethanol nano fluid at 40°C.

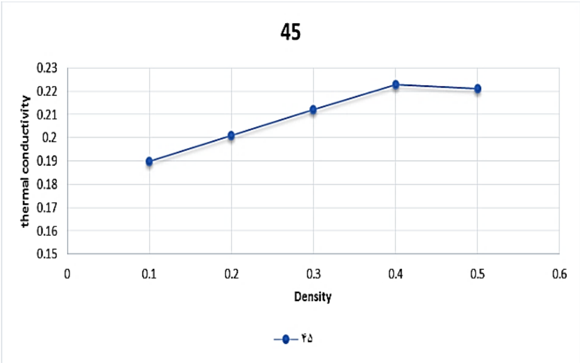

Fig. 8. Thermal conductivity in terms of particle volume fraction for ethanol nano fluid at 45ºC.

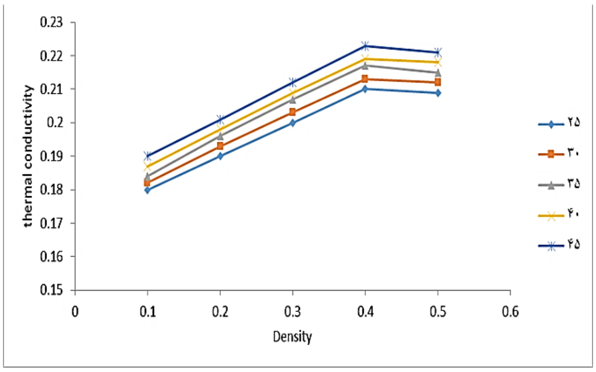

Fig. 9. Comparison of thermal conductivity results in terms of particle volume fraction for nano-fluid ethanol 25-45 ºC.

Figure (9) shows the thermal conductivity curve of the aluminum isopropylate nanoparticles on the ethanol base fluid, in which the thermal conductivity is measured in terms of particle concentration at the temperatures tested. As can be seen from the graph, our optimum concentration for ethanol was 0.4 and it was observed that the highest thermal conductivity was at the concentration of 0.4 and the temperature of 45 °C. Figure (15) is the thermal conductivity curve of aluminum nanoparticles on a water-based fluid in which the thermal conductivity is measured in terms of particle concentration at the temperatures tested. As shown in the diagram, our optimum concentration of water is 0.4 and it was observed that the highest thermal conductivity was at the concentration of 0.4 and the temperature of 45 °C.

As expected, the thermal conductivity of our nanofluids increased with increasing concentration, but the relationship between thermal conductivity and the concentration of our nanoparticles is linear and follows the Brinkman equation.

Investigation of viscosity graphs in terms of particle volume fraction in the temperature range of 25-45 °C.

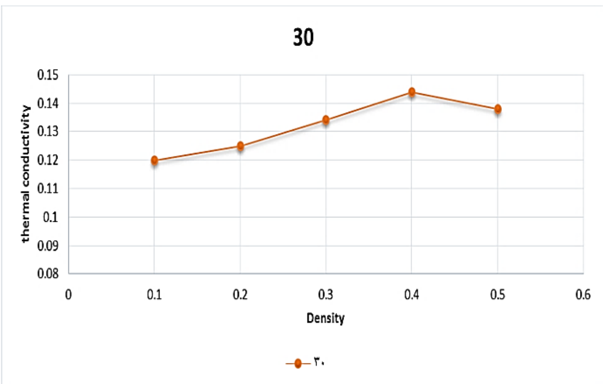

Fig. 10. Thermal conductivity in terms of particle volume fraction for water nanofluid at 25 ºC

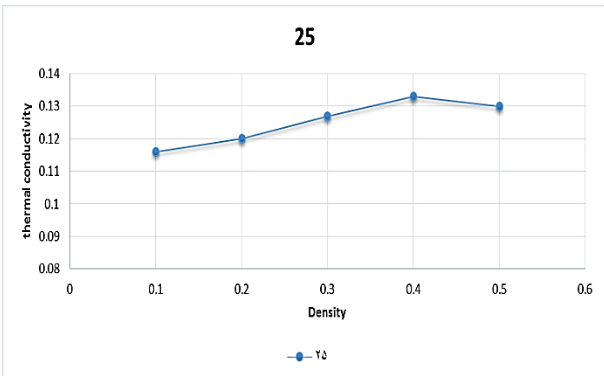

Fig. 11. Thermal conductivity in terms of particle volume fraction for water nanofluid at 30 ºC

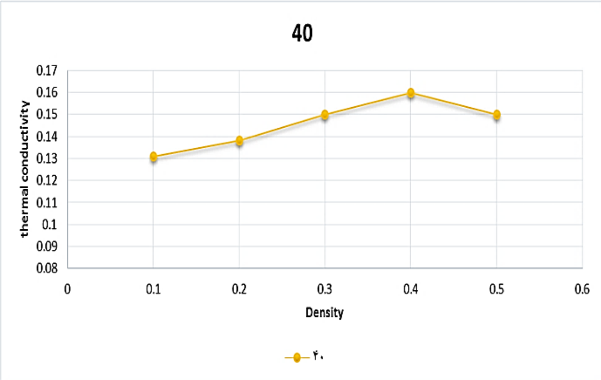

Fig. 12. Thermal conductivity in terms of particle volume fraction for water nanofluid at 35 °C.

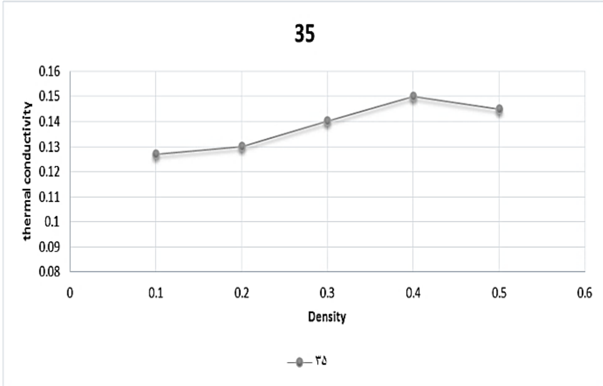

Fig. 13. Thermal conductivity in terms of particle volume fraction for water nanofluid at 40 °C.

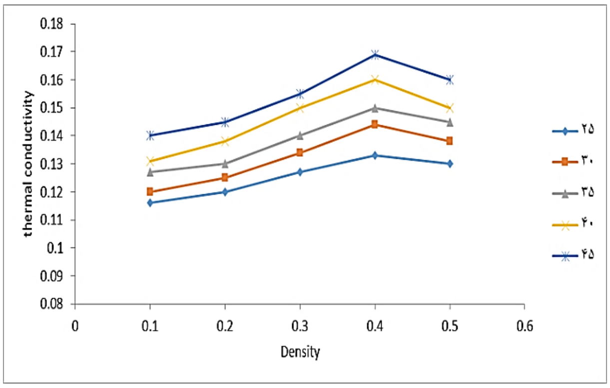

Fig. 14. Thermal conductivity in terms of particle volume fraction for nanofluidic water at 45 °C.

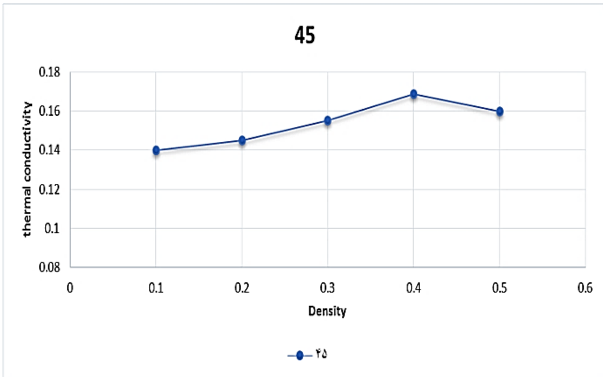

Fig. 15. Comparison of thermal conductivity results in terms of particle volume fraction for water nanofluid at 25-45 °C.

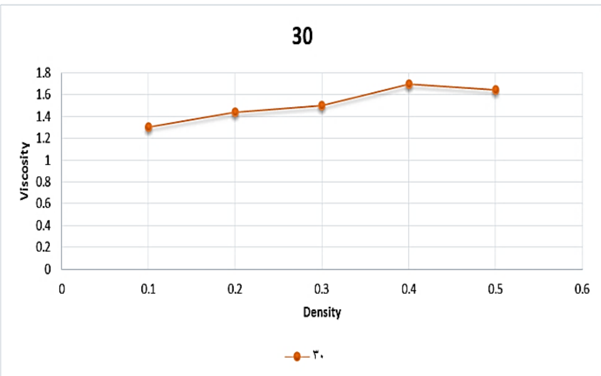

Fig. 16. Viscosity by particle volume fraction for ethanol nanofluid at 25 °C.

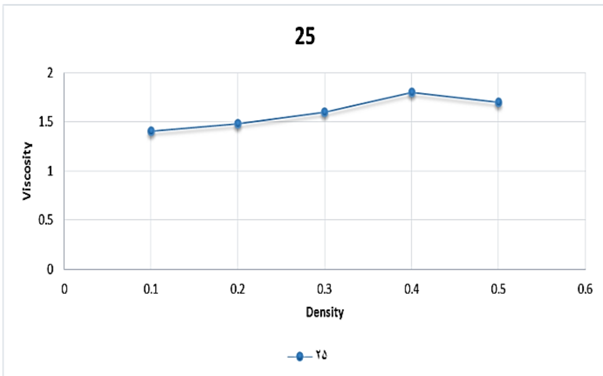

Fig. 17. Viscosity by volume fraction for ethanol nano fluid at 30 °C.

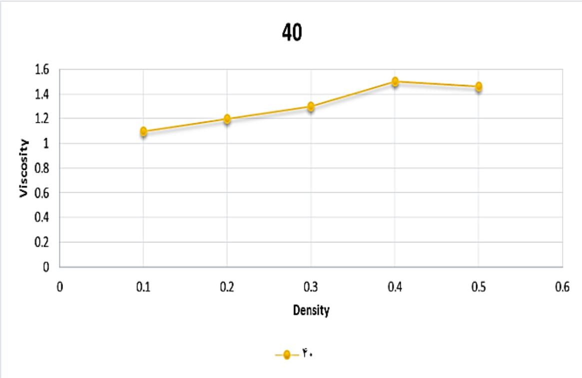

Fig. 18. Viscosity by particle volume fraction for ethanol nanofluid at 35 ºC.

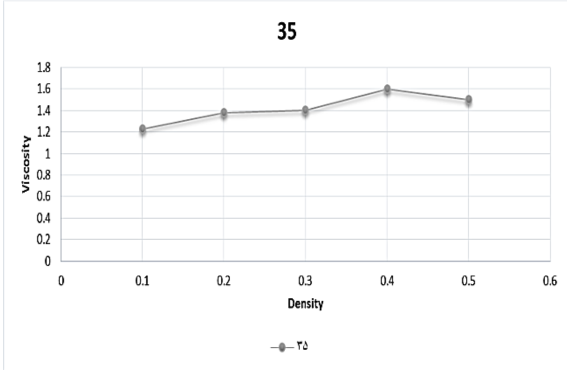

Fig. 19. Viscosity by particle volume fraction for ethanol nanofluid at 40 ºC.

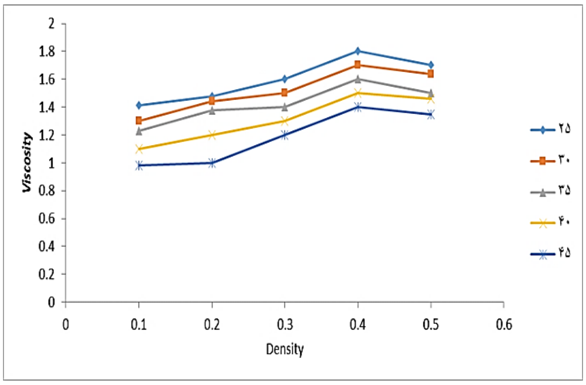

Fig. 20. Viscosity by volume fraction for ethanol nano fluid at 45 ºC.

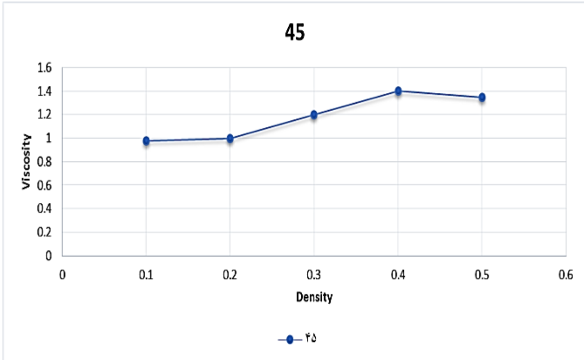

Fig. 21. Comparison of viscosity results in terms of particle volume fraction for nano-ethanol at 25-45 °C.

Figure (21) is a viscosity curve of aluminum isopropylate nanoparticles on an ethanol base fluid in which the viscosity is measured in terms of particle concentration at the temperatures tested. As can be seen in the figure (21), the optimum concentration for ethanol was 0.4 and it was observed that the highest viscosity was at the concentration of 0.4 and temperature 25 °C.

Figure (27)is a viscosity curve of aluminum nanoparticles on a water-based fluid in which the viscosity is measured in terms of particle concentration at the temperatures tested. As can be seen from the diagram for this fluid, our optimum concentration is 0.4 and it was observed that the highest viscosity was at the concentration of 0.4 and the temperature of 25 °C. As expected, it was observed that viscosity increases with increasing concentration, although the relationship between viscosity and concentration is nonlinear, although at low concentrations this relationship can be linear according to Einstein but increases with increasing concentration as the concentration is nonlinear (6). Our experimental data are consistent with Einstein's formula for viscosity. The results of the study are in line with the results of .03.

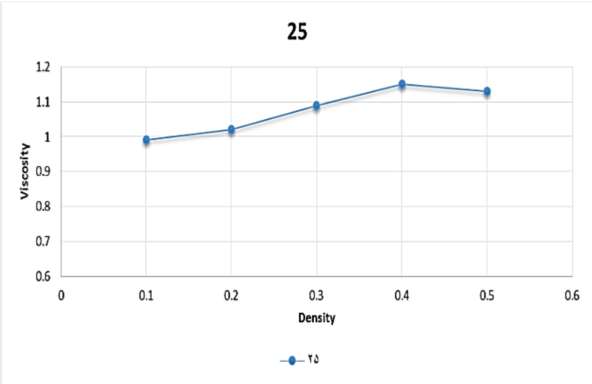

Fig. 22. Viscosity by particle volume fraction for water nanofluid at 25 ºC.

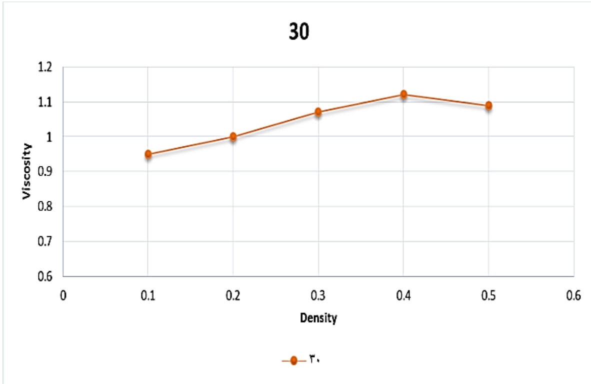

Fig. 23. Viscosity by volume fraction for water nanofluid at 30 ºC.

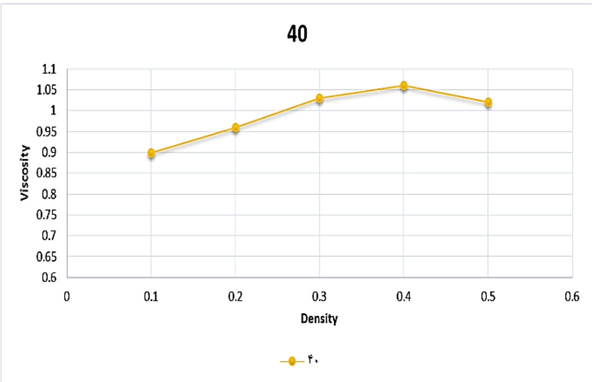

Fig. 24. Chart viscosity in terms of particle volume fraction for water nanofluid at 35 ºC.

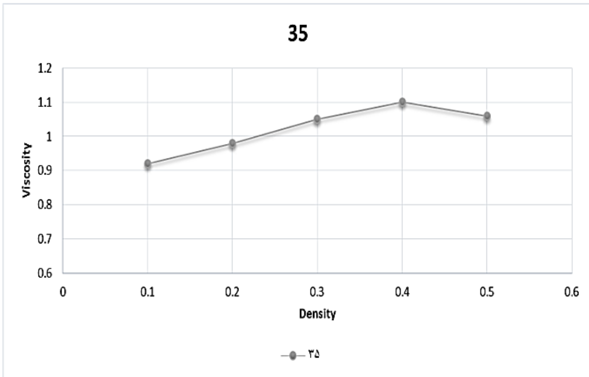

Fig. 25. Viscosity by volume fraction for water nanofluid at 40 ºC.

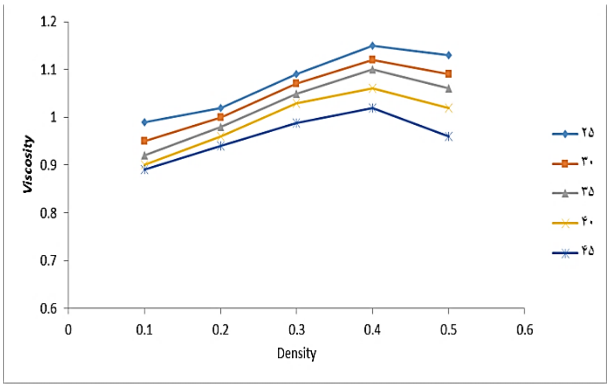

Fig. 26. Particle volume viscosity for water nanofluid at 45 ºC

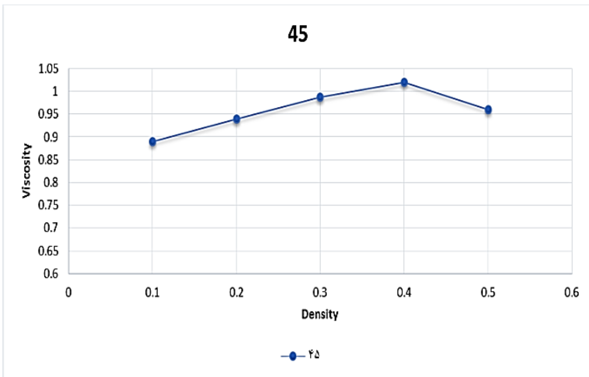

Fig. 27. Comparison of viscosity results in terms of particle volume fraction for nanofluidic water at 25-45 ºC.

5. CONCLUTION

Experimental studies of the thermal conductivity and viscosity of water-Al_2O_3 and ethanol-aluminum triisopropylate nanofluids showed that the nano fluids exhibit higher thermal conductivity than base fluids. Even though, the concentrations of nanoparticles are very low, the thermal conductivity of nanofluids causes a significant increase in the volume of nanoparticles. The nanofluids were prepared by combining the Al_2O_3 nanoparticles with aluminum triisopropylate and then dispersed in the base fluids by an ultrasonic device. In this study, Al_2O_3 and aluminuim triisopropylate with a particle thickness of about 2 nm were used at different bulk concentrations and different temperatures. Thermal conductivity and viscosity of nanofluids were measured and showed that the thermal conductivity and viscosity of nanofluids were increased with growing of the concentration of nanoparticles and the temperature increased with the decrease of viscosity and increase of thermal conductivity. The present study shows that the viscosity of the nanofluid was reduced to a lower amount in the absence of nanoparticles. In the other words, the presence of nanoparticles in the studied fluids decreased the viscosity of the fluids compared to the viscosity of the same fluids in the base state without the nanoparticles. Though, when the concentration reaches to optimum value and passes through the optimum level, then the nanoparticles do not decrease the viscosity, which is not desirable and optimal. So, in this study the optimum concentrations were considered which are different to the type of fluid. Ideal nanofluids should not only have high thermal conductivity but also have low viscosity. The nanofluids studied in this project exhibited Newtonian behavior in the particular range of volume fractions and temperatures. The investigated viscosity and thermal conductivity of the nanofluids is increased with growing of volume fraction of particles. So it can be said that, the higher the fluid content of the nanoparticle causes the higher the viscosity of the nanoparticle fluid. The figures show that the increase in viscosity is significantly higher than in thermal conductivity. As observed in the figures, the viscosity increased with increasing the W/V % of nanoparticles. So, this increased intensity of viscosity increased with the raise of nanoparticle volume percentage than the thermal conductivity of our nanofluids. Thus, it was observed that the thermal conductivity of nanofluids increased linearly with the increasing volume fraction of nanoparticles. In this study, we tried to investigate the most parameters that influence the size of thermal conductivity and nanofluid viscosity. Some of these parameters, including the effect of temperature, different concentrations of nanofluids and the physical shape of the nanoparticles need to be tested. On the other hand, the stability of nanofluids also has many variables that all the parameters mentioned in the section of thermal conductivity and viscosity can be considered in nanofluid stability. Furthermore, the stability of nanofluids depends on different factors and parameters such as Brownian motion of nanoparticles, formation of nanoparticles around the nanoparticles, formation and formation of nanoparticle clusters, nature of heat transfer in nanoparticles, and local displacement in nanofluids due to the movement of nanoparticles. these investigations of mechanisms will make us more aware of the process of changes in nanofluids.

6. ACKNOWLEDGMENT

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