EXPERIMENTAL INVESTIGATION OF THERMAL CONDUCTIVITY OF HYBRID NANOFLUID MWCNTs-Al_2O_3/POE

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F1 - Princípios – Termodinâmica, Mecânica dos Fluidos e Transferência de Calor

Abstract. *In this experimental study the thermal conductivity of a new hybrid nanofluid formulated from the addition of nanoparticles of alumina (Al_20_3) and multi walled carbon nanotubes (MWCNTs) in POE oil was investigated. Nanoparticles of Al_20_3 and MWCNTs were dispersed in POE oil at the mass ratio of 50/50 with gravimetric concentrations of 0.10 g / L, 0.25 g / L, 0.50 g / L and 1.00 g / L. The hybrid nanofluids MWCNTs-Al_2O_3/POE weresubjected to ultrasonic sonication processes with immersion probe and rotating magnetic stirring to improve stability. The thermal conductivity was measured at temperatures of 20 °C to 50 °C. The thermal conductivity of the hybrid nanofluid at the concentration of 1.00 g / L was slightly higher than the base fluid (POE oil) throughout the temperature range.*

Keywords: *hybrid nanofluid, Al_20_3, MWCNTs, thermal conductivity.*

1. INTRODUCTION

The Thermal conductivity of the nanoparticles contributes substantially to the efficiency of heat transfer processes in heat exchangers, and for these reasons, it is surely the most extensively addressed topic in new product development and application of nanofluid technology. The concept of "nanofluid" consisting basically of a biphasic mixture containing solid nanoparticles in suspension in the base-fluid (oil lubricant, water, ethylene glycol, refrigerant gas) is able to confer to the conventional thermal fluid high performance of the heat transfer processes.

The first generation of nanofluids, known in the academic world as "nanofluids" or "simple nanofluids", has been the object of intense research in the last decades and has as main characteristic the fact that these materials are constituted from a single type of solid nanoparticle in suspension in a base fluid.

The second generation of nanofluids, called "hybrid nanofluids" is an extension of first generation nanofluids, with the particularity of being characterized by the addition of two or more dispersed dissimilar nanoparticles in a fluid base. (Sajid and Ali, 2018)

The inclusion of more than one type of nanoparticle in the base fluid potentiates the heat transfer of the hybrid nanofluids through the synergistic effects of different solid nanoparticles. In addition, hybrid nanofluid can meet other industry demands: low cost and /or sustainability.

2. MATERIALS AND METHODS

2.1 Materials of the hybrid nanofluid

According to the literature, the nanoparticles most frequently used in the formulation of simple and hybrid nanofluids are single or multiple-walled carbon nanotubes (MWCNTs, SWCNTs), alumina or aluminum oxides (Al_2O_3) and titanium oxides (TiO_2), because they exhibit excellent thermophysical properties.

The multiple-walled carbon nanotubes (MWCNTs) and the alumina (Al_2O_3) nanoparticles used in the formulation of the hybrid nanofluid samples of this research are manufactured in the form of dry nano-powder by Nanostructured & Amorphous Materials and by Sigma-Aldrich, respectively.

The oil POE 160PZ used as the base fluid in the formulation of hybrid nanofluid samples, the subject of this research, has its main application in the lubrication of compressors of refrigeration systems, being compatible with the refrigerating fluids R134a, R404a, R507, R508b, R407c and R410a. (Danfoss, 2015)

2.2 Synthesis of the hybrid nanofluid

The simple and low cost "two-step" method was used for the synthesis of the hybrid nanofluid proposed in the research and has two phases. The first phase comprises only the synthesis of nano-powders of alumina (Al2O3) and carbon nanotubes of walls (MWCNTs). (Hamzah et al, 2017).

Barbosa Júnior (2018) showed the second phase of preparation methods of the hybrid nanofluids MWCNTs-Al_2O_3/POE with the following execution sequence:

1. Measurement of the mass of nano-powders: the amount of mass, for each type of nanoparticle (Al_2O_3 and MWCNTs), corresponding to the concentration in (g/L) of the different nanofluid samples was measured in analytical balance with resolution of 0.0001 g;
2. Measurement of the base fluid volume: the measurement of the 100 ml volume of the base fluid (POE 160PZ oil) was performed with micropipette and graduated becker;
3. Mixing the solid nanoparticles in the base fluid: After inserting the nanoparticles into the base fluid, the nanoparticles (Al_2O_3 and MWCNTs) are mixed in the liquid medium (POE 160PZ oil) with the help of a glass rod;
4. Nanoparticle defragmentation: to attenuate the agglomerations and to improve the stability of the samples, all the nanofluids were sonicated by means of immersion ultrasound with vibration amplitude of 10%, with duration of 60 minutes;
5. Dispersion of the nanoparticles in the base fluid: the final step of nanofluid synthesis was the dispersion of the nanoparticles solids in the liquid medium (base-fluid) by means of a rotating magnetic stirrer, with rotation of 450 rpm and duration of 24 hours.

2.3 Measurement of the thermal conductivity

The thermal conductivity of the hybrid nanofluid samples were measured experimentally using the hot wire transient method. In this method, a heat pulse is applied to a needle and the temperature response is measured in the vicinity of the needle during the heat pulse. (Sajid, M.U. and Ali, H.M, 2018).

The Figure 1 shows the schematic drawing of the experimental bench, adapted from Hamid et al (2018), used in this research to measure the thermal conductivity of the hybrid nanofluid samples, containing: (1) KD2 Pro thermal properties analyzer, (2) Brookfield thermostatic bath model TC-550, (3) Brookfield small sample device SC-13R and (4) PC with software Rheocalc.

The KD2 Pro thermal property analyzer and KS-1 sensor are calibrated with reference standard fluid (glycerine) prior to initiating each measurement of the thermal conductivity of nanofluid as instructed and recommended by the equipment manufacturer.

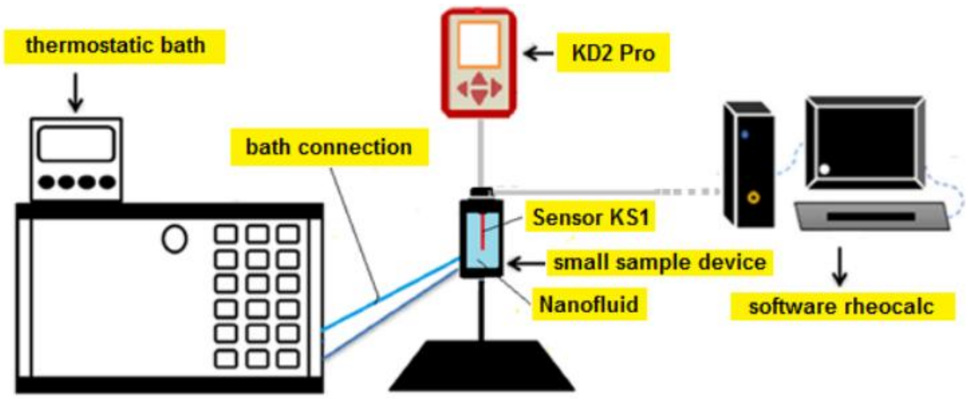

Figure 1. Experimental bench to measure the thermal conductivity of the hybrid nanofluid samples

The temperature range of the test was programmed in the software Rheocalc and the entire operation occurs automatically, the acquisition of the thermal conductivity data being captured in the KD2 Pro datalog. Later the data obtained and stored in the datalog are transferred to a spreadsheet for analysis.

3. RESULTS AND DISCUSSION

Thermal conductivity values of POE oil and hybrid nanofluid with gravimetric concentrations of 0.1; 0.25; 0.5 and 1.0 g / L at different temperatures are shown in Figure 2. According to the figure, the thermal conductivity of each sample of hybrid nanofluid remains practically constant over the entire temperature range.

It is also noted from the analysis of the Figure 2, a tendency of intensification of the thermal conductivity with the increase of the solid nanoparticle concentration in the liquid medium. This trend is consistent with data from most of the researchers found in the literature.

In the test temperature range 10 ⁰C to 50 ⁰C, the thermal conductivity values of the hybrid nanofluids with gravimetric concentrations of 0.1 g / L; 0.25 g / L and 0.5 g / L did not present significant differences compared to the base fluid (POE oil).

In Figure 2 the hybrid nanofluid MWCNTs-Al_2O_3/POE with gravimetric concentrations of 1.00 g / L present higher thermal conductivity than the POE oil and the other nanofluid hybrids tested. The hybrid nanofluid MWCNTs Al_2O_3/POE with gravimetric concentrations of 1.00 g / L also showed maximum thermal conductivity gain of 14.28% in relation to POE oil.

With the automation of the thermal conductivity test without the interference of the operator, the level of reliability and reproducibility of the obtained results was increased. In addition, the thermal conductivity was measured five times at each test temperature in order to obtain more reliability of the thermal conductivity data.

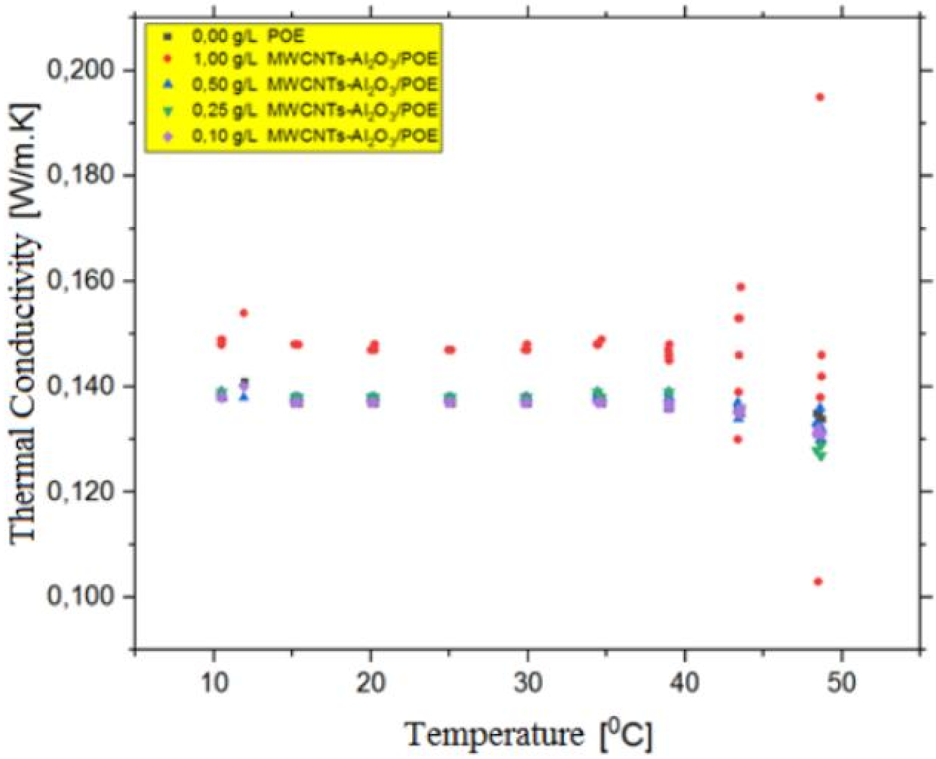

Figure 2. Thermal conductivity of POE oil and hybrid nanofluid MWCNTs-Al_2O_3/POE.

According to Sajid and Ali (2018) there are different theories to explain the mechanism of anomalous enhancement of thermal conductivity in hybrid nanofluids.

However, precise mechanisms of thermal conductivity improvement are not yet established. The main explanations given by researchers for enhancement in thermal conductivity include:

- Brownian motion and micro-convection of nanoparticles and base fluid;
- The presence of nanoparticles in various regions of suspension and contact between different layers of fluid;
- Crystalline nature and functionalized structure of hybrid nanoparticles acting as extended surfaces within base fluid;
- Optimum sonication time producing homogenous mixture which in turn leading to thermal conductivity enhancement;
- Nano-additives clustering and fluid layer formation adjacent to nano-additives surface. This clustering is dependent on concentration of nanoparticles, shape and size of nano-additives;
- Increased kinetic energy due to higher rate of collision between molecules at elevated temperature. Reduction of thermal resistance between nanoparticles and base fluid by increasing temperature;
- More interaction between nanoparticles and base fluid, thus leading to an increase in chain formation of nanoparticles at high concentrations;
- The percolation effect caused by high concentration, reducing particle to particle distance and increasing lattice vibrational frequency;
- Presence of hybrid nanoparticles causing increased diffusive heat conduction;
- Increased electrostatic repulsive forces.

4. CONCLUSIONS

The literature review allowed to expand the theoretical knowledge associated with hybrid nanofluids. Considering the results of the experimental study of the hybrid nanofluid MWCNTs-Al2O3/POE, it was possible to establish the following conclusions:

I. The preparation of hybrid nanofluid proposed by the "two-step" method using ultrasonic sonication techniques of immersion and magnetic stirring of suspended particles gave good stability characteristics, retarding agglomeration and reduced sedimentation of the nanoparticles in the base fluid;

II. The automatic measurement of thermal conductivity allowed the reproduction of the tests in the same way for all hybrid nanofluid samples, without the interference of the operator, allowing to increase the level of reliability and reproducibility of the obtained results;

III. In the temperature range 10 0C to 45 0C, the thermal conductivity of each sample of nanofluid practically remained practically constant. The normal behavior, according to the literature, would be the increase of thermal conductivity with increasing temperature;

IV. It is inferred from the tested nanofluids a tendency to intensify the thermal conductivity with increasing concentration of solid nanoparticles in base fluid. This trend is also consistent with the literature data;

V. V. The thermal conductivity of the hybrid nanofluid with a concentration of 1.00 g / L, in the stable temperature range of 10 ° C to 45 ° C, was slightly higher than the base fluid values at the same temperatures. In terms of thermal conductivity, this was the best performance among all hybrid nanofluids tested;

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