Zno a Nanofluid in Radiator to increase thermal conductivity based on ethylene glycol

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ABSTRACT

This paper presents study of effective thermal conductivity of ZnO nanofluid. . The nanofluid was prepared by dispersing Zno nanoparticles in ethylene glycol. Ethylene glycol based nanofluid containing ZnO nanoparticle at various temperatures was examined for the investigation. The thermal conductivity of nanofluids is experimentally measured with conventional method and it is found that the thermal conductivity of nanofluids increase with the nanoparticle volume concentration and temperature. The proposed models show reasonably excellent agreement with our experimental results.

Keyword: - *Nanofluid, particle, radiator,thermal conductivity*

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1. INTRODUCTION

A nanofluid is a fluid containing nanometre-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil.

Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger in grinding, machining and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. Knowledge of the rheological behaviour of nanofluids is found to be very critical in deciding their suitability for convective heat transfer applications

Nanofluids are fluids containing nanoparticles (nanometer-sized particles of metals, oxides, carbides, nitrides, or nanotubes). Nanofluids exhibit enhanced thermal properties, amongst them; higher thermal conductivity and heat transfer coefficients compared to the base fluid. Simulations of the cooling system of a large truck engine indicate that replacement of the conventional engine coolant (ethylene glycol-water mixture) by a nanofluid would provide considerable benefits by removing more heat from the engine.

2. LITERATURE REVIEW

Das et al. [1] investigated the increase of thermal conductivity with temperature for nano fluids with water as base fluid and particles of Al_2O_3 or CuO as suspension material. It has been observed that the enhancement is considerably increased for nanofluids with Al_2O_3 as well.

Wang et al. [2] reviewed summarizes recent research on fluid flow and heat transfer characteristics of nanofluids in forced and free convection flows and identifies opportunities for future research. Among the nanoparticle, alumina (Al_2O3) is one of the most common and inexpensive nanoparticle used by many researchers in their experimental investigations.

Nasiruddin et al. [3] presented heat transfer enhancement in a heat exchanger tube by installing a baffle. The effect of baffle size and orientation on the heat transfer enhancement was studied in detail. Three different baffle arrangements were considered. The results show that for the vertical baffle, an increase in the baffle height causes a substantial increase in the Nusselt number. For the inclined baffles, the results show that the Nusselt number enhancement is almost independent of the baffle inclination angle, with the maximum and average Nusselt number 120% and 70% higher than that for the case of no baffle, respectively. Results suggest that a significant heat transfer enhancement in a heat exchanger tube can be achieved by introducing a baffle inclined towards the downstream side, with the minimum pressure loss.

Peyghambarzadeh et al. [4,5] conducted experiment on forced convective heat transfer in a water based nanofluids, has been experimentally compared to that of pure water in an automobile radiator with different concentrations of nanofluids. Additionally, the effect of fluid inlet temperature to the radiator on heat transfer coefficient has also been analyzed by varying the temperature. Results demonstrate that increasing the fluid circulating rate can improve the heat transfer performance while the fluid inlet temperature to the radiator has trivial effects. Meanwhile, application of nanofluid with low concentrations can enhance heat transfer efficiency up to 45% in comparison with pure water.

Chandrasekar et al. [6] Experimental investigations on thermophysical properties and forced convective heat transfer characteristics of various nanofluids are reviewed and the mechanisms proposed for the alteration in their values or characteristics due to the addition of nanoparticles are summarized in this review.

Pang et al. [7] studied the vehicles cooling system extensively numerically and experimentally. The research covers many individual topics which include numerical modeling of engine cooling system, under hood air flow, heat transfer at water jacket, heat transfer at radiator and coolants.

3. PREPRATION OF NANO FLUID

Two-Step Method. Two-step method is the most widely used method for preparing nanofluids. Nanoparticles, nanofibers, nanotubes, or other nanomaterials used in this method are first produced as dry powders by chemical or physical methods. Then, the nanosized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing, and ball milling. Two-step method is the most economic method to produce nanofluids in large scale, because nanopowder synthesis techniques have already been scaled up to industrial production levels. Due to the high surface area and surface activity, nanoparticles have the tendency to aggregate. The important technique to enhance the stability of nanoparticles in fluids is the use of surfactants. However, the functionality of the surfactants under high temperature is also a big concern, especially for high-temperature applications. ZnO-EG nanofluid was prepared using two-step methods. The preparation of nanofluid must ensure proper dispersion of nanoparticles in the base fluid which includes convenient mechanism such as addition of surfactants or control of pH value to attain the stability of the suspension against sedimentation of nanoparticles. In the current experiment, three effective ways were used to stabilize the suspension. These methods are: use of ultrasonic processor, addition of surfactants and changing the pH value of the nanofluid. Ethylene glycol was used as the base fluid.

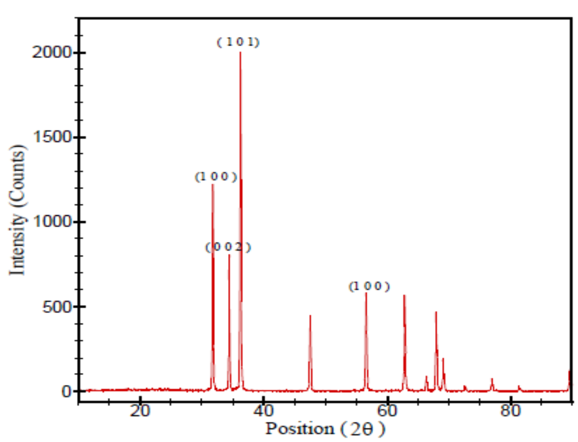

Fig. 3.1. TEM image and XRD patterns of ZnO nanoparticles

3.1 Thermal conductivity of nanofluid

3.1.1 *Thermal conductivity measurement*

The measurement of thermal conductivity is one of the significant aspects to analyze the thermal properties of ZnO- EG nanofluid.

Hamilton–Crosser (H–C) model was one of the basic models to predict the thermal conductivity of solid– liquid mixtures, K_{eff}. This model is applied to estimate thermal conductivity of the mixtures for which the ratio of solid phase thermal conductivity to that of liquid phase is greater than 100. The H-C equation is:

$$\frac{k_{eff}}{k_f} = \frac{k_p + (n-1)k_f + (n-1)\varphi(k_p - k_f)}{k_p + (n-1)k_f - \varphi(k_p - k_f)}$$

where k_p and are thermal conductivity and volume
fraction of nanoparticles, respectively and k_f is the thermal conductivity of base fluid. *n* is the empirical shape factor given by:

$$n = \frac{3}{\psi}$$

where ψ is the particle sphericity defined by the ratio of the surface area of a sphere with a volume equal to that of the particle, to the surface area of the particles. For spherical particles the value of *n* is 3.

Lu and Lin also proposed another model to predict the thermal conductivity of nanofluids as below for spherical particles

$$\frac{k_{eff}}{k_f} = 1 + 2.25\varphi + 2.27\varphi^2$$

Among measuring different thermophysical properties, thermal conductivity is generally regarded as the most difficult property to be measured due to some errors associated during the measuring operation. In the current study, the thermal conductivity of ZnO-EG nanofluids with different solid volume fraction was measured by using a KD2 Pro (decagon Inc.) thermal property analyzer with a maximum error of about 5%. The “thermal conductivity ratio” is defined as the ratio of nanofluid thermal conductivity to the water thermal conductivity.

3.2.2 Effect of temperature on thermal conductivity

The effect of temperature on enhancement of thermal conductivity of nanofluids was also studied by measuring the thermal conductivity of nanofluids with a wide range of solid volume fractions from 0.0625% to 5% at different temperatures ranging from 24.7 to 50°C . Thermal conductivity is measured after placing the nanofluid inside a temperature bath with sufficient isolation to prevent heat dissipation during the experiment.

As the temperature increases, serious increases in thermal conductivity are evident for all solid volume fractions, especially for high concentrations. Significant increase of relative thermal conductivity with respect to increasing temperature indicates that thermal conductivity depends strongly on temperature. This behavior is consistent with the previously reported results for nanofluids.

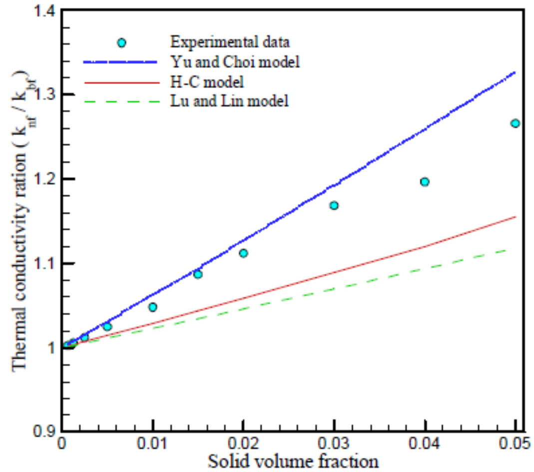

Fig. 2. Comparison between theoretical models and experimental data

This is due to higher temperatures of the fluid that the nanoparticles agglomeration would break more easily and the nano-size particles will disperse more uniformly inside the water. Indeed, from a theoretical (i.e. kinetics) view-point, with the increment of the nanofluid's bulk temperature (*T*), molecules and nanoparticles are moreactive and are able to transfer more energy from one location to another per unit of time.

3.2.3 *Proposed model:*

In this study, three experimental correlations have been proposed for thermal conductivity of ZnO-EG nanofluid (18nm) based on the experimental data as follow:

Experimental model 1:

$$\frac{k_{nf}}{k_{bf}} = 0.24859\ T^{2.504\varphi^{0.7974}} + 0.7492$$

$$R^2 = 0.99$$

Experimental model 2:

$$\frac{k_{nf}}{k_{bf}} = \frac{(46.59 + T)}{(46.098 - 135.23\varphi)} - 0.02187\ T$$

$$R^2 = 0.99$$

3.2.4 *Deviation analysis of thermal conductivity:*

As to the margin of deviation between thermal

Thermal conductivity ratio a) at different proposed correlations at

a) 5% , b) 1% temperature verses solid volume fraction b) for various concentration with respect to temperature

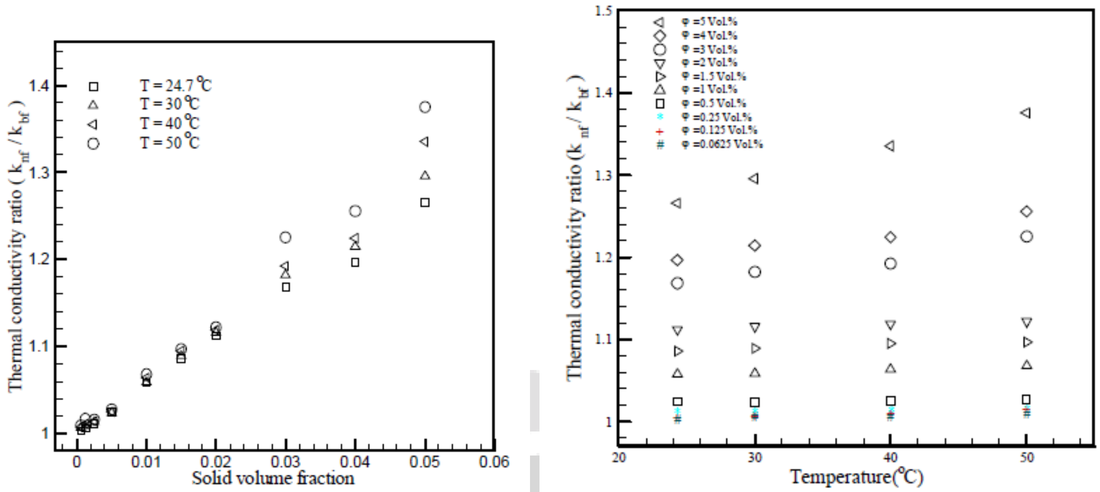

Fig. 3. Thermal conductivity ratio a) at different proposed correlationsat a) 5% , b) 1% temperature versus solid volume fraction b) for various concentration with respect to temperature

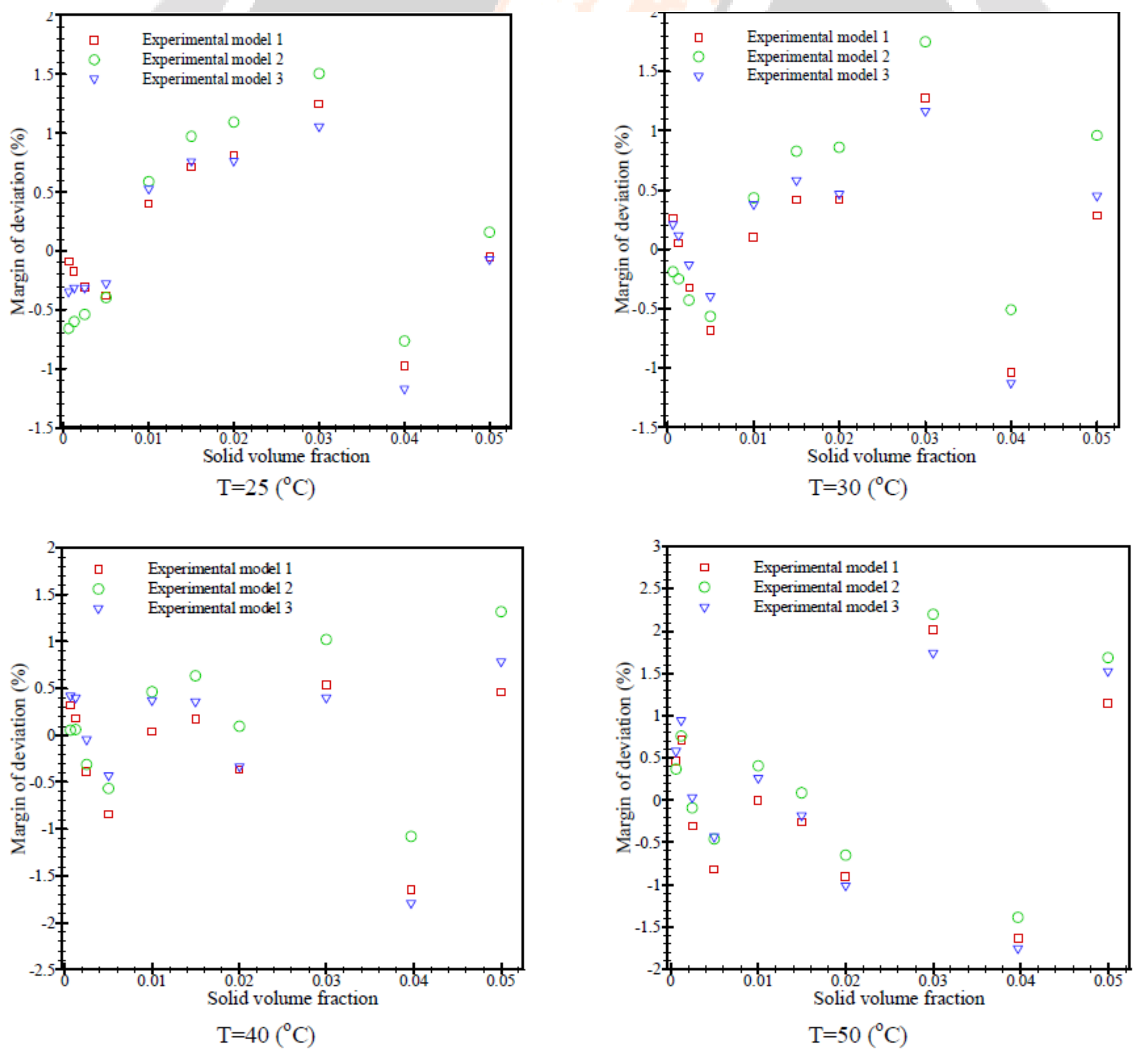

Fig.4. Margin of deviation for different temperatures

3.2.5 Sensitivity analysis:

A sensitivity analysis is conducted based on Ref. [36] for three proposed models. The sensitivity analysis shows how much the thermal conductivity is sensitive to the changes in particle loading at a given temperature. In the current study, the sensitivity analysis is performed by considering 10% change in particle loading. For example, consider the volume fraction of 2% and temperature of 30 ˚C. The sensitivity in this temperature can be calculated as following:

Sensitivity %

$$\frac{k(\ \ 2.2\%)\ k(\ \ 2\%)}{k(\ \ 2\%)}100$$

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