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Short Communication

Thermal Conductivity Enhancement in Zinc Oxide-Water Based Nanofluid System

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Abstract

Through this research article, we report our primary work of Zinc Oxide-Water (ZnO-H_2O) based nanofluid indicating increase in heat transfer as a function of concentration of ZnO nanoparticles. The main objective of present is to analyze effect of nanoparticles concentration on thermal conductivity of nanofluid. The enhancement in heat transfer of nanofluid was observed with concentration, but in irregular manner. The irregularity in enhancement of thermal conductivity is discussed using orthokinetic aggregation effect. The thermal conductivity ratio of ZnO-H_2O based nanofluid suggest that as-prepared nanofluids exhibits good heat transfer characteristics and found suitable for heat exchanger application.

Keywords: Zinc Oxide, Nanofluid, Thermal conductivity.

Introduction

A nanofluid is an adulterate mixture of nanometer-size particles dispersed in a base fluid like water. The many reports presents in literature survey of materials science shows that heat transfer is mainly dominated due to concentration of nanoparticles[1,2]. Masuda et al studied the heat thermal performance of γ-Al_2O_3, SiO_2 and TiO_2 fine nanoparticles based nanofluids. In this investigation, 4% increase in thermal conductivity for the concentration value of 1 vol.% [3]. Li et al[4] and Timofeeva et al[5] studied the heat transfer performance of Al_2O_3 based nanofluid at various temperatures in aqueous medium and ethylene glycol with volume concentration. The 5% of enhancement is observed for 0.04 M concentration. Xie et al reported the thermal conductivity increase for various base fluids like aqueous media and ethylene glycol. The 32% and 30% enhancement is observed in case of water and ethylene glycol, respectively[6]. Hwang et al witnessed 4% hike in heat transfer rate for concentration value 1 vol.%[7]. In the present work, we studied the increase of thermal conductivity for ZnO-H_2O based nanofluids with the concentration of nanoparticles. The thermal conductivity ratio was found to be greater than unity, which reflects prepared nanofluids suitable for heat exchanger application.

Materials and Methods

Analytical grade chemicals were used for the synthesis of ZnO nanoparticles. ZnO nanoparticles were derived using chemical route method, reported previously[8]. As-synthesized ZnO nanoparticles were utilized for the nanofluids preparation. The two-step method was employed for preparation of nanofluid. In this method, ZnO nanopartilces were forcefully dispersed in base fluid (Water) using strong probe sonication for 5 h. The Hot-wire method technique was used to determine thermal conductivity of nanofluids. The structural purity of ZnO nanoparticles was checked through X-Ray Diffraction (XRD) analysis. Similarly, morphology of dispersed nanoparticles was analyzed using scanning electron microscopy (SEM). For both analyses, ZnO nanoparticles were recovered by using slow evaporation method.

Results and Discussion

Figure-1(a) shows XRD pattern of ZnO nanoparticles used for dispersion in base fluid (Water). The peak position of diffraction peak found in agreement with PDF card no. 01-075-1533. No impurity peaks appears in XRD pattern, which reflects the structural purity of ZnO nanoparticles. The classical Debye-Scherrer formula was used for the estimation of particle size, which was found nearly 21.3 nm[9]. The estimated crystallite size shows deviation in case of SEM analysis. This may be due to agglomeration of nanoparticles, during slow evaporation. Figure-2 represents the variation of thermal conductivity with temperature as well as concentration of ZnO nanoparticles. The thermal conductivity of ZnO-H_2O nanofluid found superior than base fluid. Similarly, thermal conductivity increases linearly with temperature for all samples (0.01-0.05 M). The irregularity in enhancement is observed. This may be attributed to orthokinetic aggregation effect. It is very well known and accepted principle that aggregation kinetics changes radically due to thermal vibration. Thus, the irregularity in increase of thermal conductivity is attributed to orthokinetic aggregation effect[10].

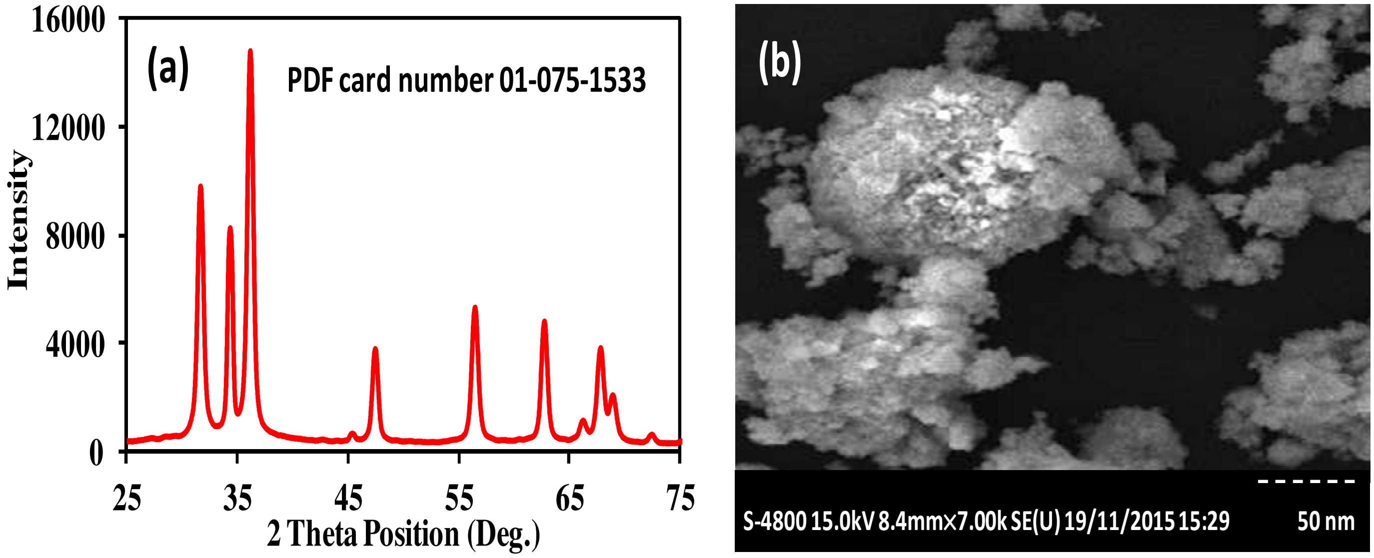

Figure-1
(a) XRD and (b) SEM image of ZnO nanoparticles.

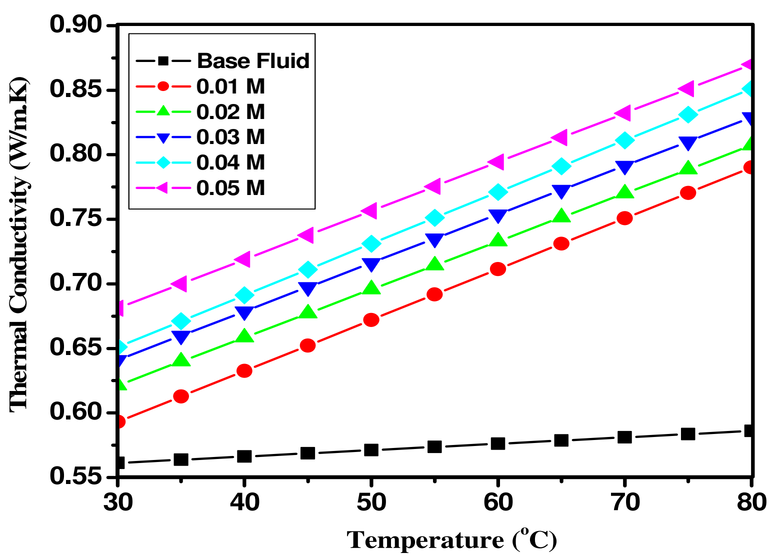

Figure-2
Variation of thermal conductivity with temperature as well as concentration of ZnO nanoparticles

The heat transfer rate is mainly depends on thermal conductivity ratio. So, its estimation is very much necessary in this work. The thermal conductivity ratio (k_{ratio}) is computed using the relation (Equation-1)

$$k_{ratio} = \frac{k_{nanofluid}}{k_{basefluid}} \quad (1)$$

Where: $k_{nanofluid}$ and $k_{basefluid}$ is thermal conductivity of nanofluids and base fluid respectively. From Table-1, it is clearly observed that thermal conductivity ratio greater than unity and increases with varying concentration. This type of nanofluids is fit for heat exchanger application, where heat transfer rate play crucial role.

Conclusion

In present work, ZnO-H_2O based nanofluid system prepared successfully by using two step method. The thermal conductivity increases as a function of ZnO nanoparticles concentration. The irregularity in thermal conductivity is attributed to orthokinetic aggregation effect. The thermal conductivity ratio is greater than unity, which shows that samples are suitable for heat exchanger application.

Table-1
Thermal conductivity ratio data of ZnO/H_2O nanofluids

Temperature (°C)	0.01 M	0.02 M	0.03 M	0.04 M	0.05 M
30	1.0570	1.1070	1.1423	1.1601	1.2134
40	1.1172	1.1630	1.1986	1.2205	1.2695
50	1.1764	1.2179	1.2540	1.2799	1.3245
60	1.2346	1.2719	1.3083	1.3382	1.3786
70	1.2918	1.3250	1.3618	1.3955	1.4318
80	1.3480	1.3771	1.4143	1.4518	1.4841

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