International Journal of Heat and Mass Transfer 115 (2017) 630–646

Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ijhmt

Review

Factors affecting the performance of hybrid nanofluids: A comprehensive review

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ARTICLE INFO

Article history:
Received 17 January 2017
Received in revised form 4 July 2017
Accepted 4 July 2017

Keywords:
Hybrid nanofluid
Thermophysical properties
Heat transfer enhancement

ABSTRACT

Hybrid nanofluids have proven its favorable impact in terms of thermophysical properties, heat transfer rate and stability. Many distinctive features of hybrid nanofluids offer an astonishing potential for many heat transfer applications. In this paper, we summarized the factors affecting the performance of hybrid nanofluid in enhancing the thermal performance of heat transfer systems. The conclusions and important summaries were also presented according to the data collected.

Contents

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http://dx.doi.org/10.1016/j.ijheatmasstransfer.2017.07.021
0017-9310/

1. Introduction

For years, many techniques and methods were implemented to enhance heat transfer performances for achieving a maximum level of thermal efficiency. Numerous efforts and studies were devoted to the development of heat transfer improvisation. However, due to wide range and complexity of certain heat transfer applications, a number of high performance thermal systems for heat transfer enhancement were established. Thus, heat transfer performance achieved more growth and stability. In addition, heat transfer capabilities normally depend on the contributions from the thermal conductivity, viscosity, specific heat and density of working fluid or material. These thermal properties are even affected qualitatively by the action of heat transfer processes.

One of the heat transfer development is the dispersion of the nanoparticles in a base fluid, known as nanofluids [1–5]. Michael and Iniyan [6] observed that the nanofluid made a significant enhancement in the thermal performance as compared to water. The thermophysical properties of nanofluid play a significant part on the heat transfer of the system. It produces a promising effect on the thermal efficiency and performance. Most of the preliminary researches have been analyzed on single phase nanoparticle for improving thermal conductivity and heat transfer coefficient of heat exchanging fluid [4,7–10]. Mozaffarian et al. [11] reported that the heat transfer properties of nanofluids were more promising due to the high thermal conductivity of solid nanoparticles, which could be greater than that of conventional heat transfer fluids such as ethylene glycol and water. In addition, most nanoparticles are made of metals, oxides and carbon-based nanotubes (CNT). Numerous studies have been devoted to the development of nanofluid, as the thermal conductivity of the base fluid showed a great difference when the suspension of the nanoparticles was presented. Maxwell [12], investigated the performance of the suspended particles, deduced that the dispersion of nano-sized particles in the base fluid leads to the improvement of the heat transfer. Pazuki et al. [13] introduced nine nanoparticles into the conventional fluids used in heat transfer processes, and these nanofluids have led to the advent which has become widely applicable due to their improved heat transfer properties. They reported that the dispersion of nanoparticles in base fluid provided a favorable impact on the viscosity of a system to a significant degree.

Many experimental studies have been conducted to measure thermal properties of nanofluids especially thermal conductivity, viscosity and other related coefficients. Gunnasegaran et al. [14] extensively experimented the effect of Al_2O_3 nanoparticles concentrations on heat transfer characteristics in Loop Heat Pipe. The alumina nanoparticles mass concentration ranging from 0% to 3% in water. Alumina mass concentrations range in this experiment were considered as operational fluid in loop heat pipe. The results showed positive influence of nanofluid employed as heat pipe working fluid on the system thermal performance. The effect of Alumina nanoparticles dispersed in ethylene-water mixture was conducted experimentally to achieve heat transfer improvement [15]. The alumina nanoparticles were synthesized and homogenized to lengthen the suspension for volume concentration of 0.2%, 0.4% and 0.6%. They observed thermal improvement when the volume concentrations increase. The highest thermal performance was inaugurated with 0.6% volume concentration by 14.6% of increment. Three different nanoparticles (Al_2O_3, CuO and SiO_2) were suspended in water-ethylene glycol mixture with 60:40 ratio by Vajjha and Das [2]. They carried out an experiment for convective heat transfer in the turbulent region. They analyzed on the impact of particle volume concentrations, thermophysical properties and particle size to the development of heat transfer performance. The outputs showed that increment in particle concentration contribute to advancement in heat transfer coefficient. The behavior of nanofluid to enhance the performance of a circular heat pipe has been experimented extensively by Mousa [16]. The nanoparticles used as working fluid was Al_2O_3 – water. The performance of the circular heat pipe was dependent on filling ratio, volume-fraction of nanofluid in base fluid and heat transfer rate. The results indicated that the thermal performance enhancement of heat pipes entrusted with nanofluid addition in base fluid. An experimental correlation was developed to predict the Prandtl number and dimensionless heat transfer rate by Mousa [16] to reduce inaccuracy of the results obtained. Hussein [17] numerically simulated the turbulent flow of nanofluid in circular heat tube. The effect of Reynolds number, volume concentrations, friction factor and Nusselt number were studied. Three types of nanoparticles (Al_2O_3, TiO and SiO_2) were simulated by using Adaptive Neuro-Fuzzy Inference System (ANFIS). The results reveal the increment of Nusselt number with increasing of both volume concentrations and Reynolds number. The increment of Nusselt number proved to influence the thermal performance of the heat tube. Another circular heat pipe experiment was carried out by Chougule et al. [18], they investigated the fully laminar convective heat transfer and friction factor of Carbon nanotube (CNT) in water. The intriguing of this experiment was that the carbon nanotube (CNT) tested with low volume concentrations of 0.15% dispersed in base fluid. The results showed an improvement in terms of Nusselt number by 18% as compared to water.

Thermal conductivity of nanofluids is the main thermal property that is appealing towards the enhancement of thermal performance. 32.4% of increment in thermal performance was obtained in the presence of thermal conductivity of Al_2O_3 nanoparticles in water based with a volume fraction of 4.3% [19]. An improvement of 16.5% was obtained in ethylene glycol based iron (Fe) nanoparticles for a particle loading of 0.3% [20]. Philip and Angayarkanni [21] reviewed the thermal conductivity of the nanofluids contributed to the overall thermal performances in heat transfer. There are several main factors that influenced the thermal conductivity of the nanoparticles, which are effect of concentration, particles size, particle aspect ratio, aggregation, nanoinclusions, additives and temperature. Many researchers developed mathematical correlations in terms of thermal conductivity models [21,22], to improve the accuracy of the experiment and provide promising results. Kumar et al. [23] numerically simulated analysis of flow and thermal field in a thermally driven cavity using nanofluid. They observed the enhancement of the local thermal conductivity of the nanoparticles were due to the motion of particles. They also indicated that thermal conductivity increased when the hydraulic diameter of the nanoparticles was increased. Heat transfer augmentation achieved due to nanofluid estimated numerically by diversifying the Grashof number, volume fraction and shape of nanoparticles. Improvement in thermal conductivity with a decrease in particles size was investigated in Al_2O_3-water nanoflu-