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Review

Up to date review on the synthesis and thermophysical properties of hybrid nanofluids

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A B S T R A C T

Research studies about nanofluids are on the rise owing to the mounting interest and demand for nanofluids as heat transfer fluids in a wide variety of applications in the recent years. This can be noticed from the number of papers published and in particular by journal special issues. To establish the field further, the purpose of this paper is threefold. First, it offers a literature review on hybrid or composite nanofluids, which are prepared either by dispersing different nanoparticles as individual constituents or by dispersing nanocomposite particles in the base fluid, taking 160 papers published from before 1995 to 2017 into account. Second, it offers a contemporary investigation on preparation and thermophysical properties of hybrid nanofluids. Lastly, this review outlines the applications and challenges associated with hybrid nanofluid; which should stimulate further research.

This review also discusses several factors affecting the thermophysical properties; including types of nanoparticles, solid volume fraction, different base fluid, stability, temperature, particle size, shape, pH, sonication, and surfactants. There are many contradictory results found in the literature on the influence of effective parameters on thermophysical properties. It has been observed that the thermophysical properties are affected by the mentioned parameters. This review also reveals that proper characterization of hybrid nanofluids results in more efficient heat transfer fluids compared to single nanoparticle based nanofluid. However, more intense research is needed towards the selection of proper hybrid nanoparticles, their preparation, characterization and long-term stability to exploit their full potential as well as to overcome the barriers in applying these new fluids in industrial scale applications. Both practitioners in companies and academics might find this review useful, as it outlines significant lines of research in the field.

Contents

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1. Introduction

Nanofluids comprise of fluids with nanometric size particles, i.e., nanoparticles. Continuous miniaturization of devices and increasing thermal loads control techniques using extended surfaces such as microchannels and fins have reached their limits. So, managing these thermal loads in the applications of high flux is a challenging issue. Fluids used for heat transfer like water and ethylene glycol have limited capabilities of heat transfer. To enhance the heat transfer abilities of conventional fluids, mill metric sized particles having high thermal conductivity were immersed in them by Ahuja (1975). However, these particles also faced the problem of sedimentation. For solving the sedimentation problem, Choi (Choi and Eastman, 1995) and his co-workers synthesized nanometric sized copper particles. These nanoparticles possess thermal conductivities of the order-of-magnitude nearly three times higher than base fluids. Due to the introduction of the nanoparticles in the base fluids, their heat transfer performance enhances with a significant effect. Nanofluids contains nanoparticles made up of metals with chemical stability such as (Copper, gold, aluminum and iron), oxides (TiO_2, Al_2O_3, SiO_2, CuO and zirconia), nonmetals (single and multi-walled carbon nanotubes, graphene, graphite), nitrides of metals (AlN, SiN), carbides of metals (SiC). The base fluids used are a conductive fluid, such as ethylene glycol or water. However, lubricants, oil, biofluids, polymeric solutions are also employed for preparing the nanofluids. Nanofluids were first coined by Choi (Choi and Eastman, 1995) as engineering colloids of nanoparticles and base fluids. These possess several properties which enable them potentially useful in several areas of heat transfer, including fuel boilers, pharmaceuticals, micro and power electronics, ventilation and air conditioning systems, reactors in power generating plants, cancer treatment therapy, metallurgical operations and hybrid engines (Choi et al., 1995; Elcock, 2007; Hindawi). Besides the enhanced thermal conductivity there are several other factors that led to the increase in the performance of the nanofluids including Brownian motion (Chon and Kihm, 2005) (Krishnamurthy et al., 2006) (Bhattacharya et al., 2004), thermophoresis (Prasher et al., 2005) (Koo and Kleinstreuer, 2004), nanoparticles clustering (Prasher et al., 2006a), and liquid layering on the nanoparticles-liquid interface (Wong and Bhshkar, 2006) (Eastman et al., 2004).

Heat transfer applications involve an enormous amount of heat exchange. Commonly methods used in microelectronics, high speeds devices, and engines with high power are driving factors for increased thermal loads. Advancement in the cooling process is required to control these thermal loads. Conventional methods used to overcome these loads and to increase heat dissipation such as the use of micro fins and channels and extended surfaces etc. have limited access (Webb and Kim, 2005) (Gupta et al., 2009a). Also, heat transfer fluids including water and ethylene glycol contributed well in many heat transfer industrial applications (Gupta et al., 2016) (Gupta et al., 2015), but lower thermal conductivity of the fluids is the main drawback in heat exchanging in these engineered devices. So, to overcome this situation, nanofluids were used by researchers. To get better results, nanoparticles of high thermally conductive materials like metals, metal oxides, and carbon into water; oil and ethylene glycol were used by researchers (Chon and Kihm, 2005) (Bhattacharya et al., 2004) to increase thermal conductivity. The heat transfer fluids to be used must possess less viscosity to prevent pressure loss. Also, density and specific heat must be suitably investigated before using the nanofluids in heat transfer applications.

Recent advances in nanofluids have led to the invention of fluids with more characteristic features. These new type of nanofluids are termed as Hybrid nanofluids. In actual practice, a single material cannot have all the positive characteristics mandatory for a specific purpose. It may be lacking in some of the rheological or thermal properties. A hybrid material combines all physical as well as chemical properties of different constituent metals (Sarkar et al., 2015). Manmade hybrid nanomaterials have extraordinary properties which a single component or material cannot possess. A hybrid nanofluid possesses better properties like as better thermal conductivity compared to individual nanofluids, mechanical resistance, physical strength, chemical stability and so on. This particular feature makes hybrid nanomaterials a special one to use in experiments (Sarkar et al., 2015). In a recent technological era, it is necessary to exchange the various properties of the metals which have forced the existence of these newly developed hybrid nanofluids. Also, because of the synergistic effect, these hybrid nanofluids are predicted to have high thermal conductivity in comparison with the single nanofluids. Possible areas where hybrid nanofluids find severe applications include: Biomedical