STATE OF THE ART RESEARCH ON EXPLOITATION OF NANOFLUIDS AS ADVANCED HEAT TRANSFER FLUIDS

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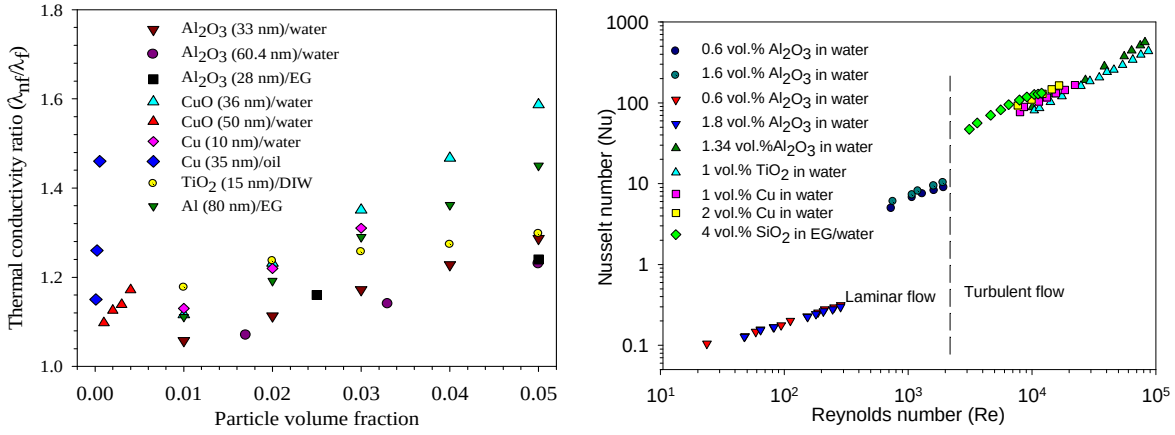
Background: Nanofluids are defined as suspensions of nanometre-sized particles in traditional heat transfer fluids and they represent a new class of heat transfer fluids. Since the inception of nanofluids in Argonne National Laboratory of USA in 1995[1], they have attracted great interest from the researchers worldwide due to their anomalous thermophysical properties and potential applications in numerous important fields such as microelectronics, micro-electromechanical systems, microfluidics, transportation, manufacturing, medical, and HVAC 2-3]. Despite of comprehensive research efforts devoted in the last decade, there remain inconsistencies in results from various research groups and controversy in heat transfer mechanisms of nanofluids [2-3]. However, it is unanimous that nanofluids exhibit considerably higher conductive and convective heat transfer performance compared to their base fluids and these evince their potential as advanced coolants. Thus it is of great importance to critically analyse the state of the art research on these thermal features of nanofluids for their exploitation as advanced heat transfer fluids.

Thermal Conductivity of Nanofluids: Thermal properties, particularly thermal conductivity of fluid play a vital role in the development of energy efficient heat transfer equipment. In order to understand the scale of thermal conductivity enhancement, some key results of the effective thermal conductivity of nanofluids as a function of nanoparticle volume fraction obtained from various research groups are shown in Figure 1(a) [2]. Although the reported data are scattered and inconsistent, nanofluids possess much higher thermal conductivities compared to their base fluids even when the concentrations of suspended nanoparticles are very low (Figure 1(a)). The enhanced thermal conductivity further increases with increasing nanoparticle volume fraction as well as temperature. Similar to thermal conductivity results, nanofluids also showed much higher effective thermal diffusivity than their base fluids and it also increases significantly with the volume fraction of nanoparticles [4]. Besides showing better heat transfer capability compared to conventional heat transfer fluids, the high thermal conductivity and thermal diffusivity of nanofluids translate into higher energy efficiency, better performance, and lower operating costs. They can reduce energy consumption for pumping heat transfer fluids. Miniaturized systems require smaller inventories of fluids where nanofluids can be used and thermal systems can be smaller and lighter.

Convective Heat Transfer of Nanofluids: Studies on convective heat transfer of nanofluids are scarce compared to studies on thermal conductivity. However, the practical applications of nanofluids as advanced heat transfer fluids are mainly in flowing systems such as mini- or micro-channels and miniaturized heat exchangers. A comparison of results of Nusselt number versus Reynolds number for laminar and turbulent flow conditions from various research groups is presented in Figure 1(b)[3]. It can clearly be demonstrated that although the results are scattered, the convective heat transfer coefficient (Nusselt number) of nanofluids increases with Reynolds number as well as concentration of nanoparticles. Literature survey shows that the heat transfer performance of nanofluids in flowing condition is much higher as compared to their base fluids [3]. However, the mechanisms behind such enhancement in heat transfer performance are not yet well-understood. Along with the enhanced conductive heat transfer, nanofluids also exhibit significantly higher convective heat transfer performance compared to base fluids which are tradition heat transfer fluids such as water, ethylene glycol and engine oil.



(a) (b)

Figure1. (a) Thermal conductivity [2] and (b) convective heat transfer [3] results of various nanofluids from literature.

Conclusions: A brief overview of state of the art research on important thermal features of nanofluids is reported in this study. Some representative results from the literature on thermal conductivity and convective heat transfer characteristics of nanofluids are also presented and analysed. Review revealed that nanofluids possess significantly higher thermal conductivity and convective heat transfer coefficient compared to their base fluids and these properties further increase with increasing concentration of nanoparticles. Based on these exciting research findings nanofluids believed to have wide range of applications and they can be used as advanced heat transfer fluids for the improvement of thermal management systems in many engineering applications including transportation, micro-electromechanical systems (MEMS), electronics and instrumentations and in medical science.

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