A Brief Review on Utilization of Hybrid Nanofluid in Heat Exchangers: Theoretical and Experimental

Haziqatulhanis Ibrahim[1], Norazlianie Sazali[1,2*], Mohd Syafiq Sharip[1], Ahmad Shahir Jamaludin[1], Wan Norharyati Wan Salleh[3], and Farhana Aziz

[1]Faculty of Mechanical and Manufacturing Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia.
[2]Centre of Excellence for Advanced Research in Fluid Flow (CARIFF), Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang, Malaysia.
[3]Advanced Membrane Technology Research Centre (AMTEC), School of Chemical and Energy, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor Darul Takzim, Malaysia.

**Corresponding author: Norazlianie Sazali at azlianie@ump.edu.my*

Abstract. Heat exchanger is important for cooling and heating in industrial sectors. Current working fluid widely used for heat transfer in heat exchangers is water, which requires large space in a plant. Researchers has found an engineered, nanosized colloidal suspensions named nanofluids that have high potential in replacing water due to its superior thermal properties. Whilst nanofluid shows a promising heat transfer enhancement in heat exchanger, the dispersion of two different types of nanoparticles in a base fluid are expected to have a better efficiency of heat transfer. This paper compiled the studies done by various researchers in implementing hybrid nanofluids as working fluid in heat exchangers and its limitations.

Keywords: Nanotechnology, Hybrid nanofluid, Heat Exchanger, Heat transfer.

1 Introduction

In order to achieve maximum thermal efficiency of heat transfer, numerous studies were carried out concerning the enhancement of heat transfer [1–3]. With addition to current globalization activity, environment is experiencing temperature rises and thus, energy savings has become an important theme in researchers' scope of work. Most of industrial sector employed the concept of heat transfer in their facilities. For decades, heat exchangers have been used widely in industries such as petrochemical industry, food processing industry and manufacturing industry. Therefore, it is essential to optimize energy usage of the heat exchangers.

Heat exchanger is a device that allows exchange of heat between two fluids until thermal equilibrium is achieved without mixing the fluids. In a heat exchanger, working fluids are used to transfer heat from or to applied fluids. Applied fluids in this context are fluids that needs to be cooled or to be heated depends on its functional usage. Conventional fluid used to absorb or transfer heat from applied fluids are water, which then results in drawback of needing large size of heat exchanger to accommodate higher heat transfer. After several attempts, a new type of working fluid called nanofluid was discovered in 1995 [4–6]. The suspension of small, nano-sized particles into working fluid has flourished attentions since then due to its superior thermophysical properties. To date, there are many literatures reporting on various types of nanofluids for enhancement of heat transfer in heat exchanger [5,7,8]. However, to author's knowledge, there are scarce to none that focuses on application of hybrid nanofluid in heat exchangers.

2 Preparation method of hybrid nanofluids

Mono nanofluid or only known as nanofluid is a single type of nanoparticles that were incorporated in a base fluid while hybrid nanofluid is mixture of two or more types of nanoparticles in different proportions, fused into base fluids at required volume concentration [9]. Two benefits of hybrid nanofluid compared to single type nanofluid are that they exhibit better thermal properties and have superior rheology [6]. There are two approaches established in preparing the hybrid nanofluids; one step method and two step method.

In single step approaches, synthesize of nanoparticles and dispersion of the particles in base fluids are conducted simultaneously. Corresponds to its name, nanofluids from this method is accomplished in only a single step. For two step method, nanoparticles will be processed separately and dispersed in a base fluid [10]. **Fig. 1** and **Fig. 2** illustrates the flow of one step method and two step method, respectively. Depending on the suitability between nanoparticles and base fluids, most of researchers commonly used two step method in their studies as it produced large scale of nanoparticles at low cost [7,10]. However, the usage of surfactant or dispersant are partially required in two step method to depress agglomeration due to forces between independent nanoparticles [10].

Fig. 1. Illustration for one step approach.

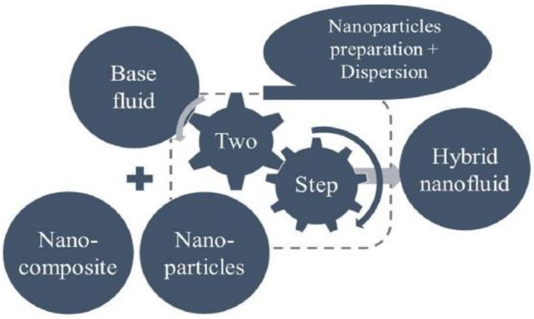

Fig. 2. Two step method graphical illustration [6].

Surfactants helps to reduce agglomeration and increase the stability of the suspension. It can be classified into four categories; (1) Non-ionic surfactant, (2) Anionic surfactant, (3) Cationic surfactant and (4) Amphoteric surfactant, and is chosen following its compatibility [6].

3 Hybrid nanofluids in heat exchangers

Following the demand in energy-efficient and economical heat transfer devices comes the idea of utilizing hybrid nanofluids in heat exchangers. Performance of nanofluids are affected by various parameters, in which thermos-physical properties (represented in **Fig. 3**) of the hybrid nanofluids itself plays an important role. Other crucial parameters include temperature, particle concentration and particle size [6,7]. Researchers conducted various studies in both numerical and experimental way in order to evaluate the performance of hybrid nanofluids when operated in heat exchangers.

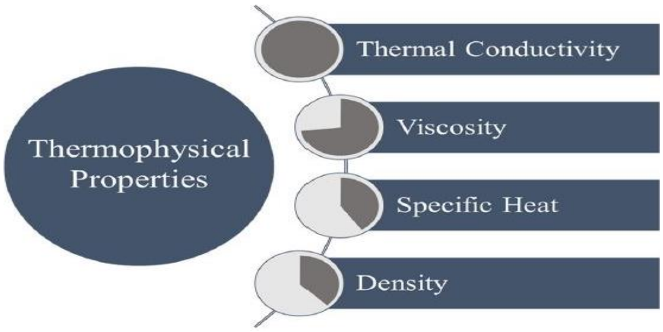

Fig. 3. Graphical illustration for thermos-physical properties of nanofluids [6].

Allahyar *et al.* [11] in their experimental work investigated thermal performance of both hybrid alumina-silver nanocomposite dispersed in distilled water and mono alumina nanofluid employed in a coiled-type heat exchanger. The experiment was conducted at constant wall temperature and under laminar flow. They observed that heat transfer rate when operated using hybrid nanofluids of 0.4% volume concentration were 31.58% higher compared to when using distilled water as the working fluid. Moreover, they noted that increase in particles concentration led to an increment in heat transfer rate. On the other hand, Huang *et al.* [12] studies the behavior of hybrid water-based alumina with multi-walled carbon nanotubes in a corrugated plate heat exchanger (demonstrated in **Fig. 4**). From their findings, heat transfer coefficient for hybrid nanofluids are slightly higher than single alumina/water nanofluid and water itself with addition that it has smaller pressure drop, denoting its energy-efficiency. In plate heat exchanger, strong turbulence due to liquid flow inside the narrow-corrugated channels helps to enhance the heat transfer [13–15].

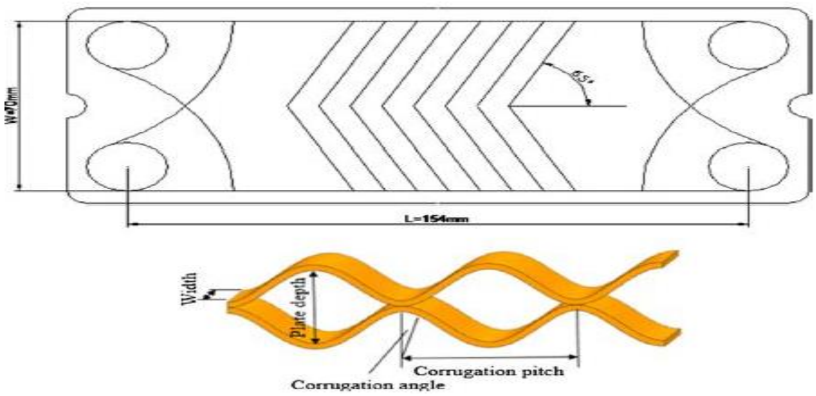

Fig. 4. Schematic plate heat exchanger used by Huang *et al.* [12].

Recently, similar study on water-based alumina-multiwalled carbon nanotubes nanofluids operated in plate heat exchanger was conducted by Bhattad *et al.* [16] using simulation CFD software. The results from their study was in conform with aforementioned study done by Huang *et al.* [12], where heat transfer coefficient increased when hybrid nanofluid was used. Three parameters; inlet temperature of nanofluid, flow rate and concentration of nanofluid that affects rate of heat transfer were evaluated in their literature. Aluminium nitride nanoparticles dispersed in ethylene glycol utilized in a double pipe heat exchanger was experimentally investigated by Hussein [17] under laminar flow. He suggested that heat transfer efficiency may augmented up to 160% when lower volume fractions of nanofluids is used. Furthermore, their results show that increment in flow rate decreases the friction factor, contradict with when volume concentration was increased. Therefore, low volume concentration is more favorable as it will produce low friction factor.

4 Conclusion

In conclusion, in depth study need to be done in order to implement the usage of hybrid nanofluids in heat exchanger. This paper presented a mini review of studies on heat transfer enhancement in a heat exchanger. Based on various literatures, it was known that hybrid nanofluid does exhibits a superior performance for heat transfer but due to its complexity, it still has not been utilized in a real scale heat exchanger. Type of heat exchanger, type of nanoparticles, volume concentration and size of nanoparticles need to be taken into consideration as it influences the performance of heat transfer in a heat exchanger.

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References

[1] Sukarno DH. 2017. Challenges for nanofluid applications in heat transfer technology. *J Phys Conf Ser*. 795(1):12020.

[2] El Bécaye Maïga S, Tam Nguyen C, Galanis N, Roy G, Maré T, Coqueux M. 2006. Heat transfer enhancement in turbulent tube flow using Al_2O_3 nanoparticle suspension. *Int J Numer Methods Heat Fluid Flow* 16(3):275–92.

[3] Dr. PK and KMP. 2017. Effect on Heat Transfer Characteristics of Nanofluids Flowing under Laminar and Turbulent Flow Regime – A Review. *IOP Conf Ser Mater Sci Eng* 225(1):12168.

[4] Taherian H, Alvarado JL, Languri EM. 2018. Enhanced thermophysical properties of multiwalled carbon nanotubes based nanofluids. Part 1: Critical review. *Renew Sustain Energy Rev* 82:4326–36.

[5] Suganthi KS, Rajan KS. 2017. Metal oxide nanofluids: Review of formulation, thermo-physical properties, mechanisms, and heat transfer performance. *Renew Sustain Energy Rev* 76:226–55.

[6] Babar H, Ali HM. 2019. Towards hybrid nanofluids: Preparation, thermophysical properties, applications, and challenges. *J Mol Liq* 281:598–633.

[7] Sajid MU, Ali HM. 2018. Thermal conductivity of hybrid nanofluids: A critical review. *Int J Heat Mass Transf* 126:211–34.

[8] Bahiraei M, Rahmani R, Yaghoobi A, Khodabandeh E, Mashayekhi R, Amani M. 2018. Recent research contributions concerning use of nanofluids in heat exchangers: A critical review. *Appl Therm Eng* 133:137–59.

[9] Phanindra Y, Kumar SD, Pugazhendhi S. 2018. Experimental Investigation on Al_2O_3 & Cu/Oil Hybrid Nano fluid using Concentric Tube Heat Exchanger. *Mater Today Pro*c 5(5, Part 2):12142–50.

[10] Ranga Babu JA, Kumar KK, Srinivasa Rao S. 2017. State-of-art review on hybrid nanofluids. *Renew Sustain Energy Rev* 77:551–65.

[11] Allahyar HR, Hormozi F, ZareNezhad B. 2016. Experimental investigation on the thermal performance of a coiled heat exchanger using a new hybrid nanofluid. *Exp Therm Fluid Sci*. 76:324–9.

[12] Huang D, Wu Z, Sunden B. 2016. Effects of hybrid nanofluid mixture in plate heat exchangers. *Exp Therm Fluid Sci* 72:190–6.

[13] Khan TS, Khan MS, Chyu M-C, Ayub ZH. 2010. Experimental investigation of single phase convective heat transfer coefficient in a corrugated plate heat exchanger for multiple plate configurations. *Appl Therm Eng* 30(8):1058–65.

[14] Wajs J, Mikielewicz D. 2016. Influence of metallic porous microlayer on pressure drop and heat transfer of stainless steel plate heat exchanger. *Appl Therm Eng* 93:1337–46.

[15] Nilpueng K, Wongwises S. 2015. Experimental study of single-phase heat transfer and pressure drop inside a plate heat exchanger with a rough surface. *Exp Therm Fluid Sci* 68:268–75.

[16] Bhattad A, Sarkar J, Ghosh P. 2018. Discrete phase numerical model and experimental study of hybrid nanofluid heat transfer and pressure drop in plate heat exchanger. *Int Commun Heat Mass Transf* 91:262–73.

[17] Hussein AM. 2017. Thermal performance and thermal properties of hybrid nanofluid laminar flow in a double pipe heat exchanger. *Exp Therm Fluid Sci* 88:37–45.