INVESTIGATION ON THE OPTICAL AND THERMAL CONDUCTIVITY CHARACTERISTICS OF NANOFLUIDS

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INVESTIGATION ON THE OPTICAL AND THERMAL CONDUCTIVITY CHARACTERISTICS OF NANOFLUID

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ABSTRACT

A renewable power source such as solar energy is one of the possible solutions that could be used to solve the problem of global warming caused by fossil fuels which contributed to a high carbon dioxide emissions. Solar energy is naturally available as it derived from the sun that can be transformed into thermal energy which can be used by human using a device such as solar collector. Conventional heat transfer fluid such as water and ethylene glycol are regarded as poor solar absorber and affect the efficiency of the solar thermal system. Addition of nanoparticles into these fluids can enhance its optical and thermal conductivity. This new generation of heat transfer fluid known as nanofluids. The aims of this study are to investigate theoretically and experimentally the optical and thermal conductivity characteristics of titanium dioxide and aluminium oxide based nanofluids. These two particles were selected due to the availability in market and the classical model of Rayleigh Approach (RA) for optical properties can be applied as their sizes are very small. Effects of surfactant (Gum Arabic, Sodium dodecylbenzenesulfonate; polyvinylpyrrolidone, particle size (<13nm, <21nm and <50 nm), volume percentages of nanoparticles (0.002, 0.004, 0.006, 0.008 and 0.010 vol. %) and pH (3, 5 and 9) on optical properties of nanofluids have also been investigated. Apart from that, the stability of nanofluids was measured through zeta potential measurement and observation. KD2-Pro thermal properties analyzer and UV-Vis spectrophotometer were used to measure the thermal conductivity and optical properties of the samples, respectively. In stability measurement using zeta potential, SDBS surfactant exhibited highest zeta potential compared to other surfactants for both titanium dioxide and aluminium oxide nanofluids. Based on the observation method, titanium dioxide is poor in stability in most of conditions at 0.01% of volume percentages compared to aluminium oxide nanofluids The analytical results based on Rayleigh approach showed that the bigger size (<50nm) of nanoparticles and the larger the volume percentages of nanoparticles (0.010 vol. %) lead to a higher extinction coefficient of both nanofluids. The comparison of extinction coefficient between theoretical and experimental was successfully calculated in this study. All types of nanofluid showed better thermal conductivity compared to distilled water. Titanium dioxide gave the highest enhancement (28.17%) of thermal conductivity compared to base fluid. Finally, titanium dioxide with addition of Gum Arabic surfactant was selected to study the effect of elapse time on nanofluid due to a good stability, optical and thermal conductivity. From this study, thermal conductivity and optical properties of this nanofluid decreased with time within 1 month.

ABSTRAK

Sumber kuasa yang boleh diperbaharui seperti tenaga solar adalah salah satu penyelesaian yang boleh digunakan untuk menyelesaikan masalah pemanasan global yang disebabkan oleh bahan api fosil yang menyumbang kepada pelepasan karbon dioksida yang tinggi. Tenaga solar boleh diperolehi secara semulajadi kerana berasal dari matahari yang boleh berubah menjadi tenaga haba yang boleh digunakan oleh manusia dengan menggunakan alat seperti pengumpul solar. Cecair konvensional pemindahan haba seperti air dan *ethylene glycol* dianggap sebagai penyerap solar yang lemah dan memberi kesan kepada kecekapan sistem termal suria. Penambahan nanopartikel ke dalam cecair ini boleh meningkatkan kekonduksian optik dan haba. Generasi baru cecair pemindahan haba ini dikenali sebagai *nanofluids*. Tujuan kajian ini adalah untuk menyiasat secara teori dan ujikaji ciri-ciri kekonduksian optik dan haba untuk titanium dioksida dan aluminium oksida *nanofluids*. Kedua-dua nanopartikel ini telah dipilih kerana sedia ada di pasaran dan model klasik Rayleigh Approach (RA) digunakan untuk menganalisis ciri-ciri optik kerana saiz nanopartikel ini adalah sangat kecil. Kesan surfaktan (*Gum Arabic, Sodium dodecylbenzenesulfonate; polyvinylpyrrolidone),* saiz (<13nm, <21nm dan <50nm), jumlah peratusan isipadu nanopartikel (0.002, 0.004, 0.006, 0.008 dan 0.010 vol. %) dan nilai pH (3, 5 dan 9) ke atas ciri-ciri optik nanofluids juga telah dilakukan. Kestabilan *nanofluids* diperhatikan melalui kaedah mengambil foto dan melalui pengukuran potensi zeta. Di samping itu, KD2-Pro penganalisis haba dan UV-Vis spectrophotometer masing-masing digunakan untuk mengukur kekonduksian haba dan ciri-ciri optik sampel. Dalam pengujian potensi zeta, keputusan menunjukkan surfaktant jenis SDBS mempamerkan nilai potensi zeta tertinggi berbanding dengan surfaktant lain bagi kedua-dua jenis nanofluids. Manakala dari segi pemerhatian, didapati titanium dioxide nanofluids mempunyai ciri kestabilan yang rendah pada hampir semua keadaan pada 0.01% peratusan isipadu nanopartikel berbanding dengan aluminium oxide nanofluids. Hasil kajian berdasarkan teori klasik Rayleigh Approach juga menunjukkan bahawa saiz nanopartikel yang lebih besar (<50nm) dan nanopartikel yang lebih besar jumlah peratusan isipadu (0.010 vol. %) membawa kepada peningkatan *extinction coefficient* yang lebih tinggi untuk kedua-dua jenis *nanofluids*. Perbandingan pengukuran antara teori dan eksperimen telah berjaya dikira dalam kajian ini. Seterusnya, kekonduksian haba *nanofluids* diukur pada jenis zarah, surfaktan dan nilai pH cecair asas dan nilai dibandingkan dengan model Maxwell. Semua jenis *nanofluids* menunjukkan kekonduksian haba yang lebih baik berbanding dengan air suling. Titanium dioksida memberikan peningkatan kekonduksian haba yang paling tinggi (28.17%) berbanding aluminium oksida *nanofluids*. Akhir sekali, titanium dioksida dengan penambahan surfaktan gum Arabic (GA) telah dipilih untuk mengkaji kesan masa pada *nanofluid*s kerana kestabilan, kekonduksian optik dan termal yang baik. Daripada kajian ini, kekonduksian termal dan sifat optik *nanofluids* ini menurun dengan masa dalam tempoh 1 bulan.

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APPROVAL

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LIST OF ABBREVIATIONS AND SYMBOLS

Ag	-	Silver
Al_2O_3	-	Aluminium Oxide
CNT	-	Carbon Nanotube
Cu	-	Copper
CuO	-	Copper Oxide
D	-	Diameter of Particles
DW	-	Distilled Water
DAC	-	Direct Absorption Collector
DASC	-	Direct Absorption Solar Collector
DDA	-	Discrete Dipole Approximation
EG	-	Ethylene Glycol
Fe	-	Iron
Fe_3O_4	-	Iron (III) Oxide
GA	-	Gum Arabic
I	-	Intensity of Light
I_0	-	Intensity of Incident Light
IEP	-	Isoelectric Point
IR	-	Infrared Region
m	-	Complex Refractive Index
MWCNT	-	Multi-walled Carbon Nanotubes
PVD	-	Physical Vapor Deposition
PVP	-	Polyvinylpyrrolidone
QCA	-	Quasi Crystalline
Q_{abs}	-	Absorption Efficiency

Q_{ext}	-	Extinction Efficiency
Q_{scat}	-	Scattering Efficiency
RA	-	Rayleigh Approach
SEM	-	Scanning Electron Microscopy
SDS	-	Sodium Dodecyl Sulphate
SDBS	-	Sodium dodecylbenzenesulfonate
SiO_2	-	Silicon Oxide
SWCNHs	-	Single-Wall Carbon Nanohorns
SWCNT	-	Single-Wall Carbon Nanotubes
TEM	-	Transmission Electron Microscopy
TiO_2	-	Titanium Dioxide
ZnO	-	Zinc Oxide
A	-	Particle Size Parameter
λ	-	Wavelength
Σ	-	Coefficient
k	-	Complex Component of Refractive Index
k_p	-	Thermal Conductivity of Nanoparticles
k_{bf}	-	Thermal Conductivity of Base Fluid
$\emptyset$	-	Volume Fraction
ε	-	Dielectric Constant
n	-	Refractive Index
eff	-	Effective Medium
ρ	-	Density

CHAPTER 1

INTRODUCTION

1.1 Introduction

Fossil-based energy such as petroleum, natural gas and coal have become the world's primary energy resources for many decades. Fossil-based energy drives industrial development and the world's economy. The depletion of fossil-based energy as our primary energy resources is getting more serious due to the significant increase of world's energy consumption from year to year. Furthermore, fossil-based energy contributes to the global warming, air pollution and acid rain which force scientists to search for clean energy alternatives. The demand for energy has created increasing pressure on the search for alternatives energy resources and new ways to save and reduce energy usage.

There are a number of solutions being implemented to solve existing environmental problems including recycling of materials, reducing of carbon emissions from fossil fuels, and finding alternative energy solutions. Alternative energy resources can be in the form of renewable energy resources. A renewable energy resource is a natural energy resource that is constantly replenished. This means it has an infinite sustainability and will not run out. In Malaysia, there are a few types of renewable energy that can be used as alternative energy resources such as biomass, solar, wind and hydroelectric. These types of renewable energy are resources that are constantly and abundantly present and will never run out. These alternatives present a viable solution to problem of global warming caused by fossil fuels, which produced high carbon dioxide emissions. Therefore, the usage of clean renewable energy are amongst the possible approaches that can be used to address this problem.

Sustainable energy is one of the biggest challenges faced by society today. Thus, a renewable power source such as solar energy is one of the possible solutions that can be harnessed to address the current issue. Solar energy is one of the renewable sources of sustainable energy which does not affect the environment and has many advantages compared to other renewables energy resources. In addition, solar energy naturally available as it is derived from the sun that can be transformed into thermal energy. Using a device such as solar collector, the thermal energy can then be used either for industrial or domestic operation. Moreover, solar energy is one of the cleanest power sources as no pollutant is being released. Since, Malaysia is located within the equatorial which is hot and sunny throughout the year, solar energy is the most suitable energy resource to be generated in Malaysia. Figure 1.1 illustrates the schematic of solar thermal conversion.