HEAT TRANSFER PERFORMANCE OF GREEN BIO-GLYCOL BASED TiO_2-SiO_2 NANOFLUIDS

SITI NURSHARAH BINTI MUHAMAD ZAINON

MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

____

(Supervisor's Signature)

Full Name : DR. WAN AZMI BIN WAN HAMZAH

Position : ASSOCIATE PROFESSOR

Date : 25TH FEBRUARY 2021

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

(Student's Signature)

Full Name : SITI NURSHARAH BINTI MUHAMAD ZAINON

ID Number : MMM18003

Date : 25TH FEBRUARY 2021

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ABSTRAK

Penyebaran zarah nano dalam bendalir pemindahan haba konvensional telah terbukti dapat meningkatkan prestasi pemindahan haba bendalir. Untuk menyiasat kemampuan bendalir ini dalam meningkatkan prestasi haba, pelbagai kajian telah dilakukan sejak beberapa dekad yang lepas dengan menggunakan bendalir nano tunggal dan hibrid yang menggunapakai pelbagai jenis bendalir asas seperti air, etilena glikol, dan propilena glikol. Walau bagaimanapun, penyelidikan berkenaan sifat-sifat haba untuk zarah nano yang disebar ke dalam campuran air dan bahan pendingin hijau Bio-glikol adalah terhad kepada cecair nano tunggal. Kajian ini menunjukkan bahawa Bio-glikol menawarkan kestabilan haba yang lebih baik serta memiliki sifat fizikal yang serupa atau lebih baik berbanding dengan glikol konvensional. Tujuan kajian ini adalah untuk mengkaji kestabilan, sifat-sifat fizikal haba, prestasi pemindahan haba dan faktor geseran bendalir nano TiO_2-SiO_2 berasaskan Bio-glikol hijau. Bendalir nano hibrid disediakan pada pada kadar kepekatan isipadu dalam julat 0.5 hingga 3.0% dengan menyebarkan zarah nano TiO_2 dan SiO_2 dalam campuran 60:40 air: Bio-glikol (W/BG). Selepas itu, bendalir nano tunggal dicampurkan pada nisbah komposisi 20:80. Kekonduksian haba, kelikatan dinamik dan ketumpatan bendalir nano TiO_2-SiO_2 berasaskan Bio-glikol hijau diukur menggunakan peralatan pengukuran khusus. Sementara itu, kajian eksperimen pemindahan haba perolakan paksa dilakukan dalam aliran bergelora pada fluks haba yang tetap untuk nombor Reynolds dalam julat antara 2,300 hingga 24,000 dan suhu operasi pada 30, 50 and 70 °C. Hasil kajian menunjukkan bendalir nano TiO_2-SiO_2 berasaskan Bio-glikol hijau secara fizikalnya berada dalam lingkungan kestabilan yang baik dengan nilai potensi zeta sebanyak -53.46 mV untuk zarah nano hibrid. Kekonduksian haba bendalir nano TiO_2-SiO_2 berasaskan Bio-glikol hijau ditingkatkan sehingga 12.52% daripada campuran air/Bio-glikol pada kepekatan isipadu 3.0% dan suhu 70 °C. Sementara itu, tiada kenaikan yang ketara pada kelikatan dinamik bendalir nano TiO_2-SiO_2 berasaskan Bio-glikol hijau dengan suhu, yang mana kelikatan dinamik minimum dapat diperhatikan pada kepekatan isipadu 0.5% dan suhu 80 °C. Manakala ketumpatan bendalir nano meningkat dengan kepekatan isipadu, tetapi menurun dengan peningkatan suhu. Peningkatan pemindahan haba maksima untuk bendalir nano TiO_2-SiO_2 berasaskan Bio-glikol hijau pada suhu 30, 50, dan 70 °C masing-masing mencapai sehingga 128.1%, 73.95%, and 67.81% pada kepekatan isipadu 2.5%. Sedikit peningkatan dalam faktor geseran bendalir nano TiO_2-SiO_2 berasaskan Bio-glikol hijau diperhatikan dengan kenaikan maksima sebanyak 12%. Persamaan matematik baru telah dibangunkan untuk menganggarkan kekonduksian haba, kelikatan dinamik, nombor Nusselt, dan faktor geseran bendalir nano TiO_2-SiO_2 berasaskan Bio-glikol hijau. Persamaan ini menunjukkan ketepatan yang baik dengan purata sisihan kurang daripada 4.3%. Sebagai kesimpulan, zarah nano hibrid TiO_2-SiO_2 dalam campuran bendalir asas air/Bio-glikol disahkan berada dalam kestabilan yang bagus. Sifat-sifat bendalir nano TiO_2-SiO_2 berasaskan Bio-glikol hijau dengan variasi isipadu kepekatan dan suhu telah terbukti meningkat dengan ketara. Penggunaan bendalir nano hijau dalam peningkatan prestasi haba terbukti dan dapat digunakan untuk aplikasi pemindahan haba perolakan paksa gelora. Oleh itu, hasil kajian ini menyarankan penggunaan bendalir nano TiO_2-SiO_2 berasaskan Bio-glikol hijau pada kepekatan isipadu 2.0 hingga 2.5% untuk pelbagai aplikasi kejuruteraan.

ABSTRACT

The dispersion of nanoparticles in conventional heat transfer fluids has been proven to improve the heat transfer performance of the fluids. In order to investigate their ability to enhance thermal performance, various studies have been conducted over the past few decades using single and hybrid nanofluids suspended in various types of base fluids such as water, ethylene glycol, and propylene glycol. However, study on the thermal properties of nanoparticles dispersed in the mixture of water and green Bio-glycol are limited in the literature and only available for single nanofluids. The study showed that Bio-glycol offers greater thermal stability while possessing similar or better physical properties compared to conventional glycol. The purpose of this study is to investigate the stability, thermo-physical properties, heat transfer performance and friction factor of green Bio-glycol based TiO_2-SiO_2 nanofluids. The hybrid nanofluids was prepared at various volume concentrations ranging between 0.5 and 3.0% by dispersing TiO_2 and SiO_2 nanoparticles in the mixture of 60:40 of water: Bio-glycol (W/BG). Then, the single nanofluids were mixed at composition ratio of 20:80. The thermal conductivity, dynamic viscosity and density of green Bio-glycol based TiO_2-SiO_2 nanofluids were measured using specific measuring equipment. While the experimental study on forced convection heat transfer was done under turbulent flow at constant heat flux for the range of Reynolds number between 2,300 and 24,000 and operating temperatures of 30, 50 and 70 °C. Experimental result shows the stability of green Bio-glycol based TiO_2-SiO_2 nanofluids showed physically to be in good range of stability for suspension nanoparticles with zeta potential of -53.46 mV. The thermal conductivity of the green Bio-glycol based TiO_2-SiO_2 nanofluids was enhanced up to 12.52% higher than the mixture of W/BG at 3.0% volume concentration and temperature of 70 °C. Meanwhile, there is insignificant dynamic viscosity increment of the green Bio-glycol based TiO_2-SiO_2 nanofluids with temperature, in which the minimum dynamic viscosity was observed for 0.5% volume concentration and temperature of 80 °C. The density of the nanofluids increases with volume concentration but decreases with temperature rise. The maximum heat transfer enhancements of green Bio-glycol based TiO_2-SiO_2 nanofluids at different bulk temperatures of 30, 50 and 70 °C were observed to be up to 128.1%, 73.95%, and 67.81%, respectively for 2.5% volume concentration. A slight friction factor escalation of green Bio-glycol based TiO_2-SiO_2 nanofluids was observed with 12% maximum increment. New correlations were developed to estimate the thermal conductivity, dynamic viscosity, Nusselt number, and friction factor of green Bio-glycol based TiO_2-SiO_2 nanofluids. The equations showed good accuracy with average deviations of less than 4.3%. As a conclusion, the TiO_2-SiO_2 hybrid nanoparticles in water/Bio-glycol mixture base fluids was confirmed to be in good stability condition. The properties of the green Bio-glycol based TiO_2-SiO_2 nanofluids with variation of volume concentration and temperature were improved significantly. The employment of the eco-friendly coolant nanofluids in improving thermal performance is proven and applicable for turbulent forced convection heat transfer applications. Hence from the present study, the utilization of the green Bio-glycol based TiO_2-SiO_2 nanofluids at 2.0 to 2.5% volume concentration was recommended for various engineering applications.

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a	Thermal diffusivity
A_s	Area
Abs	Absorbance
c	Specific heat
$C_{p,nf}$	Specific heat of nanofluids
$C_{p,bf}$	Specific heat of base fluid
$C_{p,np}$	Specific heat of nanoparticles
D	Diameter
ID	Inner diameter
OD	Outer diameter
ΔV	Additional volume of the base fluid
ΔP	Differential pressure
ΔT	Temperature difference
f	Darcy friction factor
γ	Shear rate
h	Heat transfer coefficient
I	Current
k	Thermal conductivity
k_{bf}	Thermal conductivity of the base fluid
k_{nf}	Thermal conductivity of nanofluids
L	Tube length
$\dot{m}$	Mass flow rate
m_p	Mass of particle
m_{bf}	Mass of base fluid
μ	Dynamic viscosity
μ_{bf}	Dynamic viscosity of the base fluid
μ_{nf}	Dynamic viscosity of nanofluids
μ_r	Relative viscosity
Nu	Nusselt number
Nu_{DB}	Dittus-Boelter Nusselt number
Nu_{exp}	Experimental Nusselt number

ω	Weight concentration in percent
Pr	Prandtl number
ϕ_1	Initial volume concentration
ϕ_2	Final volume concentration
ϕ_{nf}	Volume concentration of nanofluids
ϕ_{p1}	Volume concentration of nanoparticles type 1
ϕ_{p2}	Volume concentration of nanoparticles type 2
ϕ_1	Initial volume concentration
Q	Power (Heat input)
q	Heat absorbed
$\dot{q}$	Heat flux
q_{input}	Heat supplied
Re	Reynolds number
ρ	Density
ρ_{bf}	Density of base fluid
ρ_{nf}	Density of nanofluid
ρ_{hnf}	Density of hybrid nanofluid
ρ_{p1}	Density of nanoparticle type 1
ρ_{p2}	Density of nanoparticle type 2
ρ_w	Density of water
ρ_w	Density of water
T	Temperature
T_b	Bulk temperature
T_{in}	Inlet temperature
T_{out}	Outlet temperature
T_s	Surface temperature
U	Uncertainty
V_1	Initial volume
V_2	Final volume
V_t	Input voltage
W	Water

LIST OF ABBREVIATIONS

AD	Average Deviation
Ag	Silver
Al	Aluminium
Al_2O_3	Aluminium oxide
Ar	Argon
Au	Gold
BG	Bio-glycol
C	Carbon
CNT	Carbon nanotube
C	Carbon
CuO	Copper dioxide
Di	Diamond
DLVO	Derjaguin, Landau, Verwey, and Overbeek
EG	Ethylene glycol
Fe	Iron
Fe_3O_4	Iron (II, III) oxide
GO	Graphene oxide
LCD	Liquid Crystal Display
LD_{LO}	Lowest lethal dose
MD	Maximum deviation
MgO	Magnesium oxide
MWCNT	Multi-walled carbon nanotube
N_2	Nitrogen
NaOH	Sodium hydroxide
NIOSH	National Institute of Occupational Safety and Health
PEC	Performance evaluation criterion
PG	Propylene glycol
PWE	Pulse wire evaporation
rGO	Reduced graphene oxide
SD	Standard deviation
Si	Silicon

SiO_2	Silicon dioxide
Si_3N_4	Silicon nitride
SWCNT	Single-walled carbon nanotubes
TEM	Transmission electron microscopy
THW	Transient hot wire
TiO_2	Titanium oxide
UV-Vis	Ultraviolet-visible
W	Water
ZnO	Zinc oxide

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