UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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A thesis submitted
in fulfilment of the requirements for the degree of
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2024

DECLARATION

I declare that this thesis entitled “Formulation of Graphene Nanoplatelets Nanofluid as Heat Transfer Fluid on Photovoltaic-Thermal System Analysis” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : NURUL IZZATI AKMAL BINTI MUHAMED RAFAIZUL

Date : 18TH JUNE 2024

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature : ....

Supervisor Name : MOHD AFZANIZAM MOHD ROSLI

Date : 19 June 2024

DEDICATION

To my beloved mother and father.

ABSTRACT

Photovoltaic-thermal (PV/T) systems have gained significant attention as an energy-efficient and sustainable technology. The use of nanofluids as heat transfer fluid in PV/T system has generated a lot of interest in recent years due to their improved thermophysical properties compared to conventional heat transfer fluids. Although researchers' interest in improving the performance of PV/T systems by using nanofluids as heat transfer fluid has grown over the past years, there is still a lack of studies related to this application. This study investigates the efficiency enhancement of PV/T systems by utilizing graphene nanoplatelets (GNP) nanofluids compared to conventional water-based fluids. This research aims to create a formulation of GNP at concentrations of 0.2, 0.4, 0.6, 0.8 and 1.0 wt.%, determine the physical properties of GNP through FESEM, PSA and XRD analysis and thermophysical properties of the nanofluids through thermal conductivity, viscosity, density and specific heat capacity, and evaluate the overall performance of the PV/T utilizing the best concentration of GNP nanofluid. To formulate the nanofluid, the two-step method is used. The addition of surfactant, polyvinylpyrrolidone (PVP) is done to enhance the stability of the nanofluid and is assessed through direct observation method. The best nanofluid concentration undergoes thermophysical properties test and is utilized in a PV/T system to run an indoor experiment using an indoor solar simulator. Through a comprehensive analysis of thermal and electrical efficiencies at varying flow rates in range of 20 to 80 L/hr, the research aims to evaluate the impact of nanofluid technology on PV/T system performance. The results demonstrate that GNP nanofluids were successfully formulated through the two-step method and exhibit superior thermal conductivity and other heat transfer properties, with the concentration of 0.6 wt.% having the best stability and thermophysical properties tested which are thermal conductivity (0.6611 W/mK), viscosity (1.22 mPa.s), density (476.8 kg/m^3) and specific heat capacity (3606.4 J/kgK) leading to enhanced thermal efficiency up to 80% in PV/T systems across all flow rates. Additionally, the electrical efficiency of PV/T systems achieved 8.9% efficiency, highlighting the potential benefits of improved thermal management and heat dissipation. Overall, the study concludes that GNP nanofluids outperform conventional heat transfer fluids in terms of efficiency, with 88.9% and an enhancement of 17% across various flow rates and solar irradiance ranging from 200 to 800 W/m^2, emphasizing the significant role of nanofluid technology in advancing the sustainability and effectiveness of solar energy applications. The findings provide valuable insights for optimizing the operation of PV/T systems and pave the way for further research into enhancing the performance of renewable energy systems through nanofluid innovation.

FORMULASI BENDALIR NANO GRAFIN NANOPLATLET SEBAGAI BENDALIR PEMINDAHAN HABA BAGI ANALISIS SISTEM TERMA FOTOVOLTAN

ABSTRAK

Sistem terma fotovoltan (PV/T) telah mendapat perhatian yang ketara sebagai teknologi yang cekap tenaga dan mampan. Penggunaan bendalir nano sebagai bendalir pemindahan haba dalam sistem PV/T telah menjana banyak minat sejak beberapa tahun kebelakangan ini kerana sifat termofiziknya yang lebih baik berbanding dengan bendalir pemindahan haba konvensional. Walaupun minat penyelidik untuk meningkatkan prestasi sistem PV/T dengan menggunakan bendalir nano sebagai bendalir pemindahan haba telah berkembang sejak beberapa tahun lalu, masih terdapat kekurangan kajian berkaitan aplikasi ini. Kajian ini menyiasat peningkatan kecekapan sistem PV/T dengan menggunakan bendalir nano grafin nanoplatlet (GNP) berbanding bendalir berasaskan air konvensional. Penyelidikan ini bertujuan untuk mencipta formulasi GNP pada kepekatan 0.2, 0.4, 0.6, 0.8 dan 1.0 wt.%, menentukan sifat fizikal GNP melalui analisis FESEM, PSA dan XRD dan sifat termofizik bendalir nano melalui kekonduksian terma, kelikatan, ketumpatan dan kapasiti haba tentu, dan menilai prestasi keseluruhan PV/T menggunakan kepekatan terbaik bendalir nano GNP. Untuk formulasi bendalir nano, kaedah dua langkah digunakan. Penambahan surfaktan, polivinilpirolidon (PVP) dilakukan untuk meningkatkan kestabilan bendalir nano dan dinilai melalui kaedah pemerhatian terus. Kepekatan bendalir nano terbaik menjalani ujian sifat termofizik dan digunakan dalam sistem PV/T untuk menjalani eksperimen dalaman menggunakan simulator suria dalaman. Melalui analisis komprehensif kecekapan terma dan elektrik pada kadar aliran yang berbeza dalam julat 20 hingga 80 L/jam, penyelidikan bertujuan untuk menilai kesan teknologi bendalir nano ke atas prestasi sistem PV/T. Keputusan menunjukkan bahawa cecair nano GNP telah berjaya diformulasikan melalui kaedah dua langkah dan mempamerkan kekonduksian terma yang unggul dan sifat pemindahan haba yang lain, dengan kepekatan 0.6 wt.% mempunyai kestabilan terbaik dan sifat termofizik yang diuji iaitu kekonduksian terma (0.6611 W/ mK), kelikatan (1.22 mPa.s), ketumpatan (476.8 kg/m^3) dan kapasiti haba tentu (3606.4 J/kgK) yang membawa kepada kecekapan haba yang dipertingkatkan sehingga 80% dalam sistem PV/T merentas semua kadar aliran. Selain itu, kecekapan elektrik sistem PV/T mencapai kecekapan 8.9%, menyerlahkan potensi manfaat pengurusan terma yang lebih baik dan pelesapan haba. Secara keseluruhan, kajian menyimpulkan bahawa bendalir nano GNP mengatasi bendalir pemindahan haba konvensional dari segi kecekapan, dengan 88.9% dan peningkatan sebanyak 17% merentasi pelbagai kadar aliran dan sinaran suria antara 200 hingga 800 W/m^2, menekankan peranan penting teknologi bendalir nano dalam memajukan kemampanan dan keberkesanan aplikasi tenaga suria.

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LIST OF ABBREVIATIONS

Al_2O_3	-	Aluminium oxide
ARB	-	Arabinogalactan
ASEL	-	Applied Solar Energy Laboratory
ASTM	-	American Society for Testing and Materials
C	-	Carbon
CNT	-	Carbon nanotubes
COP	-	Coefficient of performance
CSP	-	Concentrated solar power
CTAB	-	Cetyltrimethylammonium bromide
CuO	-	Copper oxide
DSC	-	Differential scanning calorimetry
EDS	-	Energy dispersive spectroscopy
EG	-	Ethylene glycol
Fe_3O_4	-	Iron oxide
FESEM	-	Field emission scanning electron microscopy
FWHM	-	Full width at half maximum
GHG	-	Greenhouse gas
GNP	-	Graphene nanoplatelets
HRTEM	-	High-resolution transmission electron microscopy
IEC	-	International Electrotechnical Commission
IR	-	Infrared
LED	-	Light-emitting diode
MgO	-	Magnesium oxide

MPP	-	Maximum power point
MWCNT	-	Multi-walled carbon nanotube
PCM	-	Phase change material
PSA	-	Particle size analysis
PV	-	Photovoltaic
PV/T	-	Photovoltaic-thermal
PVD	-	Physical vapor deposition
PVP	-	Polyvinylpyrrolidone
SDBS	-	Sodium dodecyl benzene sulfonate
SDC	-	Sodium deoxycholate
SDS	-	Sodium lauryl sulphate
STI	-	Short-term instability
SWCNT	-	Single-walled carbon nanotube
TGA	-	Thermogravimetric analysis
UTeM	-	Universiti Teknikal Malaysia Melaka
UV	-	Ultraviolet
VCO	-	Virgin coconut oil
XRD	-	X-ray diffraction

LIST OF SYMBOLS

A	-	Collector area
C_p	-	Specific heat capacity
D	-	Crystallite size
FF	-	Fill factor
G	-	Solar irradiance
I	-	Current
K	-	Scherrer constant
k	-	Thermal conductivity
P	-	Power
Q	-	Heat
R	-	Function of 'n' independent linear parameter
T	-	Temperature
U_R	-	Relative uncertainty
V	-	Voltage
w	-	weight
β	-	Full width at half maximum (FWHM)
η	-	Efficiency
$\dot{m}$	-	Mass flow rate
θ	-	Peak position angle
λ	-	Wavelength
v	-	Viscosity
ρ	-	Density
σ	-	Uncertainty

φ - Weight concentration

LIST OF SUBSCRIPTS

$C_{p,bf}$	-	Specific heat capacity of base fluid
$C_{p,nf}$	-	Specific heat capacity of nanofluid
$C_{p,np}$	-	Specific heat capacity of nanoparticles
I_{max}	-	Maximum current
I_{sc}	-	Short-circuit current
P_{max}	-	Maximum electrical power
Q_t	-	Collected heat
T_i	-	Inlet temperature
T_o	-	Outlet temperature
V_{max}	-	Maximum voltage
V_{oc}	-	Open-circuit voltage
w_{bf}	-	Weight of base fluid
w_{np}	-	Weight of nanoparticles
η_e	-	Electrical efficiency
η_o	-	Overall efficiency
η_{th}	-	Thermal efficiency
ρ_{bf}	-	Density of base fluid
ρ_{nf}	-	Density of nanofluid
ρ_{np}	-	Density of nanoparticles
σ_{X_n}	-	Uncertainty of parameter X_n
$\sigma_{\dot{m}}$	-	Uncertainty of mass flow rate
$\sigma_{\eta_{el}}$	-	Uncertainty of electrical efficiency

σ_{η_o}	-	Uncertainty of overall efficiency
$\sigma_{\eta_{th}}$	-	Uncertainty of thermal efficiency
σ_G	-	Uncertainty of irradiance
σ_P	-	Uncertainty of power
σ_R	-	Uncertainty of function R
σ_T	-	Uncertainty of temperature

LIST OF APPENDICES

LIST OF PUBLICATIONS

The followings are the list of publications related to the work on this thesis:

JOURNAL PAPER:

Rafaizul, N.I.A.M., Rosli, M.A.M., Salimen, N., Herawan, S.G. and Hussain, F., 2024. Formulation of Graphene Nanoplatelets Water-Based Nanofluids using Polyvinylpyrrolidone (PVP) as Surfactant. *Journal of Advanced Research in Micro and Nano Engineering*, *16*(1), pp.35-47.

Rafaizul, N.I.A.M., Rosli, M.A.M., Salimen, N., Habibi, I.A., Permanasari, A.A. and Herawan, S.G., 2024. Applications of Graphene Nanoplatelets as Working Fluids in Photovoltaic Thermal Systems: A Review. *International Journal of Nanoelectronics and Materials (IJNeaM)*, *17*(3), pp.343-353.

CONFERENCE PROCEEDINGS:

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BOOK CHAPTER:

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