

HYBRID-INSPIRED COOLANT ADDITIVE
FOR RADIATOR APPLICATION

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DOCTOR OF PHILOSOPHY
(MECHANICAL ENGINEERING)

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 award of the degree Doctor of Philosophy (Mechanical Engineering).

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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.

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ABSTRAK

Oleh kerana permintaan yang semakin meningkat dalam aplikasi perindustrian, nanofluid telah menarik perhatian penyelidik yang banyak dalam beberapa dekad yang lalu. Nanoselulosa dengan tambahan air (W) dan Ethylene Glycol (EG) untuk penyejuk untuk aplikasi radiator kereta mempamerkan sifat-sifat bermanfaat untuk meningkatkan kecekapan radiator. Kecekapan yang lebih baik membawa kepada reka bentuk radiator yang lebih padat dan meningkatkan ketahanan enjin. Tumpuan kerja sekarang adalah untuk menyiasat prestasi oksida logam mono atau hibrid seperti Al_2O_3 dan TiO_2 dengan atau tanpa nanocellulose (CNC) diekstrak tumbuhan dengan kepekatan yang berbeza-beza sebagai nanofluid pemindahan haba yang lebih baik berbanding dengan air suling sebagai penyejuk radiator. Oleh itu, objektif kerja sekarang adalah untuk memperbaiki dan mencipta penyejuk radiator baru berdasarkan aluminium oksida dan CNC dengan penyejuk yang sedia ada (EG) dan untuk mengkaji hakisan penyejuk CNC pada radiator automotif. Skop kerja sekarang ialah CNC tersebar di dalam cairan asas EG dan W dengan nisbah 60:40. Kepekatan isipadu seperti 0.1, 0.5, dan 0.9% sampel yang diuji telah digunakan untuk siasatan lanjut. Prestasi pemindahan haba komparatif nanofluid yang disediakan dan cecair pengangkutan haba konveksi telah disiasat dalam rig ujian radiator automotif di bawah dua keadaan yang berbeza iaitu dengan dan tanpa pengaruh penggubal draf. Hasil yang diperolehi mendedahkan bahawa pekali pemindahan haba, pemindahan haba konveksi, nombor Reynolds, nombor Nusselt mempunyai hubungan berkadar dengan kadar aliran volumetrik.

Puncak penyerapan tertinggi telah dilihat dalam kepekatan volum 0.9% TiO_2 , Al_2O_3 , CNC, $\text{Al}_2\text{O}_3 / \text{TiO}_2$, dan nanofluid $\text{Al}_2\text{O}_3 / \text{CNC}$ yang menunjukkan kestabilan suspensi nanofluid yang lebih baik. Peningkatan kekonduksian haba yang lebih baik telah diperhatikan untuk nanofluid Al_2O_3 dalam semua nanofluid mono yang diikuti oleh CNC dan TiO_2 nanofluid masing-masing. Kekonduksian termal daripada nanofluid hibrid $\text{Al}_2\text{O}_3 / \text{CNC}$ dengan kepekatan isipadu sebanyak 0.9% didapati lebih tinggi daripada nanofluid hibrid $\text{Al}_2\text{O}_3 / \text{TiO}_2$. Nanofluid hibrid $\text{Al}_2\text{O}_3 / \text{CNC}$ mendominasi nanofluid mono dan hibrid lain dari segi kelikatan pada semua kepekatan isipadu. Nanofluid CNC (semua kepekatan isipadu) memaparkan kapasiti haba yang paling tinggi daripada nanofluida mono yang lain. Di samping itu, dalam kedua-dua nanofluid hibrid, $\text{Al}_2\text{O}_3 / \text{CNC}$ menunjukkan kapasiti haba yang paling rendah. Kepekatan volum yang dioptimumkan dari alat analitis statistik didapati 0.5%. Kepekatan isipadu Nanofluid dengan 0.5% (CNC / Al_2O_3 dan CNC) dipilih sebagai cecair pengangkutan termal berbanding dengan campuran EG-W convection. Hasil eksperimen menunjukkan bahawa pekali pemindahan haba eksperimen, pemindahan haba konveksi, nombor Reynolds, nombor Nusselt mempunyai hubungan berkadar dengan kadar aliran volumetrik.

ABSTRACT

Due to the increasing demand in the industrial application, nanofluids has attracted a considerable attention of researchers in the last few decades. Nanocellulose with water (W) and Ethylene Glycol (EG) addition to coolant for car radiator application exhibits beneficial properties to improve the efficiency of the radiator. Improved efficiency leads to more compact design of the radiator and increase the durability of the engine. The focus of the present work is to investigate the performance of mono or hybrid metal oxide such as Al_2O_3 and TiO_2 with or without plant base extracted nanocellulose (CNC) with varying concentration as a better heat transfer nanofluid as compared to distilled water as radiator coolant. Therefore, the objective of the present work is to improve and create a new radiator coolant based on aluminium oxide and CNC with readily available coolants (EG) and to investigate the erosion of CNC coolant on automotive radiator. The scope of the present work is CNC dispersed in base fluid of EG and W with 60:40 ratio. The volume concentrations such as 0.1, 0.5, and 0.9% of tested samples have been used for further investigation. Comparative heat transfer performance of prepared nanofluids and convection thermal transport fluid has been investigated in the automotive radiator test rig under two different circumstances i.e., with and without the influence of draft fan. Obtained result reveals that heat transfer coefficient, convective heat transfer, Reynolds number, Nusselt number has proportional relation with volumetric flow rate.

The highest absorption peak have been noticed in 0.9% volume concentration of TiO_2 , Al_2O_3 , CNC, $\text{Al}_2\text{O}_3/\text{TiO}_2$, and $\text{Al}_2\text{O}_3/\text{CNC}$ nanofluids which indicate the better stability of nanofluids suspension. Better thermal conductivity improvement have been observed for Al_2O_3 nanofluids in all mono nanofluids followed by CNC and TiO_2 nanofluids respectively. Thermal conductivity of $\text{Al}_2\text{O}_3/\text{CNC}$ hybrid nanofluids with 0.9% volume concentration has been found to be superior to $\text{Al}_2\text{O}_3/\text{TiO}_2$ hybrid nanofluids. $\text{Al}_2\text{O}_3/\text{CNC}$ hybrid nanofluid dominates over other mono and hybrid nanofluids in terms of viscosity at all volume concentrations. CNC nanofluids (all volume concentrations) exhibited the highest specific heat capacity than other mono nanofluids. Additionally, in both the hybrid nanofluids, $\text{Al}_2\text{O}_3/\text{CNC}$ showed the lowest specific heat capacity. The optimized volume concentration from statistical analytical tool was found to be 0.5%. Nanofluid volume concentration with 0.5% (CNC/ Al_2O_3 and CNC) was selected as thermal transport fluid to be compared with convectional EG-W mixture. The experiment result shows that experimental heat transfer coefficient, convective heat transfer, Reynolds number, Nusselt number has proportional relation with volumetric flow rate.

TABLE OF CONTENT

DECLARATION	
TITLE PAGE	
ACKNOWLEDGEMENTS	ii
ABSTRAK	iii
ABSTRACT	iv
TABLE OF CONTENT	v
LIST OF TABLES	x
LIST OF SYMBOLS	xiv
CHAPTER 1 INTRODUCTION	1
1.1 Introduction	1
1.2 Project Background	1
1.3 Problem Statement	2
1.4 Objectives	3
1.5 Scope	3
1.6 Significance of the Study	3
1.7 Thesis Outline	4
CHAPTER 2 LITERATURE REVIEW	5
2.1 Introduction	5
2.2 Background of Project	5
2.3 Coolant	5
2.3.1 Water	6
2.3.2 Ethylene Glycol	6
2.3.3 Diethylene Glycol	7

2.3.4	Propylene Glycol	7
2.3.5	Freezing Point, Viscosity and Specific Heat of Ethylene Glycol	8
2.4	Radiator	10
2.4.1	Down Flow Radiator	11
2.4.2	Cross Flow Radiator	12
2.5	Nanocellulose	13
2.6	Nanofluids Innovation	13
2.6.1	Thermal Conductivity Investigation	14
2.6.2	Influence of Nanoparticles Volume Concentration on Thermal Conductivity	15
2.6.3	Influence of Particle Size on Thermal Conductivity	17
2.6.4	Effect of Density on Thermal Conductivity	18
2.7	Aluminium Oxide	19
2.7.1	Viscosity and Density of Aluminum Oxide Nano-fluid	21
2.7.2	Enhancing the Stability of the Nanofluids	21
2.7.3	Stability Evaluation Methods	22
2.8	Hybrid/Composite Nanofluid	23
2.8.1	Definition of Hybrid/Composite Nanofluids	23
2.8.2	Nanoparticles Mixture Ratio	24
2.9	Preparation of Hybrid/Composite Nanofluids	24
2.9.1	One-Step Method	25
2.9.2	Two-Step Method	25
2.10	Convection	26
2.10.1	Forced Convection	26
2.11	Advantages and Disadvantages of Nanofluids	26
2.11.1	Advantages	26

2.11.2	Disadvantages	27
2.13	Summary	33
CHAPTER 3 METHODOLOGY		34
3.1	Introduction	34
3.2	Preparation of Nanocellulose Coolant	34
3.2.1	Characterization Techniques	35
3.2.2	Thermophysical Properties	38
3.3	Test Rig Setup	43
3.4	Radiator Test Rig	43
3.5	Experiment Apparatus	44
3.5.1	24 V Pump	44
3.5.2	1 kW Heater with PID Temperature Controller	44
3.5.3	Thermocouples	45
3.5.4	Radiator	45
3.5.5	Arduino Software	45
3.6	Experimental Procedure	46
3.7	Experimental Parameters	47
3.8	Dimensionless Parameters	48
3.8.1	Reynolds Number (Re)	48
3.8.2	Prandtl Number (Pr)	48
3.8.3	Nusselt Number (Nu)	49
CHAPTER 4 RESULTS AND DISCUSSION		50
4.1	Introduction	50
4.2	Nanofluid Dispersion and Characterization	50

4.2.1	Sedimentation Observation	50
4.2.2	Transmission Electron Microscopy (TEM)	52
4.2.3	UV-Vis Spectrum analysis	55
4.2.4	X-Ray Diffraction (XRD)	59
4.2.5	Fourier Transform Infrared (FTIR) Spectroscopy	61
4.2.6	Field Emission Scanning Electron Microscopy (FESEM) Evaluation	62
4.3	Thermo-Physical Properties Evaluation	65
4.3.1	Thermal Conductivity of Nanofluids	65
4.3.2	Dynamic Viscosity of Nanofluids	67
4.3.3	Density Nanofluids	69
4.3.4	Specific Heat of Nanofluids	69
4.3.5	Nanofluid Optimization	71
4.3.6	Heat Transfer and Flow Behaviour Analysis	72
4.3.7	Experimental Heat Transfer Coefficient	72
4.3.8	Convection Heat Transfer	73
4.3.9	Reynolds Number	74
4.3.10	Nusselt Number	75
4.3.11	Thermal Heat Analysis of Nanofluid	76
4.3.12	Temperature at Radiator Fin	80
4.4	Statistical analysis	81
4.4.1	Development of First Order and Second Order of thermal conductivity (CNC/Al ₂ O ₃) using RSM	82
4.4.2	Development of First Order and Second Order of Viscosity (CNC/Al ₂ O ₃) using RSM	84
4.4.3	Development of First Order and Second Order of Density using RSM	87
4.4.4	Development of First Order and Second Order of Specific Heat (CNC/Al ₂ O ₃) using RSM	89

CHAPTER 5 CONCLUSION AND RECOMMENDATION	92
5.1 Introduction	92
5.2 Conclusion	92
5.3 Recommendation	93
REFERENCES	95
APPENDIX A	104

LIST OF TABLES

Table 2.1	Summary of previous studies related to nanofluid	13
Table 2.2	Thermal conductivity (W/m-K) of various material at 300 K	14
Table 2.3	94% of Aluminium oxide data sheet	19
Table 3.1	Parameters and description of variables of the experiment	46
Table 4.1	Qualitative stability evaluation of mono and hybrid nanofluids	51
Table 4.2	Thermo-physical measurement of varying volume concentration at 70 °C	70
Table 4.3	Anova analysis for thermal conductivity	82
Table 4.4	Anova table for viscosity	84
Table 4.5	Anova table for density	87
Table 4.6	Anova table for specific heat	89

LIST OF FIGURES

Figure 2.1	Ethylene Glycol structure	6
Figure 2.2	Diethylene Glycol structure	7
Figure 2.3	Propylene Glycol structure	8
Figure 2.4	Freezing points of EG and W	8
Figure 2.5	Freezing points of EG and W 2	9
Figure 2.6	Viscosity of EG and W	9
Figure 2.7	Specific heat of EG and W	9
Figure 2.8	Boiling point of EG and W	9
Figure 2.9	Cooling system in car	10
Figure 2.10	Down flow radiator	11
Figure 2.11	Cross flow radiator	12
Figure 2.12	Thermal conductivity of Al ₂ O ₃ -Water nanofluids at different concentration	15
Figure 2.13	Thermal conductivity of EG based copper nanofluids	15
Figure 2.14	Relationship between weight fraction and thermal conductivity ratio of Al ₂ O ₃ /Water nanofluid with different particular sizes at 10 °C	16
Figure 2.15	Relationship between weight fraction and thermal conductivity ratio of Al ₂ O ₃ /Water nanofluid with different particular sizes at 30 °C	17
Figure 2.16	Relationship between weight fraction and thermal conductivity ratio of Al ₂ O ₃ /Water nanofluid with different particular sizes at 50°C	17
Figure 2.17	Density of Al ₂ O ₃ -Radiator coolant nanofluid as a function of temperature	18
Figure 2.18	Molecular structure of Al ₂ O ₃	19
Figure 2.19	Schematic diagram of two-step method for nanofluids preparations	24
Figure 2.20	3N full factorial	29
Figure 2.21	CCD for 3 design variables	31
Figure 2.22	BBD for 3 design variables	31
Figure 3.1	Schematic representation of X-ray diffraction	35

Figure 3.2	Schematic representation of FTIR spectroscopy	36
Figure 3.3	Thermal conductivity and heat capacity device	39
Figure 3.4	Brookfield DV-I prime viscometer	40
Figure 3.5	Viscosity calibration for pure water	41
Figure 3.6	Schematic diagram of radiator test rig	42
Figure 3.7	Schematic diagram of Arduino circuit	45
Figure 3.8	Complete setup of radiator test rig	46
Figure 4.1	TEM image of Al ₂ O ₃ dispersed nanofluids (Magnification X19,000)	53
Figure 4.2	TEM image of TiO ₂ dispersed nanofluids (Magnification X29,000)	53
Figure 4.3	TEM image of CNC dispersed nanofluids (Magnification X50,000)	53
Figure 4.4	TEM image of Al ₂ O ₃ /TiO ₂ dispersed nanofluids (Magnification X50,000)	54
Figure 4.5	TEM image of Al ₂ O ₃ /CNC dispersed nanofluids (Magnification X62,000)	54
Figure 4.6	UV spectrum of TiO ₂ nanofluid with various concentrations	55
Figure 4.7	UV spectrum of Al ₂ O ₃ nanofluid with various concentrations	56
Figure 4.8	UV spectrum of CNC nanofluid with various concentrations	56
Figure 4.9	UV spectrum of Al ₂ O ₃ /CNC nanofluid with various concentrations	57
Figure 4.10	UV spectrum of Al ₂ O ₃ /TiO ₂ nanofluid with various Concentrations	57
Figure 4.11	XRD pattern of Al ₂ O ₃ nanoparticles	58
Figure 4.12	XRD pattern of CNC nanoparticles	59
Figure 4.13	XRD pattern of TiO ₂ nanoparticles	59
Figure 4.14	FTIR spectrums of TiO ₂ , Al ₂ O ₃ (mono) and Al ₂ O ₃ /TiO ₂ (hybrid) nanofluids	60
Figure 4.15	FTIR spectrums of CNC mono and Al ₂ O ₃ /CNC hybrid Nanofluids	61
Figure 4.16a	FESEM micrograph of Al ₂ O ₃ nanoparticles (Magnification X100,000)	61
Figure 4.16b	EDX spectrum of Al ₂ O ₃ nanoparticles	62
Figure 4.17a	FESEM micrograph of CNC nanoparticles (a) film (Magnification X100,000) and (b) powder (Magnification X100,000)	62
Figure 4.17b	EDX spectrum of CNC nanoparticles	63

Figure 4.18a	FESEM micrograph of TiO ₂ nanoparticles (Magnification X100,000)	63
Figure 4.18b	EDX spectrum of TiO ₂ nanoparticles	64
Figure 4.19	Thermal conductivity of all nanofluids vs. temperature plot	66
Figure 4.20	Viscosity with respect to temperature	67
Figure 4.21	Density comparison as a function of temperature and volume	68
Figure 4.22	Comparison of specific heat capacity of mono and hybrid nanofluids with various volume concentrations	70
Figure 4.23	Experimental heat transfer coefficient as a function of flow rate	72
Figure 4.24	Convective heat transfer as a function of flow rate	73
Figure 4.25	Reynolds number vs. flow rate plot	74
Figure 4.26	Nusselt number vs. flow rate plot	75
Figure 4.27	Thermal imaging of base fluids (EG-W) in radiator (a)-(e)	76
Figure 4.28	Thermal imaging of Al ₂ O ₃ /CNC with 0.5% volume concentration in radiator (a)-(e)	77
Figure 4.29	Thermal imaging of CNC with 0.5% volume concentration in radiator (a)-(e)	78
Figure 4.30	Temperature profile for 3.5 LMP flow rate at radiator fin	79
Figure 4.31	Temperature profile for 4.5 LMP flow rate at radiator fin	79
Figure 4.32	Temperature profile for 5.5 LMP flow rate at radiator fin	80
Figure 4.33	The predicted thermal conductivity	82
Figure 4.34	Factorial plot for thermal conductivity	83
Figure 4.35	Contour plot for thermal conductivity	83
Figure 4.36	The predicted viscosity	85
Figure 4.37	Factorial plot for viscosity	85
Figure 4.38	Contour plot for viscosity	86
Figure 4.39	Factorial plot for density	87
Figure 4.40	Interaction plot for density	88
Figure 4.41	Factorial plot for specific heat	89
Figure 4.42	Interaction plot for specific heat	90

LIST OF SYMBOLS

ϕ	Volume concentration
ρ	Density
Ω	Weight concentration
μ	Dynamic Viscosity
Re	Reynolds Number
D_h	Hydraulic Diameter
Pr	Prandtl Number
C	Specific Heat Capacity
k	Thermal Conductivity
Nu	Nusselt Number
h	Heat Transfer
V	Volume
ω	Specific Weight

LIST OF ABBREVIATIONS

CNC	Crystalline Nanocellulose
Al ₂ O ₃	Aluminium Oxide
FESEM	Field Emission Scanning Electron Microscope
EDX	Energy Dispersive X-ray Detector
TEM	Transmission Electron Microscope
TiO ₂	Titanium dioxide
FTIR	Fourier-transform infrared spectroscopy
XRD	X-Ray Diffraction
EG	Ethylene glycol
DEG	Diethylene Glycol
RSM	Response Surface Method
WD	Working Distance
ZnO ₂	Zinc Dioxide
Fe	Iron
CuO	Copper Oxide
A ² LL	Advanced Automotive Liquid Lab
UV-Vis	Ultra Violet-Visible
PVD	Physical Vapor Deposition
Al	Aluminium
O	Oxygen
C	Carbon
ANOVA	Analysis of Variance

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