HYBRID-INSPIRED COOLANT ADDITIVE FOR RADIATOR APPLICATION

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DOCTOR OF PHILOSOPHY
(MECHANICAL ENGINEERING)

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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 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, Al_2O_3 / TiO_2, dan nanofluid Al_2O_3 / CNC yang menunjukkan kestabilan suspensi nanofluid yang lebih baik. Peningkatan kekonduksian haba yang lebih baik telah diperhatikan untuk nanofluen Al_2O_3 dalam semua nanofluid mono yang diikuti oleh CNC dan TiO_2 nanofluid masing-masing. Kekonduksian termal daripada nanofluid hibrid Al_2O_3 / CNC dengan kepekatan isipadu sebanyak 0.9% didapati lebih tinggi daripada nanofluid hibrid Al_2O_3 / TiO_2. Nanofluid hibrid Al_2O_3 / 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, Al_2O_3 / 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, Al_2O_3/TiO_2, and Al_2O_3/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 Al_2O_3/CNC hybrid nanofluids with 0.9% volume concentration has been found to be superior to Al_2O_3/TiO_2 hybrid nanofluids. Al_2O_3/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, Al_2O_3/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.

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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_2O_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^2LL	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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