HEAT TRANSFER ENHANCEMENT USING NANOFLUIDS IN THE AUTOMOTIVE COOLING SYSTEM

ADNAN MOHAMMED HUSSEIN

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Signature:
Name of Supervisor: PROF. DATO' DR. HJ. ROSLI BIN ABU BAKAR
Position: PROFESSOR
Date: DECEMBER 2014

Signature:
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LIST OF ABBREVIATIONS

Symbol	Meaning
A	Area
B	Bias error
C	Specific heat capacity
d	Minor dimension of radiator tube
D	Major dimension of radiator tube
E	Voltage
f	Friction factor
F	Force
f_s	Skin friction coefficient
g	Gravity
h	Heat transfer coefficient
I	Current
k	Thermal conductivity
L	Length
LPM	Liter per minute
m	Mass
n	Number of radiator tubes
N	Dimensionless number
p	Pressure
P	Power
pH	Acidity scale
$\dot{Q}$	Heat transfer rate
R	Precision error
S	Specific gravity
T	Temperature
u	Velocity
$\dot{V}$	Volume flowrate
$\dot{m}$	Mass flowrate
$\bar{\sigma}$	Average standard deviation
σ	Standard deviation
$\forall$	Volume

α	Thermal diffusivity
$\emptyset$	Volume fraction of solid phase
φ	Weight ratio of solid phase
μ	Viscosity
ρ	Density
η	Efficiency
CFD	Computational Fluid Dynamics
EG	Ethylene glycol
max	Maximum
min	Minimum
rpm	Revolution per minute

Subscripts

eff	Effective
f	Liquid phase
p	Solid phase
nf	Nanofluid phase
in	Inlet
out	Outlet
c	Coolant
cross	Cross section
s	Surface
b	Bulk
rej	Rejected
x	x-axis
y	y-axis
z	z-axis
av	Average

Dimensionless Number

Nu	Nusselt number
Pe	Peclet number
Pr	Prandtl number
Re	Reynolds number

ABSTRACT

The automotive cooling system is a significant part of the car that removes the engine generated heat outside across the radiator. The increasing demand of nanofluids for industrial applications has led many researchers to focus on the subject in the last decade. The limited thermophysical properties and heat transfer of liquids across the car radiator have resulted in much research to find better coolant fluids. Space constraints are another key issue in the automotive applications to remove heat from high heat flux generating surfaces of automobile engines. In order to improve thermophysical properties of the coolant fluid to enhance heat transfer in the automotive cooling system, nanofluids have been utilized as a coolant. This study aims to enhance heat transfer with a slight pressure drop in the automotive cooling system by using multi types of nanoparticles dispersed in various types of basefluids. The appropriate type of nanofluids and the influence of different nanofluids on the heat transfer performance for the car cooling system have been identified. The radiator performance efficiency to reduce the radiator size and weight has been studied. The friction factor and heat transfer enhancement using different types of nanofluids are studied. The TiO_2 and SiO_2 nanopowders suspended in four different base fluids (pure water, EG, 10%EG+90%W and 20%EG+80%W) are prepared experimentally. The thermophysical properties of both nanofluids and base fluids have been measured and validated with the standard and the experimental data available. The experimental test rig setup included a car radiator, collecting tank, pump, rotameter, valves and plastic tubes. The evaluation of the friction factor and heat transfer coefficient by taking readings of the temperature and pressure drop under laminar flow condition were conducted. The volume flowrate was found to be in the range of (1-5LPM) for pure water and (3-12LPM) for other base fluids; while, the inlet temperature and nanofluid volume fraction were in the range of (60-80^{o}C) and (1- 4%) respectively. The CFD analysis for the nanofluids flow inside the flat tube of a car radiator under laminar flow was carried out. A simulation study was conducted by using the finite volume method to solve the continuity, momentum, and energy equations. The geometry meshing of problem with a description of the boundary conditions was performed by using commercial software to determine the friction factor and heat transfer coefficient. The experimental results showed the friction factor decreased with the increase of the volume flowrate and increased with the increase of nanofluid volume fraction but slightly decreased with the increase of the inlet temperature. The simulation results showed good agreement with the experimental data with deviation not exceeding 4%. The experimental results showed the heat transfer coefficient increased with the increase of the volume flowrate, the nanofluid volume fraction and the inlet temperature. The simulation results showed good agreement with the experimental data with deviation not exceeding 6%. In addition, the SiO_2 nanofluid showed higher values of the friction factor and heat transfer coefficient than TiO_2 nanofluid. The base fluid (20%EG+80%W) gave higher values of the heat transfer coefficient and proper values of friction factor compared to other base fluids. The 4% of SiO_2 nanoparticles suspended in (20%EG+80%W) base fluid was significant augmentation of heat transfer in the automobile radiator. The regression equations among input (Reynolds number, Prandtl number, and nanofluid volume fraction) and response (friction factor and Nusselt number) were found to be correlated. The experimental results were compared with the experimental data available and there were good agreements with a maximum deviation of approximately 5%.

ABSTRAK

Sistem penyejukan automotif adalah sebahagian penting dari kereta kerana mengeluarkan penjanaan haba enjin luar di seluruh radiator. Pada dekad yang lalu, permintaan cecair nano semakin meningkat bagi aplikasi perindustrian telah menjadi tumpuan pada ramai penyelidik. Cecair terhad sifat haba dan pemindahan haba di seluruh radiator kereta telah membawa kepada mencari cecair penyejuk yang lebih baik. Kekangan ruang adalah satu lagi isu utama dalam aplikasi industri untuk mengeluarkan haba dari haba yang tinggi permukaan menjana fluks enjin kereta. Dalam usaha untuk memperbaiki sifat haba cecair penyejuk untuk meningkatkan pemindahan haba dalam sistem penyejukan automotif, nanofluids telah digunakan sebagai penyejuk. Jenis sesuai nanofluid dan pengaruh nanofluids berbeza memberi kesan kepada prestasi pemindahan haba untuk sistem penyejukan kereta telah dikenal pasti. Kecekapan prestasi radiator untuk mengurangkan saiz radiator dan berat badan telah dikaji. Tesis ini termasuk kedua-dua kajian eksperimen dan simulasi untuk meningkatkan pemindahan haba, serta dibuat pentanda aras bagi kajian ini menggunakan sistem penyejukan automotif. Pelbagai jenis nanofluids telah dikaji, termasuklah faktor geseran dan pekali pemindahan haba. Nanopowders TiO_2 dan SiO_2 di gabungkan dengan empat jenis cecair asas yang berbeza (iaitu air tulen, EG, 10%EG+90%W dan 20%EG+80 %W) disediakan untuk uji kaji ini. Ciri-ciri kedua-dua termofizikal nanofluids dan cecair asas diukur serta disahkan dengan standard data uji kaji yang ada. Ujian ini termasuk persediaan radiator kereta dan kesan di bawah keadaan operasi pada peningkatan pemindahan haba dianalisis di bawah keadaan aliran lamina. Kadar alir isipadu, adalah dalam lingkungan (1- 5LPM) untuk air tulen dan (3-12LPM) untuk cecair asas lain; manakala, suhu masuk dan kepekatan jumlah nanofluid adalah dalam lingkungan (60-80 oC) dan (1 - 4%) masing-masing. Di samping itu, analisis CFD untuk cecair nano mengalir dalam tiub rata radiator kereta di bawah aliran lamina juga dijalankan. Kajian simulasi dijalankan dengan menggunakan keadah number berangka tidak terhingga bagi menyelesaikan keterusan, momentum dan tenaga persamaan. Proses geometri bersirat dan keadaan sempadan adalah dilakukan dengan menggunakan GAMBIT kemudian menggunakan perisian FLUENT untuk mencari faktor geseran dan pekali pemindahan haba. Keputusan eksperimen menunjukkan faktor geseran berkurang dengan peningkatan kadar alir jumlah dan meningkat dengan pecahan isipadu nanofluid tetapi sedikit berkurangan dengan peningkatan suhu masukan. Tambahan pula, keputusan simulasi menunjukkan keadaan yang baik dengan data uji kaji dengan sisihan tidak melebihi 4%. Keputusan eksperimen menunjukkan pemindahan haba pekali bertambah dengan peningkatan kadar alir isipadu, pecahan jumlah nanofluid dan suhu masukan. Begitu juga, keputusan simulasi menunjukkan keputusan yang baik antara data uji kaji dengan sisihan tidak lebih daripada 6%. Tambahan pula, cecair nano SiO_2 muncul nilai yang tinggi faktor geseran dan pekali pemindahan haba daripada TiO_2 cecair nano. Selain itu, cecair (20%EG+80%W) memberikan nilai yang tinggi pekali pemindahan haba dan nilai-nilai yang betul faktor geseran daripada cecair asas lain. Ia seolah-olah menunjukan bahawa nanopartikel SiO_2 tersebar ke (20%EG+80%W) cecair asas adalah kerana peningkatan yang ketara daripada sifat haba daripada yang lain. Ia juga menunjukan, nanopartikel SiO_2 tersebar ke (20%EG+80%W) cecair asas yang memberi kesan pembesaran yang ketara pemindahan haba dalam radiator kereta. Persamaan regresi antara input (nombor Reynolds, nombor Prandtl dan nanofluid jumlah penumpuan) dan tindak balas (faktor geseran dan nombor Nusselt) telah dijumpai. Keputusan analisis menunjukkan bahawa parameter input penting untuk meningkatkan pemindahan haba dengan sistem penyejukan automotif. Perbandingan antara keputusan eksperimen dan data penyelidik lain turut dijalankan dan terdapat satu keadaan yang baik dengan sisihan maksimum kira-kira 5%.

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