COMPUTATIONAL ANALYSIS OF NANOFLUIDS IN CAR RADIATOR

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To my beloved parents

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ABSTRACT

Nanofluids are basically nanoparticles in base fluids. Nanofluids have unique features different from conventional solid-liquid mixtures in which nano sized particles of metals and non-metals are dispersed. Due to enhancement of mechanical properties, nanofluids are widely used in heat transfer industries. Two type of base fluids which are water and 50-50 mixture of Ethylene Glycol with water (EGW) are tested. Copper (Cu) and Alumina (Al_2O_3) nanoparticles with volume fraction or concentration of 0.5 percent and 5 percent are examined in this study. In the recent decades, car manufacturers are exploring nanotechnology and applying onto mass production car such as Hybrid car that symbolize green products. Nanofluids in car radiator will increase heat transfer of the engine, reducing radiator size hence reducing fuel consumption and higher efficiency. On the other hand, water based nanofluids have better heat transfer compared to EGW based nanofluids. Results also show higher concentration will have better heat transfer. Thermal conductivity of nanoparticles will directly affect the thermal conductivity of the nanofluids and it is proportional related.

ABSTRAK

Nanofluids dasarnya nanopartikel dalam cecair asas. Nanofluids mempunyai ciri-ciri yang unik yang berbeza daripada campuran pepejal-cecair konvensional di mana zarah nano bersaiz logam dan bukan logam tersebar dalam nanofluids. Oleh kerana peningkatan sifat mekanikal, nanofluids digunakan secara meluas dalam industri pemindahan haba. Dua jenis asas cecair iaitu air dan campuran 50-50 Ethylene Glycol dengan air (EGW) telah diuji. Tembaga (Cu) dan Alumina (Al_2O_3) nanopartikel dengan jumlah kepekatan 0.5 peratus dan 5 peratus dikaji dalam kajian ini. Dalam dekad kebelakangan ini, pengeluar kereta sedang mengkaji teknologi nano dan melaksanakan ke pengeluaran besar-besaran kereta seperti kereta hibrid yang melambangkan produk hijau. Nanofluids dalam radiator kereta akan meningkatkan pemindahan haba enjin, mengurangkan saiz radiator seterusnya mengurangkan penggunaan bahan api dan kecekapan yang lebih tinggi. Sebaliknya, nanofluids berasaskan air mempunyai pemindahan haba yang lebih baik berbanding dengan EGW nanofluids berasaskan. Keputusan juga menunjukkan kepekatan yang lebih tinggi akan mempunyai pemindahan haba yang lebih baik. Kekonduksian terma nanopartikel akan memberi kesan secara langsung kepada keberaliran haba yang nanofluids.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Nomenclature

G	-	Interfacial conductance
h	-	Equivalent thickness – distance over which the temperature drop is the same as at the interface
J	-	Joule
J_Q	-	Heat flux
k	-	Thermal conductivity
K	-	Kelvin
Pa	-	Pascal
Q	-	Heat
r	-	Particles radius
R_k	-	Thermal interfacial resistance, Kapitza Resistance
s	-	Second
T	-	Temperature

Greeks Symbols

$\emptyset$	-	Volume fraction
μ	-	Dynamic Viscosity
θ	-	Angle between the heat direction and particle axis
Δ	-	Difference

Subscript

f	-	base fluid
eff	-	effective
p	-	solid particle
nf	-	nanofluids

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Vehicle thermal management is a crosscutting technology because it directly or indirectly affects engine performance, fuel economy, safety, reliability, aerodynamics, driver and passenger comfort, material selection, emissions, maintenance and component life of a vehicle. The heat rejection requirements of vehicles are continually increasing due to trends toward more power output with smaller engine.

In the past few decades, rapid developments of nanotechnology have led to emerging of new generation of coolants called “nanofluids”. Nanofluids are defined as suspensions of nanoparticles in a base fluid. The size of nanoparticles are varied from 1 to 100 nm, with the commonly use base fluid of water, ethylene glycol or mixture of both.

Nanotechnology is being used or considered for use in many application targeted to provide cleaner, more efficient energy supplies and uses. Most of the research have been done on nanofluids are supporting the fact and theory of nanofluids enhance the heat transfer of the system. By carefully selection of particles material, size, shape, concentration and base fluid type, nanofluids will definitely perform much better coolant than conventional water coolant.

Xiang-Qi et al (2007) highlighted that the most obvious problem of the early stage of development by Maxwell (1873) is lack of suspension of metal or metal oxide particles in the base fluid. With the recent technology, researchers are expected nanofluids have increase the stability of the suspensions and improve the heat transfer capabilities. However, fluid flow and heat transfer characteristic in various base fluids with suspended nanoparticles can be altered. Despite the benefits of using nanofluids in various industries and the suspensions problem of nanoparticles, the other challenges are included the lack of agreement between experimental results from different researchers and lack of theoretical understanding of the mechanisms.

Brandon Fell et al (2007) mentioned that nanofluids increase conduction and convection coefficients, allowing for more heat transfer out of the coolant. General Motor is involving in development of nanofluids use in automobile industry. The benchmark for heat transfer of current radiators is 140kW of heat at an inlet temperature of 95ºC. The basic radiator has a width of 0.5 to 0.6 meter, a height of 0.4 to 0.7 meter and a depth of 0.025 to 0.038 meter, however, these dimension are greatly depends on the make and engine size of the vehicle.

Dongsheng et al (2009) highlighted the advantages of using nanofluids compared to conventional solid liquid suspensions. The benefits are included high specific surface area and therefore more heat transfer surface between particles and fluids, high dispersion stability with predominant Brownian motion of particles, Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification, reduced particle clogging as compared to convention slurries, thus promoting system miniaturization, and adjustable properties, including thermal conductivity and surface wettability, by varying particle concentrations to suit different applications.

As highlighted above, the size of nanoparticles are critical due to stability of nanofluids, Sadik et al (2009) listed the processes of making metal nanoparticles include mechanical milling, inert-gas condensation technique, chemical precipitation, chemical vapor deposition, micro-emulsions, spray pyrolysis and thermal spraying.

Clement et al (2011) mentioned that the changes of viscosity, density and thermal conductivity are critical in nanofluids. There are five classical models for effective thermal conductivity of nanofluids, this also shows the aforementioned disadvantages, which is lack of agreement between results. However, Maxwell's model is widely used or modified such as Hamilton-Crosser's model.

John Phillip et al (2012) highlighted that enhancement in thermal conductivity with decrease in particle size. Zoubida (2012) grouped the classical model for dynamic viscosity, included Brickman model, Einstein model and other, while Brickman model is widely used in other research. Few assumptions have to be considered before using nanofluids in the systems includes no chemical reactions, negligible external forces, dilute mixture, negligible viscous dissipation, negligible radiative heat transfer and thermal equilibrium in nanoparticle and base fluids.

1.2 Research Objective

The objective of this thesis are:

1) To analyze and to compare heat transfer of car radiator with and without nanofluids using computational results.
2) To analyze and to compare heat transfer of car radiator with different nanofluids with different base fluid, nanoparticles and concentration.

1.3 Problem Statement

Heat losses in real thermodynamics processes results in heating of combustion chamber surfaces and necessitate cooling to prevent component overheating, oil coking and power loss due to reduced volumetric efficiency. Well-designed cooling and lubrication systems are prerequisites for optimum engine operation, keeping operating temperatures and friction of all moving parts within predetermined acceptable limits.

High performance and high output engine is the trend of recent design of internal combustion. However, in order to achieve this, an efficient radiator has to be in place. Large radiator may perform the same heat loss, but will occupy the limited space under the bonnet. Introducing nanofluids to radiator will have greater heat transfer with smaller radiator size and better performance.

Several models can be used for thermal conductivity and viscosity, but only one of the models in each property will be considered. Type of particle material and base fluid will affect the heat transfer rate. The aforementioned parameters and properties will be further discussed in later chapter.

1.4 Scope of Research

This thesis is to conduct a research on the application of nanofluids in car radiator. Followed by integrating the existing information of car radiator and nanofluids. Then simulate heat transfer of car radiator with nanofluids and finally to verify and validate the simulation results.

1.5 Organization of Thesis

Chapter 1 introduction consists of background of the research, the objective of this research, problem statement and scope of research. Chapter 2 literature review describes the researches related to nanofluids and car radiator. Chapter 3 research methodology describes the development process of this study, identification of research variable, development of preliminary model, data and accuracy checking. Chapter 4 results and discussion shows the thermal conductivities of nanofluids, temperature of nanofluids, comparison of outlet temperature and temperature gradients along a selected tube. Chapter 5 conclusion and recommendation describes on the conclusion lead by this research and recommendation for further study.

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