ENHANCEMENT OF HEAT TRANSFER COEFFICIENT IN AN AUTOMOBILE RADIATOR BY USING NANOCOOLANT

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Specially dedicated to *Mek* and my beloved wife *Akmal Wani* and my precious gift from Allah,*Muhammad Anas Malik*

I love you all.

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ABSTRACT

Enhancement of heat transfer phenomenon is gaining research importance in applications of various fields of engineering,from microelectronics to highly powered lasers.It is acknowledged that among three modes of heat transfer (conduction,convection and radiation);most of the heat transfer takes place by conduction and convection in many situations.However,the conventional approaches like extended surface,application of vibration to the heat transfer surfaces,usage of microchannels and additional fluid pumping power to the system were thought to have reached their limits.Hence,various attempts to increase thermal conductivity of the fluid itself have been made..The practical demonstration of this theory was initiated in the year 1995 by U.S Choi who came out with the term “Nanofluid”.

Every system generating heat needs cooling arrangement in order to improve performance and for economical maintenance of the system.The initial effort of the present research study is to enhance the heat transfer phenomenon in a vehicle radiator by the application of nanofluids for higher thermal conductivity.In the recent years,few researchers worked on similar applications using nano particles such as Al_2O_3,CuO,SiO_2,TiO_2 and MWCNT’s and water or water with Ethylene Glycol as a coolant base fluids.However, all the investigations were limited to application of the nano coolants in experimental equipment.This paves the method for the present investigation in improvement of the heat transfer phenomenon by different factors affecting thermal conductivity in an automobile radiator.

The effect of nanofluid heat transfer enhancement in water and coolant based systems with different nano particles and concentrations are investigated from an engineering system perspective. One such system considered is a “KELISA (1000cc) – CAR RADIATOR” cooling circuit using different nanofluids to replace the conventional engine coolant.Results include quantifications of increase in engine heat rejection for the coolant circuit by the use of nanofluids instead of the conventional coolant.

ABSTRAK

Penambahbaikan dalam proses pemindahan haba semakin penting dalam penyelidikan pelbagai bidang dalam kejuruteraan,daripada mikroelektronik kepada laser berkuasa tinggi.Ianya telah diakui bahawa antara tiga cara pemindahan haba(pengaliran,perolakan dan radiasi);kebanyakan pemindahan haba berlaku disebabkan oleh pengaliran dan perolakan di dalam kebanyakan situasi.Tetapi, pendekatan konvensional seperti menambahkan permukaan,aplikasi getaran pada permukaan pemindahan haba,penggunaan saluran mikro dan juga penambahan bendalir kuasa mengepam ke dalam sistem dianggarkan telah mencapai batasannya.Oleh itu,pelbagai percubaan untuk meningkatkan kekonduksian terma telah dibuat.Demonstrasi praktikal untuk teori ini diasaskan pada tahun 1995 oleh U.S Choi yang mana menggunakan terma “Nanofluid”.

Setiap sistem yang menghasilkan haba memerlukan aturan penyejukan supaya prestasi dapat ditingkatkan dan juga untuk penyelenggaraan sistem yang menjimatkan.Tujuan asal penyelidikan ini ialah untuk meningkatkan fenomena pemindahan haba pada radiator kenderaan dengan menggunakan aplikasi nanofluids untuk kekonduksian terma yang lebih tinggi.Dalam masa beberapa tahun kebelakangan ini,beberapa penyelidik menggunakan aplikasi yang sama menggunakan partikel nano seperti Al_2O_3,CuO,SiO_2,TiO_2 dan MWCNT’s dan air atau air bersama Ethylene Glycol sebagai bendalir asas dalam penyejuk.Akan tetapi,semua penyelidikan yang dilakukan terhad kepada aplikasi penyejuk nano ini dalam peralatan eksperimen sahaja.Ini membuka jalan untuk kaedah penyelidikan ini dalam meningkatkan fenomena pemindahan haba dengan factor –faktor yang menjejaskan kekonduksian terma dalam radiator kenderaan.

Kesan nanofluid dikaji dari segi perspektif kejuruteraan.Sistem kenderaan yang dikaji ialah sistem “Kelisa (1000cc) – radiator kereta”,litar penyejuk yang menggunakan nanofluid berlainan menggantikan penyejuk enjin konvensional.

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LIST OF ABBREVIATION

A = peripheral area (m2)

C = specific heat (J/kg.K)

Dh = hydraulic diameter (m)

HTC = heat transfer coefficient (W/m2.K)

k = thermal conductivity (W/m.K)

ṁ = mass flow rate (kg/s)

Q = heat transfer rate (W)

Re = Reynolds number

T = temperature (K)

W = weight of nanoparticle (g)

MWCNT = multi-walled carbon nanotube

THW = transient hot wire

EG = ethylene glycol

PG = propyelene glycol

Subscript

b = bulk

bf = basefluid

nf = nanofluid

in = inlet

out = outlet

s = wall

np = nanoparticle

LIST OF SYMBOLS

Greek symbols

μ = viscosity (kg/m.s)

ρ = density (kg/m3)

φ = volume concentration

INTRODUCTION

1.1 Introduction

The progress of the technology in thermal systems has encouraged the attraction in process to improve heat transfer activity.Heat exchanger performance can be increased drastically by using a few enhancement techniques.A lot of researches and studies has been allocated to build up test set up and also experiments carried out to determine the conditions that improve heat transfer activity.Usually heat transfer enhancement techniques have been applied to the heat exchanger such as radiators,refrigerator,industries and many more.The objective of improving heat transfer is to boost high heat fluxes in heat exchanger so that the dimension of the heat exchanger can be reduced and optimized.Hence, the cost to produce the heat exchanger will be cheap enough and also temperature driving force can be decreased.Furthermore,by using the enhancement of heat transfer techniques,heat exchangers can work at slower velocity but still can produce equal or better heat transfer coefficient.The decrease of pressure drop will cause the cost to drop much cheaper.Because of all these benefits,the research in heat transfer enhancement will become more appealing and the application of the techniques in heat exchangers can attract many more attention.

Generally heat transfer enhancement techniques are classified into three types which are:

(1) Passive Techniques

(2) Active Techniques

(3) Compound Techniques

1.1.1 Passive Techniques

These methods do not oblige any immediate info of outside force which they utilize it from the system itself which eventually prompts an increment in fluid pressure drop.They usually utilize surface or geometrical alterations to the flow channel by using inserts or extra devices.It will stimulate higher heat transfer coefficients by aggravating or changing the current flow with the exception of broadened surfaces.Heat transfer augmentation by this method can be attained by utilizing; treated surfaces, broadened surfaces, upgraded equipments et cetera.

1.1.2 Active Techniques

For these methods,external power is utilized to encourage the sought flow alteration and the attending change in the rate of heat transfer. Increase of the rate of heat transfer by this system can be attained by mechanical supports, surface vibration, and electrostatic fields, etc.

1.1.3 Compound Techniques

When any two or more of these techniques are employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by either of them when used individually, is termed as compound enhancement.This technique involves complex design and hence has limited applications.Basically the experiment set up used in this research is working with single phase fluids like water, engine oil and ethylene glycol.The performance of the experiment set up is purely depends on the thermal conductivity of the working fluid.The thermal conductivity of the single phase fluid may be enhanced with the addition of small amount of nano sized particles.This is also one of the passive method of heat transfer enhancement is by adding additives to liquids.Solid particles have thermal conductivities several times higher than those of conventional fluids.General information of thermal conductivity of various solids and liquids are shown in Table 1.1.It is observed that solids are having more thermal conductivity than the liquids and gaseous.

At the point when any two or a greater amount of these methods are utilized at the same time to acquire improvement in heat transfer that is more prominent than that created by both of them when utilized separately, is termed as compound enhancement.This strategy includes complex outline and thus has constrained applications.Basically the test set up utilized as a part of this exploration is working with single stage liquids like water, motor oil and ethylene glycol.The execution of the analysis set up is absolutely relies on upon the thermal conductivity of the working fluid.the thermal conductivity of the single stage liquid may be improved with the expansion of little measure of nano measured particles.This is likewise one of the detached technique for heat exchanger enhancement by adding substances to liquids.Solid particles have thermal conductivities a few times higher than those of ordinary fluids.General data of thermal conductivity of different solids and fluids are indicated in Table 1.1.It is observed that solids are having more thermal conductivity than the fluids and vaporous.

Table 2.1 Thermal conductivity of various solids and liquids

	Material	Thermal conductivity (W/m K)
Metallic solids	copper	401
aluminum		237
Nonmetallic solids	silicon	148
alumina	(Al_2O_3)	40
Metallic liquids	Sodium	72.3 (644 K)
Nonmetallic liquids	Water	0.613
	ethylene glycol (EG)	0.253
	engine oil (EO)	0.145

1.2 Problem Statement

Conventional coolants have been widely employed to dissipate the developed heat in majority of the engineering applications.Typical coolants include three states of matter like solid liquid and gases based on the application and mode of heat transfer.However, with the latest technological advancements an emerging class of new coolants NANOCOOLANTS (Coolant with nano particles dispersed) finds their application in macro and microscopic scale.Nano fluids, finds their application in most of the engineering applications from microelectronics to high powered lasers than conventional coolants. A typical nano fluid is prepared by dispersing nano particles in the base fluid (water, ethylene glycol, oil) at volumetric concentration. The specific advantages of the nano fluids include enhanced thermal properties when compared with the base fluid.Usage of additives in coolants has been employed from decades to enhance the heat transfer phenomenon and reduce the pressure head. However, enough care is to be exercised when additives are employed since they not only improve the heat transfer phenomenon but also report to the loss of life cycle of the components by fouling and other factors like loss of pressure head, sedimentation and more.With the increased demands for higher power and exhaust gas regulations necessity for hybrid vehicles and vehicles with higher power are increasing enormously.On the other hand only 40 % of the developed heat during combustion is utilized for generating power remaining heat is transferred to exhaust. Hence there is a necessity to regulate this heat and maintain the temperature of the engine so as to enhance the performance.The common additives in cooling system of an automobile include either in hot/ cold region include adding ethylene glycol which enhance the properties of water like freezing point and boiling point. Majority of the automobile radiators uses a liquid cooling system where water with ethylene glycol is employed as cooling medium to transfer the heat effective from the engine.However, such conventional coolants provide inadequate heat transfer phenomenon and therefore a necessity for high performing thermal system arises.This can be achieved by increasing the size of the thermal system/cooling system.Due to the stringent design conditions,increased frontal areas, drag coefficients,in an automobile a necessity for improving the heat transfer phenomenon of the cooling medium is becoming necessary.A number of research papers can be found on the improvement of the heat transfer phenomenon by enhanced thermal properties of cooling medium by adding nano particles as additives in the cooling medium .The heat transfer phenomenon has been enhanced by suspending nano particles of the order few nm in the cooling medium is treated as nano fluid where these fluids display improved thermal properties compared to base fluids.The heat developed in an automobile is transferred to engine coolant and this made the researchers to concentrate on the improving the performance of the cooling system in an automobile.In a typical cooling system of an automobile radiator, the cooling medium is pumped into the exchanger by a pump and heat transfer takes place from the hot fluid and forced air which is drawn over the passage of the tubes where this cooling medium is being carried.A number of fins are arranged to convect away heat.However the necessity for improvement and investigate further with different concentrations of nano particles and different operating conditions.Earlier research articles were restricted to the experimental equipment to represent real condition for example heater represent the vehicle engine and so on.With the considerations above and varying factors the present research has been carried out to investigate the performance of the automobile radiator in the developed test set up using the real car engine system which is “Kelisa 1000cc”.

1.3 Research Objectives

The specific objectives of this research are:

- To formulate stable nanofluid using MWCNT's
- To investigate the effect of adding nanoparticle in commercial coolant
- To investigate the best volume concentration for nanofluid within current scope

1.4 Scope of Research

It is impossible to investigate all ranges of particulates systems within this scope of research. Due to this, this research has been focused on the following aspects.

- **Materials** - Multiwalled carbon nanotubes (MWCNTs) have been chosen as the subject matter. This is because little work has been reported on the convective heat transfer of nanofluids made from these materials.
- **Test setup** - A car engine system (Kelisa 1000cc) was utilized to check the heat transfer performance using nanofluid as the coolant
- **Flow rate** – 2,4,6 LPM flow rates have been chosen to proceed this research

References

Assael, M. J., Chen, C., Metaxa, I., & Wakeham, W. A. (2004). Thermal Conductivity of Suspensions of Carbon Nanotubes in Water 1, 25(4), 971–985.

Chandrasekar M, Suresh S, Chandra Bose A., Experimental studies on heat transfer and friction factor characteristics of Al2O3/water nanofluid in a circular pipe under laminar flow with wire coil inserts. Experimental Thermal and Fluid Science,2010, vol. 34, pp. 122–130.

Chavan, D., & Pise, A. T. (2013). Performance Investigation of an Automotive Car Radiator Operated With Nanofluid as a Coolant. Journal of Thermal Science and Engineering Applications, 6(2), 021010. doi:10.1115/1.4025230

Choi, S.U.S., Enhancing thermal conductivity of fluid with nanoparticles. In:Siginer, D.A., Wang, H.P. (Eds.),Developments and Applications of Non-Newtonian Flows",ASME, FED.231/ MD.66. New York, 1995, pp. 99–103

Choi, S.U.S., Zhang, Z.G., Yu, W., Lockwood, F.E.,Grulke,E.A., Anomalous thermal conductivity enhancement in nanotube suspensions, Applied Physics Letter, 2001, vol. 79,pp. 2252-2254.

Chopkar M, Das PK, Manna I., Synthesis and characterization of nanofluid for advanced heat transfer applications. Scripta Materialia, 2006, vol. 55, pp. 549–52.

Choi, C., Yoo, H.S., Oh, J.M., Preparation and heat transfer properties of nanoparticle-in-transformer oil dispersions as advanced energy-efficient coolants, Current Applied Physics,2008, vol. 8, pp. 710-712.

Choi, C.J., Seok Pil Jang, Stephen U.S. Choi, Electrokinetic effects of charged nanoparticles in microfluidic Couette flow,Journal of Colloid and Interface Science, 2011, vol. 363, pp.59-63

Chougule, S. S., & Sahu, S. K. (2014). Comparative Study of Cooling Performance of Automobile Radiator Using Al 2 O 3 -Water and Carbon Nanotube-Water Nanofluid. Journal of Nanotechnology in Engineering and Medicine, 5(1), 011001. doi:10.1115/1.4026971

Das, S.K., Choi, S.U.S., Yu, W., Pradeep, T., Nanofluids:Science and Technology, Wiley- Interscience, 2007, pp. 397.

Das, S.K., Putra, N., Thiesen, P., Roetzel, W., Temperaturedependence of thermal conductivity enhancement for nanofluids, Journal of Heat Transfer, 2003, vol. 125, pp. 567574.

Ding Y, Alias H, Wen D, Williams RA., Heat transfer of aqueous suspensions of carbon nanotubes (CNT nanofluids),International Journal of Heat and Mass Transfer, 2006, vol. 49,pp. 240–250.

Elias, M. M., Mahbubul, I. M., Saidur, R., Sohel, M. R., Shahrul, I. M., Khaleduzzaman, S. S., & Sadeghipour, S. (2014). Experimental investigation on the thermo-physical properties of Al2O3 nanoparticles suspended in car radiator coolant. International Communications in Heat and Mass Transfer, 54, 48–53. doi:10.1016/j.icheatmasstransfer.2014.03.005

Heris, S. Z., Shokrgozar, M., Poorpharhang, S., Shanbedi, M., & Noie, S. H. (2014). Experimental Study of Heat Transfer of a Car Radiator with CuO/Ethylene Glycol-Water as a Coolant. Journal of Dispersion Science and Technology, 35(5), 677–684. doi:10.1080/01932691.2013.805301

Huminic, G., & Huminic, A. (2012). Application of nanofluids in heat exchangers: A review. Renewable and Sustainable Energy Reviews, 16(8), 5625–5638. doi:10.1016/j.rser.2012.05.023

Hussein, A. M., Bakar, R. A., Kadirgama, K., & Sharma, K. V. (2014). Heat transfer enhancement using nanofluids in an automotive cooling system. International Communications in Heat and Mass Transfer, 53, 195–202. doi:10.1016/j.icheatmasstransfer.2014.01.003

Hussein, A. M., Sharma, K. V., Bakar, R. A., & Kadirgama, K. (2014). A review of forced convection heat transfer enhancement and hydrodynamic characteristics of a nanofluid. Renewable and Sustainable Energy Reviews, 29, 734–743. doi:10.1016/j.rser.2013.08.014

Hussein, A. M., Sharma, K. V., Bakar, R. A., & Kadirgama, K. (2013). The effect of cross sectional area of tube on friction factor and heat transfer nanofluid turbulent flow. International Communications in Heat and Mass Transfer, 47, 49–55. doi:10.1016/j.icheatmasstransfer.2013.06.007

Ijam, A., & Saidur, R. (2012). Nanofluid as a coolant for electronic devices (cooling of electronic devices). Applied Thermal Engineering, 32, 76–82. doi:10.1016/j.applthermaleng.2011.08.032

Jang, S.P., Choi, S.U.S., Effects of various parameters on nanofluid thermal conductivity, Journal of Heat Transfer, 2007,Vol. 129, pp. 617 – 623

Kulkarni, D. P., Vajjha, R. S., Das, D. K., & Oliva, D. (2008). Application of aluminum oxide nanofluids in diesel electric generator as jacket water coolant. Applied Thermal Engineering, 28(14-15), 1774–1781. doi:10.1016/j.applthermaleng.2007.11.017

Leong, K. Y., Saidur, R., Kazi, S. N., & Mamun, A. H. (2010). Performance investigation of an automotive car radiator operated with nanofluid-based coolants (nanofluid as a coolant in a radiator). Applied Thermal Engineering, 30(17-18), 2685–2692. doi:10.1016/j.applthermaleng.2010.07.019

Naraki, M., Peyghambarzadeh, S. M., Hashemabadi, S. H., & Vermahmoudi, Y. (2013). Parametric study of overall heat transfer coefficient of CuO/water nanofluids in a car radiator. International Journal of Thermal Sciences, 66, 82–90. doi:10.1016/j.ijthermalsci.2012.11.013

Nieh, H.-M., Teng, T.-P., & Yu, C.-C. (2014). Enhanced heat dissipation of a radiator using oxide nano-coolant. International Journal of Thermal Sciences, 77, 252–261. doi:10.1016/j.ijthermalsci.2013.11.008

Noie, S. H. (2006). Investigation of thermal performance of an air-to-air thermosyphon heat exchanger using ε-NTU method. Applied Thermal Engineering, 26(5-6), 559–567. doi:10.1016/j.applthermaleng.2005.07.012

Pak, B.C., Cho, Y.I., Hydrodynamic and heat transfer study ofdispersed fluids with submicron metallic oxide particles",Experimental Heat Transfer, 1998, Vol. 11, No. 2, pp. 151 –170.

Pang, S. C., Kalam, M. a., Masjuki, H. H., & Hazrat, M. a. (2012). A review on air flow and coolant flow circuit in vehicles' cooling system. International Journal of Heat and Mass Transfer, 55(23-24), 6295–6306. doi:10.1016/j.ijheatmasstransfer.2012.07.002

Peyghambarzadeh, S. M., Hashemabadi, S. H., Hoseini, S. M., & Seifi Jamnani, M. (2011). Experimental study of heat transfer enhancement using water/ethylene glycol based nanofluids as a new coolant for car radiators. International Communications in Heat and Mass Transfer, 38(9), 1283–1290. doi:10.1016/j.icheatmasstransfer.2011.07.001

Peyghambarzadeh, S. M., Hashemabadi, S. H., Naraki, M., & Vermahmoudi, Y. (2013). Experimental study of overall heat transfer coefficient in the application of dilute nanofluids in the car radiator. Applied Thermal Engineering, 52(1), 8–16. doi:10.1016/j.applthermaleng.2012.11.013

Peyghambarzadeh, S. M., Hashemabadi, S. H., Jamnani, M. S., & Hoseini, S. M. (2011). Improving the cooling performance of automobile radiator with Al2O3/water nanofluid. Applied Thermal Engineering, 31(10), 1833–1838. doi:10.1016/j.applthermaleng.2011.02.029

Sidik, N. A. C., Mohammed, H. a., Alawi, O. a., & Samion, S. (2014). A review on preparation methods and challenges of nanofluids. International Communications in Heat and Mass Transfer, 54, 115–125. doi:10.1016/j.icheatmasstransfer.2014.03.002

Sundar L.S., Farooky H. Md., Naga Sarada, S., Singh, M.K.,Experimental thermal conductivity of ethylene glycol and water mixture based low volume concentration of Al2O3 and CuO nanofluids, International communications in heat and mass transfer, 2013, vol. 41, 41-46.

Sundar LS, Sharma KV., Heat transfer enhancements of low volume concentration Al2O3 nanofluid and with longitudinal strip inserts in a circular tube, International Journal of Heat and Mass Transfer, 2010, vol. 53, pp. 4280–4286.

Teng, T.-P., & Yu, C.-C. (2013). Heat dissipation performance of MWCNTs nano-coolant for vehicle. Experimental Thermal and Fluid Science, 49, 22–30. doi:10.1016/j.expthermflusci.2013.03.007

Vajjha, R.S., Das, D.K., Experimental determination of thermal conductivity of three nanofluids and development of new correlations, International Journal of Heat and Mass Transfer,2009, Vol. 52, pp. 4675-4682

Vajjha, R. S., Das, D. K., & Namburu, P. K. (2010). Numerical study of fluid dynamic and heat transfer performance of Al2O3 and CuO nanofluids in the flat tubes of a radiator. International Journal of Heat and Fluid Flow, 31(4), 613–621. doi:10.1016/j.ijheatfluidflow.2010.02.016

Vermahmoudi, Y., Peyghambarzadeh, S. M., Hashemabadi, S. H., & Naraki, M. (2014). Experimental investigation on heat transfer performance of /water nanofluid in an air-finned heat exchanger. European Journal of Mechanics - B/Fluids, 44, 32–41. doi:10.1016/j.euromechflu.2013.10.002

Xuan., Y, Li, Q., Heat transfer enhancement of nanofluids, International Journal of Heat and Fluid Flow, 2000, vol. 21, pp.58-64

Xuan, Y., Li., Q., Investigation on convective heat transfer and flow features of nanofluids, Journal of Heat Transfer, 2003, vol.125, pp. 151-155

Xuan, Y.M., Roetzel, W., Conceptions for heat transfer correlation of nanofluids, International Journal of Heat and Mass Transfer, 2000, vol. 43, pp. 3701 – 3707

Charyulu, D. G., Singh, G., & Sharma, J. K. (1999). Performance evaluation of a radiator in a diesel engine case study, 1999