International Journal of Scientific & Engineering Research Volume 11, Issue 7, July-2020
ISSN 2229-5518

Improving the cooling performance of automobile radiator with ethylene glycol water based nanofluids

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Abstract— In this paper, the performance of ethylene glycol and water based TiO2 nanofluids as an automobile radiator coolant is determined experimentally. Forced convective heat transfer coefficient of TiO2 nanofluids has been measured and compared with the data of base fluid in an automobile radiator.Nanofluidswerepreparedtaking40%ethyleneglycoland60%waterwi the volume concentrations of 0.1%, 0.3% and 0.5% of TiO2 nano powder. All the experiments were conducted in the range of Reynoldsnumbersfrom4000to15,000.In all the experiments the nanofluids made to flow through the radiator tubes with elliptical cross section and airflows with constant speed in the crosswise direction in between the tubes of a tube bundle. Results demonstrate that increasing the fluid circulation rate can improve the heat transfer performance while the fluid inlet temperature to the radiator has little or no effect. Nanofluids investigated in the present work with low concentrations enhanced the heat transfer rate up to 37% in comparison with base fluid. The results of the investigation are presented graphically in terms of non-dimensional heat transfer coefficient as a function of volume concentration, temperature and flowrate.

Index Terms -TiO2, nanofluid, Nusselt number, Performance Radiator

1. Introduction

Conventional coolants have been widely employed to dissipate heat in majority of the engineering applications. Typical coolants include matter in all three states namely solid, liquid and gas based on the requirements of application and possible mode of heat transfer. However, with the latest technological advancements, an emerging class of new coolants namely nano-coolants (coolants with dispersed nano- particles) find their applications in a variety of engineering applications and are expected to replace conventional coolants in the near future. A typical nanofluid is prepared by dispersing certain types of select nano- particles in a suitable base fluid (water, ethylene glycol and coolant) with different volume concentrations; some of the specific advantages of nanofluids include enhanced thermal properties when compared to the base fluid. Mixing of additives in coolants has been in use from de- cades to enhance the heat transfer and reduce the pressure drop along the flow. However, enough care is to be exercised when additives are employed since they not only improve the heat transfer but also responsible to reduce the life of the components by fouling and other factors like increased pressure drop and sedimentation. With the increased demand for higher power and clean exhaust gas regulations necessity for hybrid vehicles and vehicles with higher power are increasing enormously.

On the other hand only 60% of the heat developed during combustion is utilized for generating useful power and remaining heat is rejected to exhaust. Hence there is a necessity to regulate this heat and maintain the temperature of the engine so as to enhance the performance. Common additives used in cooling system of an automobile include ethylene glycol which improves the properties of water such as 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 excess heat from the engine. However, such conventional coolants provide inadequate heat transfer and therefore a necessity for high performance thermal systems arise. 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, the necessity for improving the heat transfer phenomenon in the cooling medium is becoming essential. To present the state of the art, a review has been carried out highlighting the contributions of each article and summarized below.

Huminic and Huminic[1] summarized the enhancement of convective heat transfer of nanofluids in heat exchangers, especially with a focus on presentation of the theoretical and experimental results for

Nomenclature

A	area, m²
C_p	specific heat,
D_h	hydraulic diameter
F	frictionfactor
h	heat transfer coefficient
k	thermal conductivity,
m	mass flow rate
Nu	Nusselt number K
n	empirical shape factor
P	tube periphery, m
Pr	Prandtl number K
Q	heat transfer rate,
Re	WReynolds number
S	cross sectional area of the tube, m²
T	temperature, K

Greek letters

ρ	density, kg/m³
μ	viscosity, kg/m s
ø	volume fraction

Subscripts

b	bulk
exp.	experimental
nf	nanofluid
out	output
p	particle
w	wall

the effective thermal conductivity, viscosity and the Nusselt number on application of nanofluids in various types of heat exchangers. A similar study on the nanofluids with correlations developed for heat transfer and friction factor for different kinds of nanofluids flowing in a plain tube under laminar and turbulent flow conditions has been compiled. It is reported about the correlations developed for the estimation of heat transfer coefficient and friction factor of nanofluid in a plain tube with inserts under laminar and turbulent flow conditions by Sundar and Singh [2]. Thermo-physical properties and heat transfer characteristics in forced convective heat transfer in nanofluids are reviewed and the specific applications of nanofluids are presented by Chandrasekar et al. [3]. Experimental investigation on the heat transfer characteristics of γ-Al_2O_3/water and TiO_2/water nanofluids was conducted using a shell and tube heat exchanger under turbulent flow condition by Farajollahi et al. [4]. It has been concluded that nanoparticle with small mean diameter (TiO_2nanoparticle) has a lower optimum volume concentration. TiO_2/water and γ-Al_2O_3/water nanofluids possess better heat transfer behavior at the lower and higher volume concentrations, respectively. The heat transfer coefficient and friction factor of TiO_2- water nanofluid flowing in a horizontal double-tube counter flow heat exchanger under turbulent flow conditions are investigated by Duangthongsuk and Wongwises[5]. The results show that the convective heat transfer coefficient of nanofluid is slightly higher than that of the base liquid to an extent of 6–11%. The heat transfer coefficient of the nanofluid increases with an increase in the mass flow rate of the hot water and nanofluid, and increases with a decrease in the nanofluid temperature, and the temperature of the heating fluid has no significant effect on the heat transfer coefficient of the nanofluid. Zamzamian et al. [6], studied nanofluids of Al_2O_3 and CuO prepared with ethylene glycol as a base fluid and estimated the convective heat transfer of nanofluids using theoretical correlations and compared with the experimental data from a double pipe heat exchanger. It has been enhancement in convective heat transfer coefficient of the nanofluids as compared to the base fluidis ranging from 2% to 50%.

Naphon et.al. [7] studied enhancement of heat pipe thermal efficiency with TiO_2 nanofluids with a ssize of 21 nm. Noie et al. [8] considered a two-phase closed thermosiphon as a heat transfer device and Al_2O_3 nanofluidis considered as working fluid at concentrations of 1–3% and observed 14.7% enhancement. Jungetal. [9], conducted experiments on the en- hancement of the convective heat transfer with nanofluids flowing in microchannels and found that the Nusselt number increases with increase in the Reynolds number in laminar flow regime. Sajadi and Kazemi [10] proposed a new correlation for the Nusselt number using the results of the experiments with TiO_2 nanoparticles dispersed in reported that the water. Nguyen et al. [11] investigated the behavior and heat transfer enhancement of Al_2O_3 nanofluids inside a closed system for cooling of micro processors or other electronic components and observed heat transfer enhancement up to 40% compared to that of the base fluid at 6.8% volume concentration. Leong et al. [12] studied the application of nanofluids as working fluids in shell and tube heat recovery exchangers in a biomass heating plant and observed increase in heat transfer coef- ficient up to 7.8% when 1% copper nanoparticles in ethylene glycol based fluids are used. Park and Jung [13] observed the enhancement of nucleate boiling heat transfer in refrigerants for building chillers by adding 1.0% of CNTs in refrigerants R-123 and R-134a and observed heat transfer enhancement up to 36.6% at low heat fluxes. Kulkarni et al. [14] conducted heat transfer experiments with Al_2O_3, CuO and SiO_2 nanofluids by considering ethylene glycol and water mixture as a base fluid. Yu et al. [15] studied the effects of porosity and pore diameter on the thermal efficiency of the carbon foam finned heat exchanger and observed 15% thermal performance enhancement. Harris et al. [16] de- signed and developed a micro-cross flow heat exchanger to maximize the heat transfer between working fluid and air. Joardarand Jacobi [17] developed a delta wing type vortex generator and experimentally tested in a wind tunnel for a compact heat exchanger. The heat transfer and pressure drop are assessed successfully in dry and wet conditions and vortex generator method is proven to be improving the thermal– hydraulic performance. Ding et al. [18]has observed significant enhancement of the convective heat transfer in a horizontal tube using CNT nanofluids and observed 3.5% heat transfer enhancement at 5% weight concentration at a Reynolds number of 800.

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 into the 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 improve convective heat transfer. A few papers on the application of the nanofluids in automobile radiators can be seen in [19–23]. As there is necessity for improvement in heat transfer rate, the authors made an attempt to investigate further with different concentrations of nanoparticles and different concentrations of nanoparticles and different operating conditions. A majority of earlier research articles were restricted to the laminar flow of the coolant which is not very realistic and the flow enters into turbulent flow region in automobile cooling systems. Hence in the present research the Reynolds number of the cooling medium is maintained at transition region. On the other hand, the value of pH in the fluid is more than7,which makes the fluid to be acidic assisting in corrosion and fouling of the channels, reported in the earlier studies. With the above considerations and varying factors the present research has been carried out to investigate the

ISSN 2229-5518

performance of the automobile radiator using the test rig developed for the purpose.

Two-step preparation process

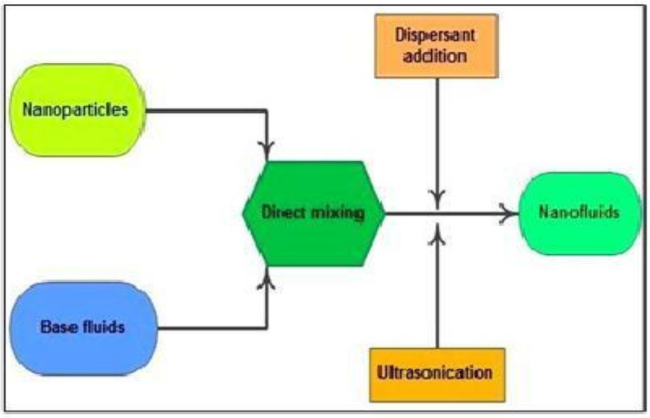

Fig 1: Two-step preparation process of nanofluid

Two-step preparation process is extensively used in the synthesis of nanofluids by mixing base fluids with commercially available nano-powders obtained from different mechanical, physical and chemical routes such as milling, grinding, and sol-gel and vapour phase methods. An ultrasonic vibrator or higher shear mixing device is generally used to stir nano-powders with host fluids. Frequent use of ultra-sonication or stirring is required to reduce particle agglomeration. Eastman, Lee, Wang used two-step method to produce alumina nanofluids. Murshed prepared TiO2-water nano-suspension by the same method. Xuan used commercially available Cu nanoparticles to prepare nanofluids of both water and transformer oil. Kim used two-step method to prepare CuO dispersed Ethylene glycol nanofluids by Sonication and without stabilizers. Two-step method can also be used for synthesis of carbon nano-tubes based nanofluids. Single -walled and multi-walled carbon nano-tubes are first produced by pyrolysis method and then suspended in base fluids with or without the use of surfactants. Some authors suggested that two-step process is very suitable to prepare nanofluids containing oxide nanoparticles than those containing metallic nanoparticles. Stability is a big issue that inherently related to this operation as the powders easily aggregate due to strong van der Walls force among nanoparticles. The most common two-step method is shown in Fig 1.8 In spite of such disadvantages this process is still popular as the most economic process for nanofluids production.
A nanofluid is a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nano-tubes(CNT). Common base fluids include water, ethylene glycol and oil.

Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chillers, heat exchanger, in grinding, machining and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. Knowledge of the rheological behaviour of nanofluids is found to be very critical in deciding their suitability for convective heat transfer applications. Nanofluids also have special acoustical properties and in ultrasonic fields display additional shear-wave reconversion of an incident compressional wave; the effect becomes more pronounced as concentration increases. In analysis such as computational fluid dynamics (CFD), nanofluids can be assumed to be single phase fluids. However, almost all of new academic paper uses two-phase assumption. Classical theory of single phase fluids can be applied, where physical properties of nanofluid are taken as a function of properties of both constituents and their concentrations.

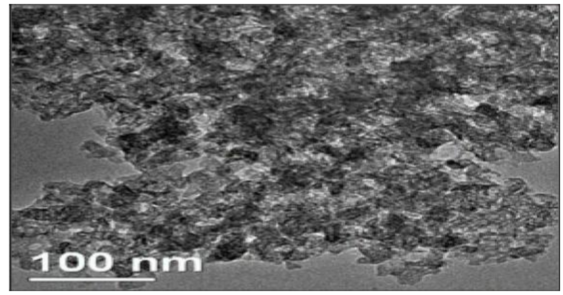

Fig 2: TEM image of Al2O3 nanoparticles

The reactive mixtures between two or more fluids are a vast research field. The study of the optimal composition of heat or cooling carriers from the solar water heating, from heat exchangers, from cooling systems of engines and generators, from thermal stations is a challenge because it must fulfil some conditions, such as: high thermal transfer coefficient, high specific heat (in case of heating carriers), no corrosion of the pipes or metallic parts in contact etc. The most used heat carriers are: burning gases, hot air, water vapours (steam), hot water, engine oil, mineral oils and melted salts.

The selected nanoparticles to obtain the nanofluid have an average size of 10nm (according to the supplier's specifications), a specific surface of 160 m2/gr and density of 3.7 gr/cm3.

From the literature some information about the main parameters that have influence on mixtures was selected (temperature, speed and mixing time), and most of the researchers report that nanoparticles dispersions in different base fluids are made at maximum speed (depending on the devices) and at room temperature although there are some studies that report the analyses of nanofluids at different temperatures (20°C, 35°C and 50°C). When referring to time, this varies a lot according to the amount of nanofluid that is intended to be achieved. The shape of the reactor's bottom can have a significant effect on the hydrodynamic conditions inside it and hence the ability to achieve a homogeneous suspension. Cylindrical shaped tanks to lead to increased mass of particles in suspension by eliminating areas that are "dead" at the intersection of the tank wall. "Dead" areas or regions of segregation are found at the intersection of walls, especially in flat-bottomed tanks.

3. Experimental setup and procedure

The experimental test rig is developed with commercially available car radiator. It consists of coolant storage tank, an industrial heater, a high temperature durable pump, a radiator, and a fan. Instrumentation involves a set of thermocouples, anemometer, and a temperature indicator to record the temperatures and fluid flow rate. The schematic view of the developed test rig is shown in Fig. 1. The front view and rearview of experimental test rig are shown in Figs.2 and 3respective- ly. The coolant in the tank is heated upto the desired temperature and the pump is switched on allowing the coolant to flow through the radiator and the fan is switched onto absorb heat from the hot fluiand subsequently dissipate to the environment. The temperatures are recorded at the inlet and outlet of the radiators collecting chamber. The nanofluid is assumed to be flowing with a uniform Reynolds number assuming normal distribution in the channels of the radiator. Where Nu is the average Nusselt number for the whole radiator, m is the mass flowrate which is the product of density and volume flowrate of fluid, Cp is the fluid specific heat capacity, A is the peripheral area of radiator tubes, Tin and

Tout are the inlet and outlet temperatures, Tb is the bulk temperature which was assumed to be the average values of inlet and outlet temperature of the fluid moving through radiator, and Tw is the tube wall temperature which is the average value two surfaces thermocouples, k is the fluid thermal conductivity and Dh is the hydraulic diameter of the tube. It should also be mentioned that all the physical properties were calculated at fluid bulk temperature.

Objective

For the purpose of producing high efficiency engine we need look at reducing a vehicle weight by optimizing design and size of a radiator is a necessity for making the new design model of radiator. Over several years researchers have focused to overcome the limited heat transfer capabilities of conventional heat transfer mediums such as water, engine oil, Ethylene glycol (EG). For the need of the high performance cooling, heating efficiency, energy saving, less generation of greenhouse gases nanotechnology is applied to thermal engineering.

1. Compact radiator size

Due to the use of nanofluid as a better substrate leading to better heat transfer due to the increased heat transfer area results in more compact size of the radiator.

2. Eliminate emission of NOx

The temperature of the engine considerably falls below 1100oC due to faster heat dissipation rate thus eliminates emission of NOX.

3. Better radiator and thermal efficiency

Due to the excellent heat transfer rate and reduced drag forces the radiator and thermal efficiencies are raised up.

4. Enhance aerodynamic shape

Reduced radiator size with same heat transfer rate gives enhanced aerodynamic shape to the vehicle body.

5. Enhancement of physical & thermal properties due to use of nanofluid

Nanofluid being a better composition leads to enhancement of physical & thermal properties

4. Results anddiscussions

4.1. Base fluid in radiator

Before conducting the systematic analysis with the use of nanofluids in the radiator, some experimental runs were conducted with basefluid

Fig.3. Front view of testrig.

(40:60% EG/W) in order to check the reliability and accuracy of the experimental setup. Fig. 4shows experimental results for

Fig.4.Rearviewoftestrg
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constant inlet temperature of 35°C.As expected, the Nusselt number is found to increase for increase in the Reynolds number. Also, comparison was made between the experimental data and two well-known empirical correlations: Eq.(9) of Gnielinski [26] and Eq.(10) of Tam and Ghajar [27]. In the measured Reynolds number range, a maximum of 2.5% deviation is observed between the present experimental data and theoretical values. Close agreement with the published literature ensures reliability of the experimental test setup and the measure data.

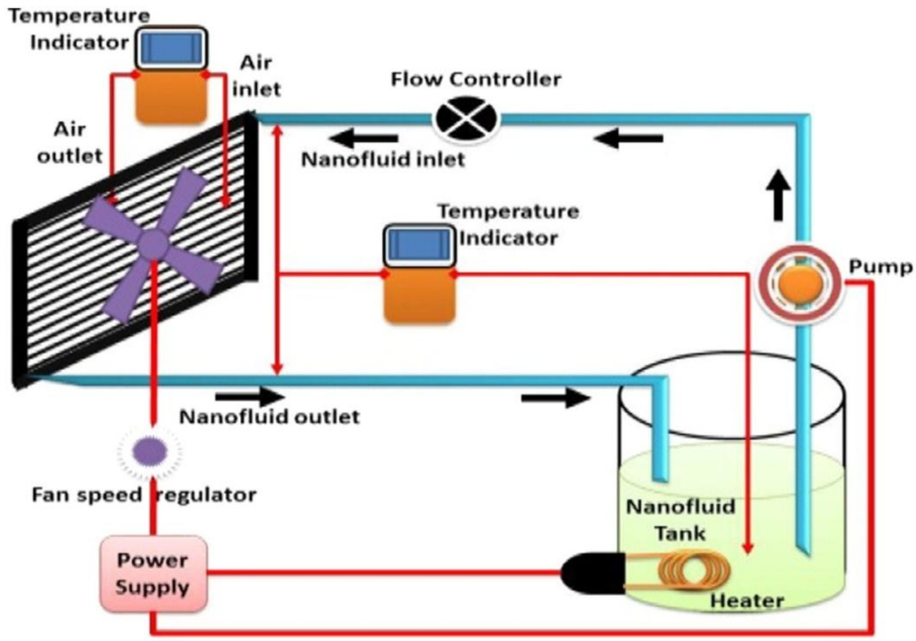

Fig. 5. Schematic representation of experimental setup.

Conventional coolants like water, ethylene glycol are not efficient enough to improve the car's performance. They development of new technology in the field of 'Nano-materials' and 'Nano-fluids'. Is effectively use these technologies in car radiators to improve engine efficiency, reduce weight of vehicle and size of radiator. They adding Al2O3 Nano fluid in car radiators. In this paper forced convective heat transfer of water and ethylene glycol based Nano fluid will be compared experimentally with water, water + ethylene glycol (60:40), water + ethylene glycol+ nanoparticles. An engine coolant is mixture of ethylene glycol and water in various ratios like 30:70, 40:60 and 50:50 respectively are mostly used in auto-mobiles. It is estimated that a higher temperature radiator could reduce the radiator size approximately by 30%. Nanoparticles with two different base fluids: ethylene glycol and pump oil. Results showed a 30 % & 40 %.Fluids for 5 vol. % of nanoparticles and the size of the nanoparticles used with both the fluids is 60 nm. It leading to perhaps a 10% fuel savings.

In water-ethylene glycol (EG) Nano fluid is used. Overall heat conductance (UA) is studied using two mixture of water-ethylene glycol combination of ratio 90:10 and 80:20. They reduced UA in 20% and 25%.In ratio of 80:20 there is 0.1% of Al2O3 nanoparticles. Due to addition of Nano fluid there is increase in heat transfer performed in 37% of output. The significant increase in the Pr of the coolant with the addition of nanoparticles results in the increase of UA. With the addition of 0.1% of nanoparticles, the Pr of the water and 80:20 water–EG increased by 61% and 106% respectively.

Flow rate (LPM)	Nanofluid hexp	Ethylene Glycol hexp
9	1590.93	915.2
8	1458.97	810.93
7	1359.98	785.3

Table no. 5.1 Result-1

The nanofluid is implemented with different Graphene nanoparticles concentrations, i.e. 0.1%, 0.3% and 0.5% and is pumped through the radiator at different flow rates of 2, 3, 4, and 5 l/min as the working fluid. In order to consider the effect of temperature on thermal performance of the radiator, different inlet temperatures of the nanofluids (35, 40, and45 °C) have been applied.It is important to mention that for any cooling system, Equal mass flow rate larger than the reduction in working fluid temperature at the exit indicates better thermal performance of cooling system. the radiator outlet temperature, Tout, as a function of fluid volume flow rate circulating in the radiator. Three series of data shown in this figure belong to base fluid and also two different concentrations of nanofluids.

5. Conclusions

In this paper, overall heat transfer coefficient in an automobile radiator has been measured experimentally for two working fluids namely 40:60% EG/W and 40:60% EG/W based TiO_2 nanofluids as a function of concentration and temperature. It is found that the presence of TiO_2 nanoparticle in 40:60% EG/W can enhance the heat transfer rate in the automobile radiator. The degree of the heat transfer enhancement depends on the quantity of nanoparticles added to the basefluid. At the concentration of 0.5%, the heat transfer enhancement of 35% compared to base fluid was observed. Increasing the flow rate of working fluid enhances the heat transfer coefficient for both pure water and nanofluid considerably while the variation of fluid inlet temperature to the radiator (in the range tested) slightly influences the heat transfer performance. It seems that the increase in the effective thermal conduc- tivity (of about 3% in this study) and the variations of the other physical properties are not solely responsible for the large heat transfer enhance- ment. Brownian motion of nanoparticles may be one of the major factors in the enhancement of heat transfers. Although there are recent advances in the study of heat transfer with nanofluids, more experimental results and theoretical understanding of the mechanisms of the particle movements are needed to explain heat transfer behavior of nanofluids.

Acknowledgements

The author Nikhil Anerao Shyam bhende, Rammahalle, Kapil Bhaisare would like to thank the management of SIT lonavala, the author Nikhil Anerao Shyam bhende, Rammahalle, Kapil Bhaisare would like to thank University of Savitribai punefor the encouragement and support.

References

[1] G. Huminic, A. Huminic, Application of nanofluids in heat exchangers: a review, Renew. Sust. Energ. Rev. 16 (2012)5625–5638.

[2] L.S.Sundar,M.K.Singh,Convectiveheattransferandfrictionfactorcor relationsof nanofluid in a tube and with inserts: a review, Renew. Sust. Energ. Rev. 20 (2013)23–35.

[3] M. Chandrasekar, S.Suresh, T.Senthilkumar, Mechanism is proposed throug thexperimental investigations on thermo physical properties and forced convective heat transfer characteristics of various nano fluids—areview,Renew.Sust.Energ.Rev. 16 (2012)3917–3938.

[4] B. Farajollahi, S.G. Etemad, M. Hojjat, Heat transfer of nanofluids in a shell and tube heatexchanger,Int.J.HeatMassTransf.53(2010)12–17.

[5] W. Duangthongsuk, S. Wongwises, Heat transfer enhancement and pressuredrop characteristics of TiO_2-water nanofluid in a double-tube counter flow heatexchanger, Int. J. Heat Mass Transf. 52 (2009) 2059–2067.

[6] Zamzamian, S.N. Oskouie, A. Doosthoseini, A. Joneidi, M. Pazouki, Experimentalin-vestigationofforcedconvectiveheattransfercoefficientinnanofluidsof Al_2O_3/EGand CuO/EG in a double pipe and plate heat exchangers under turbulent flow,Exp. Thermal Fluid Sci. 35 (2011)495–502.

[7] P. Naphon, P. Assadamongkol, T. Borirak, Experimental investigation oftitanium nanofluidsontheheatpipethermalefficiency,Int.Commun.HeatMass Transf.35(2008)1316–1319.

[8] S.H.Noie,S.Z.Heris,M.Kahani,S.M.Nowee,Heattransferenhancementusing Al_2O_3/ water nanofluid in a two-phase closed thermo siphon, Int. J. Heat Fluid Flow 30(2009) 700–705.

[9] J.Y. Jung, H.S. Oh, H.Y. Kwak, Forced convective heat transfer of nanofluids inmicro channels, Proceeding of ASME International Mechanical Engineering Congress andExposition (IMECE 2006), 2006.

[10] A.R. Sajadi, M.H. Kazemi, Investigation of turbulent convective heat transferand pressure drop of TiO_2/water nanofluid in circular tube, Int. Commun. Heat Mass Transf. 38 (2011)1474–1478.

[11] C.T.Nguyen,G.Roy,C.Gauthier,N.Galanis,Heattransferenhancementusi ngAl_2O_3 waternanofluidforanelectronicliquidcoolingsystem,Appl.Therm.En g.27(2007)1501–1506.

[12] K.Y.Leong,R.Saidur,T.M.I.Mahlia,Y.H.Yau,Modelingofshellandtubeheat recovery exchanger operated with nanofluid based coolants, Int. J. Heat Mass Transf.55 (2012) 808–816.

[13] K.J. Park, D. Jung, Boiling heat transfer enhancement with carbon nanotubesfor refrigerants used in building air-conditioning, Energy Build. 39 (2007) 1061–1064.

[14] D.P.Kulkarni,D.K.Das,R.S.Vajjha,Applicationofnanofluidsinheatingb uildingsandreducing pollution, Appl. Energy 86 (2009)2566–2573