# ESTIMATION OF ENERGY SAVING BY NANOFLUID OPERATED AIR CONDITIONING SYSTEM

**MOHD HAFIZ BIN ABDUL HALIM SHAH**

**FACULTY OF ENGINEERING**

**UNIVERSITY MALAYA**

**KUALA LUMPUR**

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**MOHD HAFIZ BIN ABDUL HALIM SHAH**

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## ORIGINAL LITERARY WORK DECLARATION

Name of Candidate**: Mohd hafiz bin Abdul Halim Shah**

(I.C/Passport No:

Registration/Matric No: **KGY 110007**

Name of Degree: **Master of Engineering**

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"):

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Field of Study: **Mechanical Engineering**

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## ABSTRACT

Nanotechnology enhancement, thermal engineering and thermal science lead to interest in development of new technology of fluids known as nanofluid. Nanometer particle size is added into base fluids are known as nanofluids material. Nanofluids is a new engineering material which use in many heat transfer application. Nanofluids offer high surface to volume ratio and compactness material compare to conventional fluids. Nanofluid has drawn high attention from researcher since it has superior thermal properties. These superior thermal properties can be used in many industries such as electronic, chemical engineering, microelectronic, transportation, manufacturing and aerospace. In such electronic industries, nanofluids offer better cooling compare to conventional fluids.

Entire analysis is conducted with air condition system which operated with nanofluids as medium for heat transfer. The analysis is conducted under the influences of volume fraction on nanofluids such as Cu-$H_2O$, $Al_2O_3$-$H_2O$, Cu-Eg and $Al_2O_3$-Eg. Further analysis is conducted under influences of heat exchange parameter with nanofluids present as medium of heat transfer. Analysis is performance for internal side of heat exchanger only.

Thermal physical properties are important parameter for energy saving in nanofluids air condition operated system. Thermal conductivity, density, viscosity and specific heat are main thermal physical properties which play roles in determination of energy uses in air conditioning system. Enhancement of thermal conductivity gives nanofluids, a suitable selection to be used as medium of heat transfer in air conditioning to save energy used during operation.

Method to determine energy saving is calculating increment of energy ratio for air conditioning system with nanofluids and compare to air condition system which operates with base fluids. On top of that, energy saving for nanofluids can be measured

by determines pumping power required by air condition with nanofluids application to base fluids application.

Energy saving of air condition operated with nanofluids can be achieved. Selections of nanofluids are important since not entire nanofluids give signification or increment result after implementation. Alumina oxide with water give the highest increment of energy saving and copper with ethylene glycol do not result any positive result. Thermal conductivity is of the important parameter in determination of energy saving for air condition. Particle shape, particle polydisperity and particle agglomeration could be a function in determination of thermal physical of nanofluid. Further study and research is a must to clarify these variables. Anyhow, nanofluids preparation is a major challenge at present and this may limit nanofluids further research and application.

**ABSTRAK**

Peningkatan dalam teknologi nano, kejuruteraan haba dan sains haba mendorong minat dalam pembangunan teknologi baru dalam pemindahan haba yang dikenali bendalir nano. Serbuk yang bersaiz nono ditambah ke bendalir asas dikenali sebagai bendalir nano. Bendalir nano adalah bahan kejuruteraan yang baru yang mana boleh digunakan dalam perbagai aplikasi pemindahan haba. Bendalir nano mempunyai nisbah permukaan kepada isipadu yang tinggi dan bahan yang lebih kecil berbanding dengan bendalir konvesional. Bendalir nano menarik minat ramai pengkaji memandangkan ia mempunyai sifat haba yang baik. Sifat haba yang baik ini boleh digunakan dalam banyak industry seperti elektronik, kejuruteraan kimia, mikroelektronik, pengangkutan, pembuatan dan juga angkasa lepas. Dalam industri elektonik, bendalir nano memberikan penyejukan yang lebih baik berbanding dengan bendalir konvensional

Keseluruhan analisa dijalan dengan sistem penghawa dingin yang beroperasi dengan bendalir nano sebagai permindahan haba. Analisa juga dijalankan dibawah pengaruh nisbah isipade ke atas bendalir nano seperti Cu-$H_2O$, $Al_2O_3$-$H_2O$, Cu-Eg and $Al_2O_3$-Eg. Analisa juga dijalan terhadap perngaruh penukar haba dengan penggunaan bendalir nano sebagai media untuk permindahan haba. Hanya bahagian dalam penukar haba diambil kira semasa analisa.

Sifat fizikal termo adalah fungsi yang sangat penting dalam penentuan penjimatan tenaga dalam penghawa dingin. Pengaliran haba, ketumpatan dan kelikatan adalah fungsi utama dalam penentuan penjimatan tenaga. Peningkatan pemindahan haba dalam bendalir nano menjadikan ia satu bahan yang sesuai digunakan sebagai pemindah haba dalam penghawa dingin.

Kaedah yang digunakan untuk menentukan peningkatan jimat tenaga adalah melalui peningkatan flux haba untuk bendalir nano. Selain itu, penjimatan tenaga juga

boleh diukur dengan pengurangan kuasa yang digunakan oleh pam semasa operasi penghawa dingin.

Sehingga setakat ini, kajian mengenai bendalir nano adalah terhad. Ini disebabkan proses pembuatan bendalir nano yang melibatkan kos yang tinggi serta memerlukan teknologi yang sangat maju. Walaubagaimanpun, kajian perlu diteruskan memandangkan bendalir nano mempunyai banyak manfaat.

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## LIST OF SYMBOL AND ABBREVIATIONS

### Nomenclature

| | |
|---|---|
| ***Bf*** | **Base fluids** |
| ***ck*** | **Thermal conductivity coefficient** |
| **μ** | **Viscosity coefficient** |
| ***Cp*** | **Specific heat(J/kg.K)** |
| **D** | **Tube diameter(m)** |
| ***f*** | **Friction factor** |
| ***k*** | **Thermal conductivity(W/m.K)** |
| $\dot{m}$ | **Mass flow rate(kg/s)** |
| ***nf*** | **Nanofluid** |
| ***np*** | **Nanoparticle** |
| **Q** | **Heat Capacity(kW)** |

### Greek symbols

| | |
|---|---|
| **ρ** | **Density(kg/m$^3$)** |
| **ϕ** | **Volume fraction** |
| **μ** | **Viscosity(N.s/m$^2$)** |

# CHAPTER 1.0 INTRODUCTION

## 1.1 OVERVIEW

Estimation of energy saving by using nanofluid for air conditioning analysis is carried out in this master report. Energy saving is calculated by increasing capacity with usage of nanofluid as transferring medium compare to base fluid as transferring medium. Increasing capacity is analysis with influence of mass flow rate, volume fraction of nanofluid , different type of nanofluid and different number tube diameter for air conditioning. Analysis is conducted under influence of Cu-$H_2O$, $Al_2O_3$-$H_2O$, Cu-Eg and $Al_2O_3$-Eg. Any calculation involve is base on the scientific or empirical equation with additional of air conditioning standard mention by ASHREA (American Society of Heating, Refrigerants and Air Conditioning Engineer).

## 1.2 BACKGROUND OF STUDY

Water, Ethylene and oil are traditional fluids which have poor thermal performance due to their poor thermal conductivity. Thus, rapid research and development on fluids to increase it thermal performance is a must. Increase thermal property can be done by adding metallic and non metallic into base fluids. Adding material into base fluid has major concern is it leads to component erosion, abrasion, increasing pressure drop, particle settling and clogging in small passage. Those characteristic cannot be tolerated for high technologies application and make those traditional fluids are not suitable candidate for heat transfer medium.

Nanofluid come to rescue and emerged as novel fluids. Nanofluid comes with superior thermal properties. Superior thermal a property is a must for high heat flux and high transfer application such as cooling in microelectronic, aviation and air conditioning system. Material in nanometre which can be dissolving into traditional heat transfer fluids is known as nanofluid. Elimination of previous issues and high

thermal conductivity make nanofluid is suitable candidate to use in high thermal heat transfer application. It has emerged as new class of engineered fluids.

Nanofluid application in air conditioning system is as working fluid for heat transfer medium on heat exchanger. Enhance of heat transfer medium result in energy saving and cost reduction. At present, huge amount of energy use in building is for air conditioning purpose. Core component for most HVAC (Heating, Ventilation and Air Conditioning) is heat exchanger. It functions as medium of transfer form air to water/refrigerant or from water/refrigerant to air for cooling or heating purpose. Such process required a huge amount of energy. Therefore, rapid development and study of using nanofluid in air conditioning system is a must in order to save energy and increase performance of air conditioning system.

## 1.3 PROBLEM STATEMENT

Air condition system uses huge amount of energy during it operation. High consumption of energy leads into increasing carbon dioxide release into environment. Carbon dioxide release into environment creates green house effect which cause global warming. Such requirement, development of energy saving technology for air conditioning system is a must at present. Air condition system energy saving can be archived through increasing capacity. Capacity improvement can be archived by using nanofluid as medium for heat transfer. Nanofluid is a novel fluid with various advantages. It can enhance heat transfer medium, suitable for high heat load operation and prevent clogging since it sizes is miniature in practical

## 1.4 OBJECTIVE OF STUDY

Analyses are conducted on present of nanofluid for fan coil unit air conditioning system. Few conditions are selected for analysis such change of mass flow rate, different tube diameter, different types of nanolfuid and volume fraction of nanofluid.

Data are taken from previous research or standard fan coil unit which already have been commercialized. Objectives of the master report are to: -

i) To estimate energy saving of air condition operated with present of nanofluid.

ii) To determine energy saving with different tube diameter with present of alumina oxide with water as nanofluids.

iii) To calculate energy saving with different mass flow rate for air condition operated with alumina oxide with water as nanofluid.

## 1.5 SCOPE AND LIMITATION

Scope of this study is estimation of energy saving in air conditioning system after present of nanofluid as working fluid. Study will focus on fan coil unit air conditions system which uses water as standard working fluid. Nanofluid preparations are done by single step or two steps approach. Single step process decomposition thermal of an arganometallic precursor in the present of either a stabilizer, chemical reduction and polyol synthesis and two steps process begin with synthesized nanomaterials to obtained as powder which then is dispersing into base fluids. Advance and sophisticated devices are needed for both processes. For both processes, manufacturing cost is extremely high. Therefore, study is conducting under data or result which given or publish by other researcher.

Heat transfer process in heat exchanger is complex since it due to many parameters such as coil design, air flow performance and refrigerant used. Until now, objective to develop universal of heat transfer performance for heat exchanger is yet not be archived since many parameter need to have more detail study before generating a universal heat transfer parameter. Such issue, this master report will solely base on data by other researcher for data such as coil design, air flow through heat exchanger, air or water entering or leaving through heat exchanger.

## 1.6 ORGANIZATION OF REPORT

The master report consists of five sections as below;

**Chapter one** – overview and introduction, background of study, problem statement, objective of study, limitation of study and scope of this master report.

**Chapter two** – literature review which energy saving in air conditioning and regulation govern for energy saving, air conditioning system (heat exchanger) as heat transfer device, working fluids for heat exchanger and nanofluids thermal physical properties. Few journals were review to enhance knowledge of nanofluids properties such as thermal conductivity, density, viscosity and specific heat which are useful parameters in air conditioning system.

**Chapter three** – address methodology to determine objectives of the master report. Content are input for heat exchanger unit, materials properties table, material constants table, mathematical model to determine heat transfer capacity, different pressure, heat transfer parameter and energy used for air conditioning.

**Chapter four** -address analysis and result for heat transfer capacity, different pressure, heat transfer parameter and energy used in air conditioning. Four types of nanofluids are being analysis under influences of volume fraction, tube diameter for heat exchanger and mass flow rate. Cu-$H_2O$, $AL_2O_3$-$H_2O$, Cu-Eg and $Al_2O_3$-Eg are nanofluids types used to performance analysis.

**Chapter five** – Conclusion achieve to the objective of the master report and recommendation for future study.

# CHAPTER 2.0 LIRERATURE REVIEW

## 2.1 ENERGY SAVING FOR AIR CONDITIONING

Reduces energy used, improvement resource management and minimize environmental impact are main goals for promotion of energy efficiency. Recently, energy planning policies is being implemented by most of the developed country. Implementation lies in variety of codes, strategies, laws and regulation. One third of the final energy consume worldwide is by building design and construction. For building section, energy certification and regulation program are basic tools for energy efficiency improvement. Design, retrofit of new building and construction of new building minimum energy efficiency are been set. There for, benchmarking program, building energy labelling and energy rating is directly linked to building energy certification (Pérez-Lombard, Ortiz et al. 2009).

Definition of energy efficiency could be as limit or reduce of energy use by device, process or system. In general, implement of energy efficiency requirement is by setting threshold value for the energy efficiency indicator for each particular system. Different kind of requirement can be set base on global, service low level requirement and demand – efficiency due to its complexity. Regulating entire building consumption is a aim for global requirement. A limit value of energy efficiency is being set for this purpose. Examples of global energy efficiency are European Energy Indicator (EPI) and American Energy Intensities (EI). Energy intensities for second regulatory is achieved when energy services are limited independently. By this, trade off with building services is not allowed. At certain extent, this regulatory reduces freedom of design. Japanese regulation (CCREUB) is example which adapt second regulatory. Freedom of design is been restricted for third regulation of energy efficiency requirement. This because energy efficiency and trade of energy demand is not possible. Definition of third regulation is ratio of the energy demand handle by system to the energy consumed

by system. Last regulatory level mention use of energy demand could not be prescribed. These types are referring to low level because energy consumption could not be determined.

In HVAC system, energy consuming by device is usually set by energy codes. At present, energy codes is minimum energy consume by HVAC systems. HVAC systems energy efficiency indicator can be expressed in few terms. Sometimes indicator is use equipment efficiency is defined at load state (partial or full) and operating systems. General indicators of energy efficiency are mention at table.

Table 1.0: Energy Efficiency Indicator (EEI) for HVAC equipment

| Equipment types | Acronym | EEI |
|---|---|---|
| DX air conditioner | EER | Energy efficiency ratio |
| | COP | Coefficient of performance |
| | SEER | Seasonal energy efficiency ratio |
| Heat pumps | EER | Energy efficiency ratio |
| | COP | Coefficient of performance |
| | SEER | Seasonal energy efficiency ratio |
| Chillers | EER | Energy efficiency ratio |
| | IPLV | Integrated part load value |
| | ESEER | European Seasonal energy efficiency ratio |

Fan coil unit (FCU) is one of HVAC systems. It consist heating or cooling coil (heat exchanger) and fan. FCU is widely used in residential, industrial and commercial building. Fan coil unit is used to control temperature in the spaced and typical

installation is without duct work. Temperature is being control either by thermostat or on/off switch. Economical value make fan coil unit is one of choices for air conditioning application however fan coil unit application can lead to high noise operation since fan is located in refrigerated space.

Central plant or mechanical room provides hot or cold water to coil. Heat is remove form or adds to air through heat transfer process. Hot water or cold water circulates through coil in order to condition a space. Typical central plant or mechanical room are cooling tower and chillier for removing heat application. Boiler and commercial water heater are most common use for heat adding process.

At present, two pipes and four pipes of fan coils are widely used for cooling and heating application. Two pipes type fan coil unit have one return pipe and one supply pipe. Supplying hot or cold water will be depend on seasonal aspect or demand by user. Two pipes of return and two pipes of supply will be used for four pipes application. Such application allows cold or hot water to enter the unit at any given time. Four pipes is most commonly use since it often necessary to heat and cold building at different area and same time.

## 2.2 HEAT EXCHANGER

Most of air conditioning, industry process and refrigerant used finned tube heat exchanger in it application. Heat transfer medium such as oil, water and refrigerant is force to flow to heat exchanger consist of equal spaced of parallel tube. Air is directly flow across tube and act as second heat transfer. Generally air flow across tube creates air resistance and for most practical application, air resistance is five or ten times higher than refrigerant side(Wang, Lee et al. 1998). Interrupted surface is one of the most popular enhance surface for heat exchanger. Heat transfer coefficient is increase by interrupted surface since developed boundary layer periodically renew. Louver fin and offset strip are most common of interrupted surface. When it come to large quantity of

production, louver fin pattern is more beneficial in cost term since it can be manufactured by high speed techniques.

For residential application, round tubes in block of parallel continuous fins are mechanically or hydraulic expanded for fins and tube heat exchanger. Louvers fins are generally brazed to flat with several independent of passage cross section of extrude tube for automotive application. Numbers of experiments were done by researcher for past few decades to find fins geometry configuration until at one time ninety one number of heat correlations was reported (Wang, Chi et al. 1998). Air side correlations for round tube louver fin configuration performance is not available. This is because air side is considered proprietary. Valuable information about fins lover was provided by Wang and his co – workers anyhow their intention to generate universal correlation heat transfer base on previous experiment is not yet accomplished. This is because fins and heat exchanger is different from one to other.

Laminar flow of two different nanofluids as investigated. Investigation was conducted in flat tube of radiator with $Al_2O_3$ and CuO in ethylene and water mixture(Vajjha, Das et al. 2010). Result shows an increment of thermal conductivity for entire nanofluids. Study on thermal heat exchanger using compact flat tube heat exchanger with number of transfer unit show a result of pressure drop increase with the increment of volume fraction. For constant velocity, increasing particle volume shows an increment of friction along the tube. In fully developed region, increasing of friction along the tube is around 2.75. Comparison is done at constant inlet velocity.

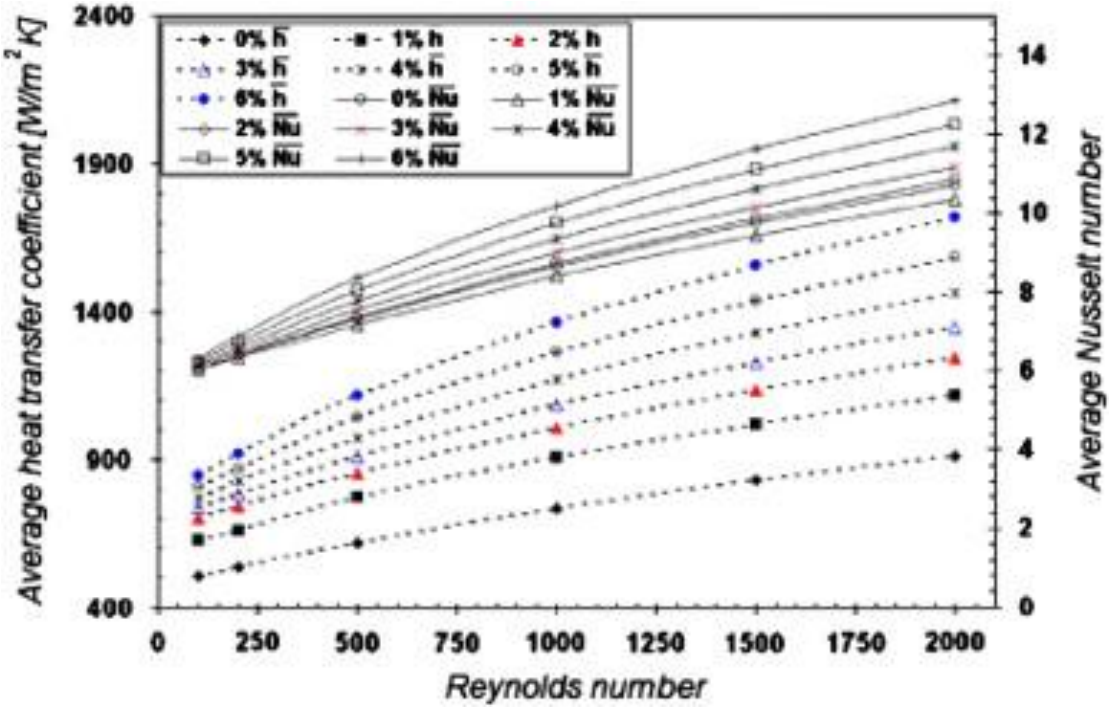


Figure 2.0 : Several of h and Nu with Re number for different particle of volumetric concentration of CuO nanofluid (Vajjha, Das et al. 2010)

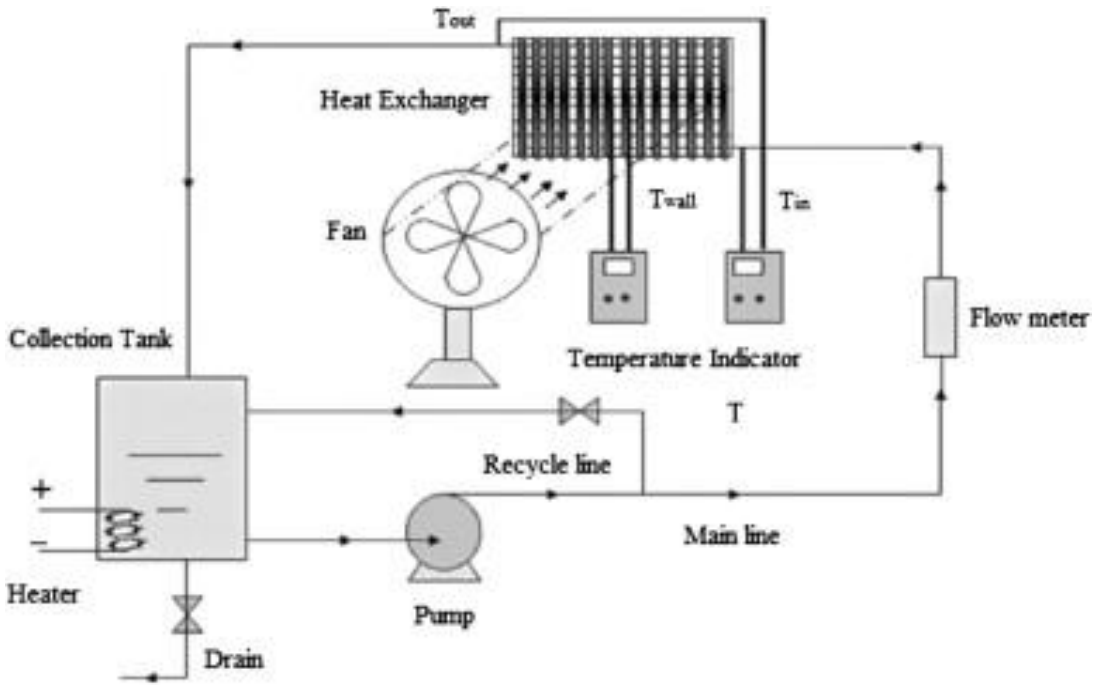


Figure 2.1 **:** Experimental setup for the study of the convective heat transfer of $Al_2O_3$/ water nanofluid under turbulent flow(Peyghambarzadeh, Hashemabadi et al. 2011)

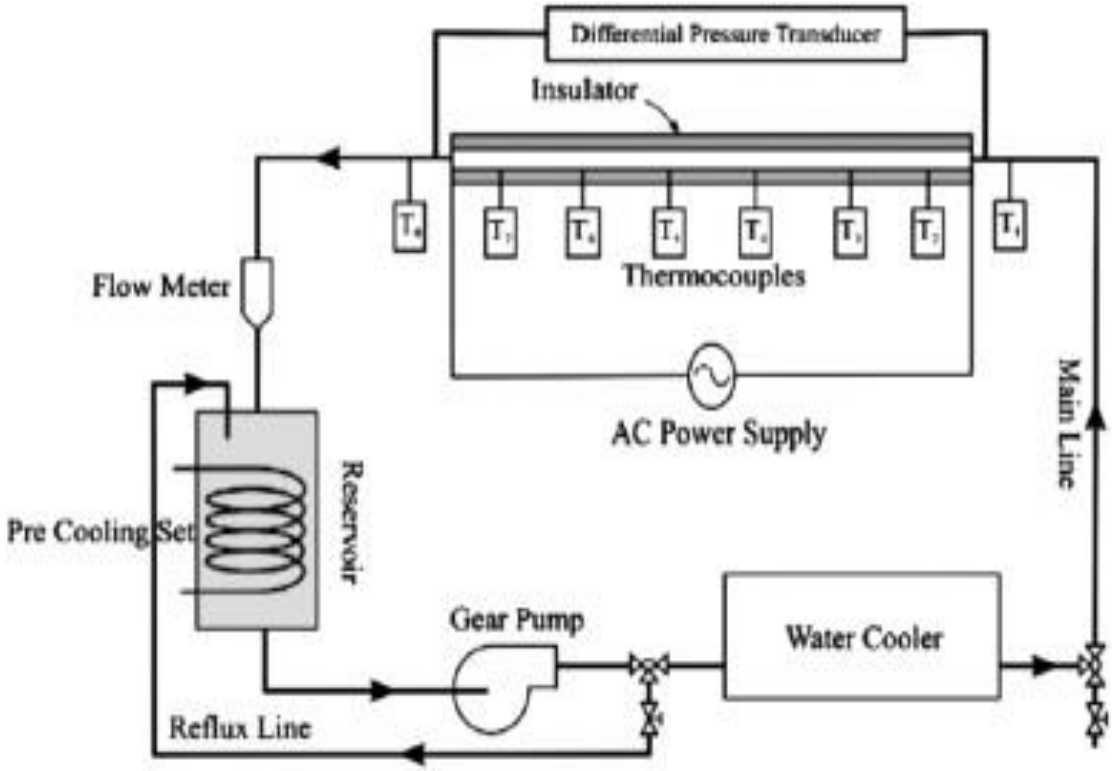


Figure 2.2: Experimental setup for the study of the flow and heat transfer characteristics of the CuO-base oil nanofluid flow inside the round tube and flattened tubes under constant heat flux(Razi, Akhavan-Behabadi et al. 2011)

## 2.3 NANOFLUID AS HEAT TRANSFER MEDIUM

Nanofluid is new generation of coolant which emerged due to rapid advances in nanotechnology. Nanofluids are relatively new class of fluids which consist of base fluid with nanoparticle (1-100nm) suspended within them. These particles are metallic or non-metallic in general. Aluminium and copper are example of metallic particle and silicon and alumina oxide are example of non-metallic particle. Generally, liquid also divided into two types which known as metallic and non-metallic. Table 1 show various types of liquid and nano particles. Example of metallic liquid is sodium and non-metallic liquid is water. Nanofluids increased thermal conductivity by allowing more heat transfer process out of coolant (Serrano, Rus et al. 2009). Enhancement of heat transfer demand of creating new technology for high heat flow process. Reduce of

weight and smaller heat exchangers are result of enhancement of heat transfer process. Smaller and lighter heat exchanger gives benefits in reduce cost and energy saving.

Table 2.0 : Various solid(nanoparticle) and (liquid)base fluid types.

| Liquids / Solid | Material |
|---|---|
| Metallic liquid | Sodium (644K) |
| Nonmetallic liquid | Ethylene glycol |
| | Engine oil |
| | Water |
| Nonmetallic solids | Silicon |
| | Alumina |
| Metallic solids | Aluminium |
| | Cooper |

## 2.4 THERMO PHYSICAL PROPERTIES FOR NANOFLUIDS

**Convective heat transfer**

Nanofluid heat transfer is very complex and heat transfer enhancement of nanofluids should be decided by many factors and not only by it thermal conductivity. Other factors such as shape and distribution, particle size, particle – fluids interaction, pH value and micro- convection play major parameters on heat transfer performance of nanofluids (Wang and Mujumdar 2007).

Constant heat flux straight pipe experiment with nanofluid as transfer medium give substantial enhancement of heat transfer compare to pure water(Xuan, Li et al. 2013) . Additional finding by them is at low volume fraction, nanofluids do not give extra burden to pumping device.

Increasing number of particles and Reynolds number increase heat transfer coefficient(Wen and Ding 2004). Experimental result shows, Nanofluid enhanced

convective heat transfer significantly by flowing through cooper tube (Diameter = 4.5mm, L = 970mm) when $Al_2O_3$ particle with water as basefluid was used as nanolfuid for experiment. Significant heat transfer coefficient enhancement was observes at entrance region and decreased with axial distance. Hence, heat transfer to particle migration also observed which result for non uniform of thermal conductivity.

Volume fraction also play major important role in determine heat transfer coefficient. Increasing volume fraction of nanofluid for CuO-$H_2O$ and $Al_2O_3$ – $H_2O$ enhance heat transfer coefficient (Noie, Heris et al. 2009).

**Thermal Conductivity**

Cooper dioxide and Alumina ($Al_2O_3$) are used widely in experimental by researcher since those material is easy available and not expensive. Entire experiments conducted by researcher show enhancement of thermal conductivity by adding nanoparticles into base fluid. 5 % of nanoparticles show increment of 60 % of thermal conductivity as compare to basefluid (J. A. Eastman 1996). Experiment was conducted with two different basefluids with $Al_2O_3$, CuO and Cu material nanoparticle. Water and He-200 oil are used as basefluids. Additional finding is nanoparticle production method shows different thermal conductivity enhancement. Using two steps method show higher thermal conductivity compare to one step method.

Nanofluids thermal conductivity is depend on nanoparticle size. Large size of nanoparticle size show enhancement of thermal conductivity. Experimental result show 100nm Cu particle enhance thermal conductivity of water compare to 36nm Cu particle (Y.M. Xuan 2003). Nanolparticle size will give influence in suspension for nanofluids. Proper selection of dispersant may improve suspension stability. Due to this, oleic acid and laurate salt are used to improve suspension stability for experiment conducted. Result show superior characteristic of suspension when Cu particle used with transformer oil compare to water. Improvement of 40% also archived in thermal

conductivity for 10nm or less Cu of nanoparticle size dispersed in ethylene glycol (J. A. Eastman 1996). Ratio surface to volume may lead to this phenomenon. Additional finding by is thermal conductivity effectiveness may increase by using acid additive to stabilize the suspension.

Particle size shows effect on flow rate for nanofluids. Smaller particle size increase flow rate since reducing particle size increasing viscosity(Namburu, Kulkarni et al. 2007). For same volume concentration, small particle size will have higher number of particle which leads to more particle interacting with the liquid phase compare to larger particle(Vajjha, Das et al. 2010).

Thermal conductivity of nanofluids also depends on variations of temperature. Significant improvement of thermal conductivity for $Al_2O_3$ (38.4nm) and CuO (28.6nm) through an experiment investigation using temperature oscillation method is reported(Das, Putra et al. 2003). Sudden increment was observed taking place for temperature range from 21 $^{\circ}$C to 52 $^{\circ}$C. Result show that nanofluid application is suitable for high density of energy which temperature is higher than room temperature. Increasing in thermal conductivity is depending on stochactic of nanoparticle since smaller particle result higher increment with temperature. CuO (29nm) and $Al_2O_3$ (36nm) nanoparticle in water suspension to various temperature and volume fraction investigation result show an increment of thermal conductivity. On top of that, nanoparticle diameter and nanopartilce material also give impact of determination of thermal conductivity value. Three times increment of thermal conductivity was finding for experiment on $Al_2O_3$-$H_2O$ suspension with mean temperature range from 27 $^{\circ}$C to 34.7 $^{\circ}$C (Li and Peterson 2007).

Suspension pH value, specific surface area (SSA) and crystallize phase of solid effect on thermal conductivity. Study show specific surface areas give enhancement of thermal conductivity while crystallize phase on nanoparticle do not give any impact on

thermal conductivity. Enhancement of thermal conductivity also yields for different pH value. Isoelectric point ( pH which molecule  no net charge) increment of thermal conductivity is higher than other pH value (Xie, Wang et al. 2002).

Generally, a lot of thermal conductivity for nanolfuids is being published. Table 2.1 shown an example of thermal conductivity develop by other researcher. Each of the correlation show is a theoretical correlation. Researcher also conducted an experimental on nanofluids to verify accuracy and improve the correlation develop by theory. At present, deviation between experimental result and theoretical result is closed to each other or the deviation can be neglected. Table 2.2 show experimental result thermal conductivity form various researchers.

Table 2.1: Thermal conductivity correlation for nanofluids(Theoretical)(Huminic and Huminic 2012)

| Reference | Year | Correlation |
|---|---|---|
| (Koo and Kleinstreuer 2004) | 2004-2005 | $\frac{K_{eff}}{K_f} = \frac{k_p + 2K_f + 2\phi(k_p - k_f)}{k_p + 2K_f - \phi(k_p - k_f)} + 5 \times 10^{0.4}\, \beta \rho_p C_p$ |
| (Prasher, Bhattacharya et al. 2005) | 2005 | $\frac{K_{eff}}{K_f} = \frac{k_p + 2K_f + 2\phi\left(k_p - k_f\right)}{k_p + 2K_f - \phi\left(k_p - k_f\right)} (1 + ARe^m Pr^{0.66}\phi)$ |
| (Xue 2005) | 2005 | $\frac{K_{eff}}{K_f} = \frac{1 - \phi + 2\phi \frac{k_p}{k_p - k_f}\, ln \frac{K_p + K_f}{2k_f}}{1 - \phi + 2\phi \frac{k_{pf}}{k_p - k_f}\, ln \frac{K_p + K_f}{2k_f}}$ |

Table 2.2: Thermal conductivity correlation for nanofluids(experimental)(Huminic and Huminic 2012)

| Reference | Year | Correlation |
|---|---|---|
| (Patel, Sundararajan et al. 2010) | 2010 | $\frac{K_{eff}}{K_f} = 1 + 0.135(\frac{k_p}{k_f})^{0.273}\phi^{0.60.4676}\left(\frac{T}{20}\right)^{0.347}\left(\frac{T100}{d_p}\right)^{0.234}$ |
| (Chandrasekar, Suresh et al. 2010) | 2010 | $\frac{K_{eff}}{K_f} = \left(\frac{Cp_{eff}}{Cp_f}\right)^{-0.023}\left(\frac{P_{eff}}{\rho_f}\right)^{1.358}\left(\frac{M_f}{M_{eff}}\right)^{0.125}$ |
| (Vajjha, Das et al. 2010) | 2010 | $\frac{K_{eff}}{K_f} = \frac{k_p + 2K_f + 2\phi(k_p - k_f)}{k_p + 2K_f - \phi(k_p - k_f)} + 5 \times 10^{0.4}\,\beta\rho_p C_p$ |
| (Corcione 2011) | 2011 | $\frac{K_{eff}}{K_f} = 1 + 0.44Re^{0.4}\,Pr^{0.66}\left(\frac{T}{T_{fr}}\right)^{10}\left(\frac{T}{Tfr}\right)^{0.03}\phi^{0.66}$ |

**Viscosity**

$Al_2O_3 – H_2O$ and $Al_2O_3$ - Eg relative viscosity of nanolfuid experiment was conducted. Result yields an increment of volume fraction for two nanofluid increase relative velocity (Wang and Mujumdar 2007). Increase relative viscosity may lead to increment of pressure drop. Increment of pressure drop may of set the energy saving by heat transfer since additional energy required during operation of specific device such air condition. Experiment conducted to measure nanopartilce suspension viscosity using capillary tube show viscosity of nanofluid decreased with increasing temperature. Outcome still can be debating since capillary tube diameter may influence viscosity at low temperature and high nanoparticle mass fraction. CNT – $H_2O$ nanofluid viscosity experiment was measured in function of shear rate by researcher. Result show

increasing CNT concentration and degreasing temperature yield an increment of viscosity of nanofluid(Ding, Alias et al. 2006). $Al_2O_3 – H_2O$ nanofluid viscosity again shear rate experiment was conducted. Outcome concludes that increasing particle concentration increased viscosity(Das, Putra et al. 2003). Researcher point out that nanofluid may be non – Newtonian even viscoelectric for some cases.

**Density and Specific heat**

Present day, data on density and specific heat for nanolfuid are limited due lack of experimental conducted by researcher. Anyhow, many researcher mention same thing which is nanofluid specific assume to be linear function of volume fraction. Any increment in volume fraction show decreasing in specific heat (Das et al, 2008). Conclusion was outcome from experiment conducted for ethylene glycol with cooper and Alumina. Density of nanolfuid is influence by volume fraction of nanoparticle. Increase volume fraction shows increasing of density (Nambur et al, 2009). Finding by researcher also mention density for nanolfuids is an assumption parameter. Entire researcher agreed that naofluid density is in linear functions of volume fraction. Anyhow, further experiment is a must since at present, data for density is limited.

Below is summarizing of correlation for viscosity which already publish by researcher around the world. Each of the correlation is limit to it specific nanofluids.

Table 2.3 : Viscosity for nanofluids by experimental or theoretical(Huminic and Huminic 2012)

| Reference | Year | Correlation |
|---|---|---|
| (Chandrasekar, Suresh et al. 2010) | 2010 | $\frac{\mu_{eff}}{\mu_f} = 1 + b\left(\frac{\phi}{1-\phi}\right)^n$ |
| (Vajjha, Das et al. 2010) | 2010 | $\frac{\mu_{eff}}{\mu_f} = 0.9197e^{22.8539e}$ |
| (Corcione 2011) | 2011 | $\frac{\mu_{eff}}{\mu_f} = \frac{1}{1 - 34.87(\frac{d\rho}{df})^{-0.3}\phi^{-2.03}}$ |

## CHAPTER 3.0 RESEARCH METHODOLOGY

Few methods or approaches can be used to analysis of energy saving. Experimental method is the most reliable method but it takes long time for setup testing facilities. Simulation approached is famous at present time. This method make data can be repeated and fast. Drawback for this method is result must be validating with testing. In this report, both methods mention above is not used. Analytical method is been used since at present many empirical equation are been derived.

Methodology analysis of energy saving for air condition by nanofluid is base on heat transfer performance. Analyses are conducted under influences of volume fraction of nanoparticle inside nanofluids. Cu-$H_2O$, $Al_2O_3$-$H_2O$, Cu-Eg and $Al_2O_3$-Eg of nanofluids are used for analysis. Volume fraction of nanoparticle such as 2 %, 4 % and 6% and heat exchanger parameter such as different number of rows also use as changing parameter for determination of energy saving in air condition. A fin tube heat exchanger is typically constructed aligned cooper tube rows and stacked aluminium fins.

Heat exchanger configuration is difficult to make an accurate calculation since geometry parameter is required during solving analytical problems. Common analytical heat exchanger involves external and internal heat transfer area such as air side and tube side. Figure 3.2 illustrated of internal and external heat transfer area in heat exchanger.

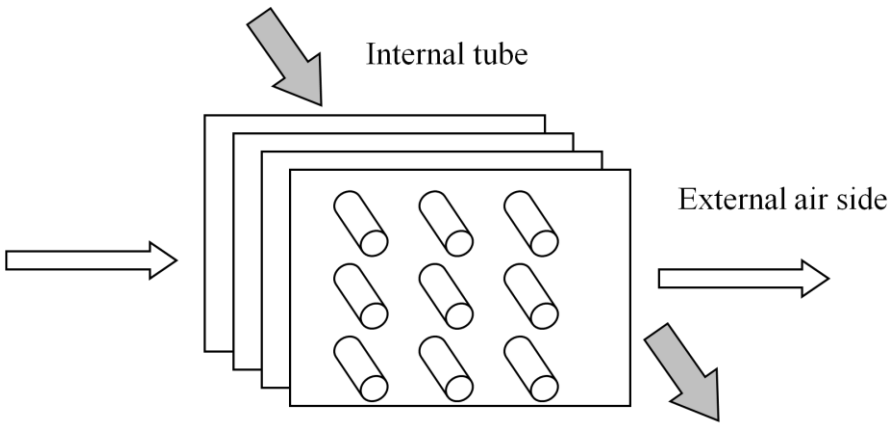


Figure 3.0: Heat transfer in heat exchanger

## 3.1 INPUT DATA

### 3.1.1 Heat exchanger diagram

Heat exchanger diagram is show in figure 3.3 is used to illustrated nanolfuids flow in air conditioning. Analysis is done on the internal side of heat exchanger. Such parameter for external side will not be shown here. Entire parameter for heat exchanger is tabulated in table 3.1.

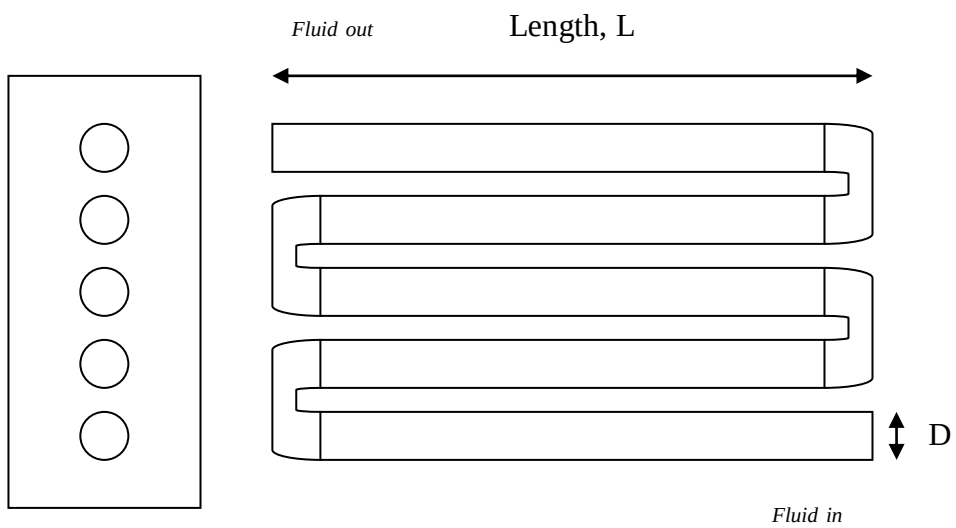


Figure 3.1: Heat exchanger diagrams

Table 3.0: Parameters for analysis

| Parameter | Value |
|---|---|
| Fluid entering temperature (°C) | 7 |
| Fluid leaving temperature (°C) | 12 |
| Length tube (m) | 1 |
| Diameter tube (mm) | 7, 10 and 12.5 |
| Mass flow rate (kg/s) | 0.1, 0.15, 0.2,0.25 |
| Thermal conductivity coefficient | 2.5 |
| Viscosity coefficient | 3.0 |

3.1.2 Material properties and constants

For analysis purpose, thermal physical properties of material used are needed. Thermal conductivity, specific heat, density and viscosity are four major properties during analysis of heat exchanger performance.

Table 3.1: Thermal physical for base fluids and Nanoparticle

| **Properties** | **Base fluids** | | **Nanoparticle** | |
|---|---|---|---|---|
| | **$H_20$** | **EG** | **$AL_2O_3$** | **CU** |
| Thermal conductivity, k(W/m.K) | 613 x $10^{-3}$ | 252 x $10^{-3}$ | 40 | 401 |
| Density, ρ (kg/$m^3$) | 1000 | 1114 | 3900 | 8490 |
| Viscosity, μ ( Ns/$m^2$) | 855 x $10^{-6}$ | 1.57 x $10^{-2}$ | - | - |
| Specific heat, Cp (J/kg.K) | 4180 | 2415 | 880 | 385 |

## 3.2 MATEMATICAL EQUATIONS

### 3.2.1 Thermal physical properties for Nanofluids

Thermal conductivity

Hamilton – Crosser use nanoparticle shape consideration for determination of nanofluid thermal conductivity(Namburu, Kulkarni et al. 2007). Thermal conductivity for spherical particle is determined by equation which takes different shape parameter as references parameter. Thermal conductivity is calculated by using below equation.

$$Knf = (1 + 7.47\phi)kbf \qquad (3.1)$$

Where

$Knf$ - Thermal conductivity of nanofluid

$kbf$ - Thermal conductivity of basefluid

$Ck$ - Thermal conductivity coefficient

Φ - Volume fraction of nanoparticle

Density

Nanofluid density is not being debate as much as other properties. Density of nanofluid is calculated by below equation (J. A. Eastman 1996).

$$\rho nf = (1 - \Phi)\rho bf + \rho np \quad (3.2)$$

Where

$\rho nf$ – Density of nanofluid

$\rho bf$ – Density of basefluid

$\rho np$ - Density of nanoparticle

$\Phi$ - Volume fraction of nanoparticle

Viscosity

Rheological properties of colloids or suspension for viscosity study is use to determine viscosity.Viscosity of nanofluid is calculated according to the input data required(Namburu, Kulkarni et al. 2007).

$$\mu nf = \mu bf(1 + C\mu\Phi) \quad (3.3)$$

Where

$\mu nf$ - Viscosity of nanofluid

$\mu bf$ - Viscosity of basefluid

$C\mu$ - Viscosity coefficient

$\Phi$ - Volume fraction of nanoparticle

Specific Heat

Specific heat of nanofluid can be taken on mass average or volume fraction. At present, debating on specific heat of nanofluid is less. Calculation of specific heat using mass average is show below(J. A. Eastman 1996).

$$Cpnf = \frac{1 - \Phi\rho bf.\ Cpbf + \Phi.\rho np}{\rho bf(1 - \Phi) + \rho np.\Phi} \quad (3.4)$$

Where

$Cpnf$ – $Specific\ heat\ of$ nanofluid

$Cpbf$ – Specific heat of basefluid

### 3.2.2 Heat Exchanger

When dealing with internal flow, flow region is an important parameter which depend on whether flow is turbulent and laminar. Reynolds number is used to determine flow condition inside the tube. (Cengel 2006)

$$Re_D = \frac{\mu_m D}{\nu} \tag{3.5}$$

Where

$\mu_m$ - Mean fluid velocity

D - Tube diameter

ν - Viscosity

Dealing with internal flow, mean velocity is necessary. Velocity is defined such that fluid density multiply with cross section area of the tube will give rate of mass flow through the tube.

$$\dot{m} = \rho \mu_m A_C \tag{3.6}$$

Where

$A_C$ - Cross section area of tube

For steady and incompressible flow in tube of uniform cross sectional area, $\dot{m}$ and $\mu_m$ are constant independent of length and $A_C = \pi D^2/4$. Reynolds number is reduce to

$$Re_D = \frac{4\,\dot{m}}{D\pi\mu} \tag{3.7}$$

Pressure drop must be consider when deal with internal flow. Pressure drop is important parameter in determine pump or fan power requirement. With simplified of

fanning friction factor, Reynolds number and Moody or Darcy friction factor, friction factor for fully develop laminar flow is

$$f = \frac{64}{Re_D} \tag{3.8}$$

Analysis of turbulent flow is ultimately relying on experimental result. Friction factor is the function of tube surface tube condition. Friction factor is increase with the increasing of surface roughness. Correlation develop by Petukhov is use to determine friction factor and it as follow

$$f = (0.790 \ln Re_D - 1.64)^{-2} \tag{3.9}$$

Fan or pump power required to overcome the flow resistance with pressure drop may express as

$$P = (\Delta p)\dot{\forall} \tag{3.10}$$

$$\Delta p = f \frac{\rho v^2{}_m}{2D}(X_2 - X_1) \tag{3.11}$$

Where

$\dot{\forall}$ - Volumetric flow rate which express as $\dot{m}/\rho$

$(X_2 - X_1)$ –Length of tube

Determination of energy use is calculation form energy output from heat exchange divided to pumping power. It follows below equation.

$$Nu = 0.0265\, Re^{0.4}\, Pr^{0.3} \tag{3.12}$$

Equation 3.12 is use for common practice in calculating local Nusselt number with some improvement form few researcher such as Sieder and tate, Winterton and so on. Experimental result also show that Nusselt number for heating and cooling is different but for this master report, general Nusselt number is use as equation 3.12 since energy saving is calculated base on comparison.

$$h = \frac{Nuk}{D} \tag{3.13}$$

$$Q = hA\Delta T \tag{3.14}$$

$$energy\ ratio = \frac{Q}{P} \tag{3.15}$$

$$q = \frac{Nu}{Pr^{1/3}} \tag{3.16}$$

Energy saving percentage for nanofluids is calculated by dividing energy ratio for nanofluids to energy ratio of base fluids. As a standard mathematical model, result is positif value show and increment and result in negative value show increment not favorable or nanofluids operated in air condition not giving any benefit.

$$\%\ energy\ saving = \frac{nanofluid\ energy\ ratio}{base\ fluid\ energy\ ration} \tag{3.17}$$

Where

$Q$ - Heat capacity

h - Thermal heat parameter

q - Heat transfer parameter

Energy saving percentage for nanofluids is calculated by dividing energy ratio for nanofluids to energy ratio of base fluids. As a standard mathematical model, result is positif value show and increment and result in negative value show increment not favorable or nanofluids operated in air condition not giving any benefit.

# CHAPTER 4.0 RESULT AND DISCUSSION

## 4.1 RESULT

### 4.1.1 Thermal Conductivity

Equation (3.1) is used to determine thermal conductivity of nanofluid with various volume fractions. Thermal conductivity result is shown in figure 4.1. Increasing volume fraction show an increment result for thermal conductivity for nanofluid. Thermal conductivity shows a linear increment with increasing volume fraction. Summarize of thermal increment is shown in table 4.1. Entire nanofluid show same percentage increment. Thermal conductivity for nanofluid with water as base fluid show higher thermal conductivity compare to nanofluid with Ethylene – glycol as base fluid.

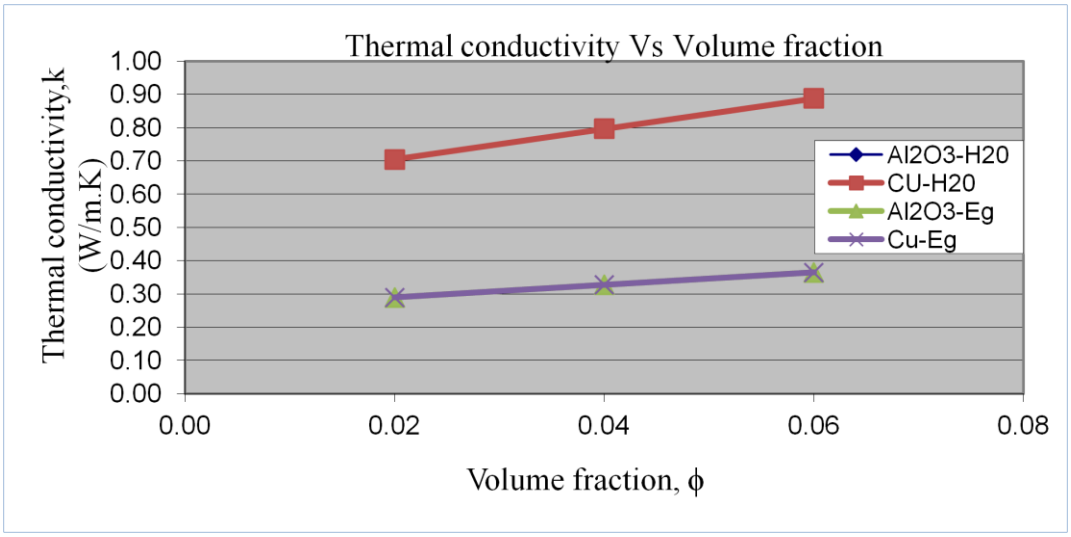


Figure 4.0: Thermal conductivity for nanofluids

Table 4.0: Percentage of thermal conductivity increment for nanofluid.

| Nanofluid | Volume fraction, ϕ | % Increment of k |
|---|---|---|
| $Al_2O_3$-$H_20$, Cu-$H_2O$, $Al_2O_3$-Eg, Cu-Eg | 0.2 | 15 |
| | 0.4 | 30 |
| | 0.6 | 45 |

4.1.2 Density

Equation (3.2) is used to determine density of nanofluid with various volume fractions. Nanofluid density result is show in figure 4.2. Increase amount of nanoparticle into nanofluid show an increment in density. Density increment is in linear increment with increment of volume fraction. Percentage increment of nanofluid density is show in table 4.2. Copper as nanoparticle show more significant increment of density in nanofluid compare to alumina as nanoparticle. Increment is not same since copper have higher density compare to alumina.

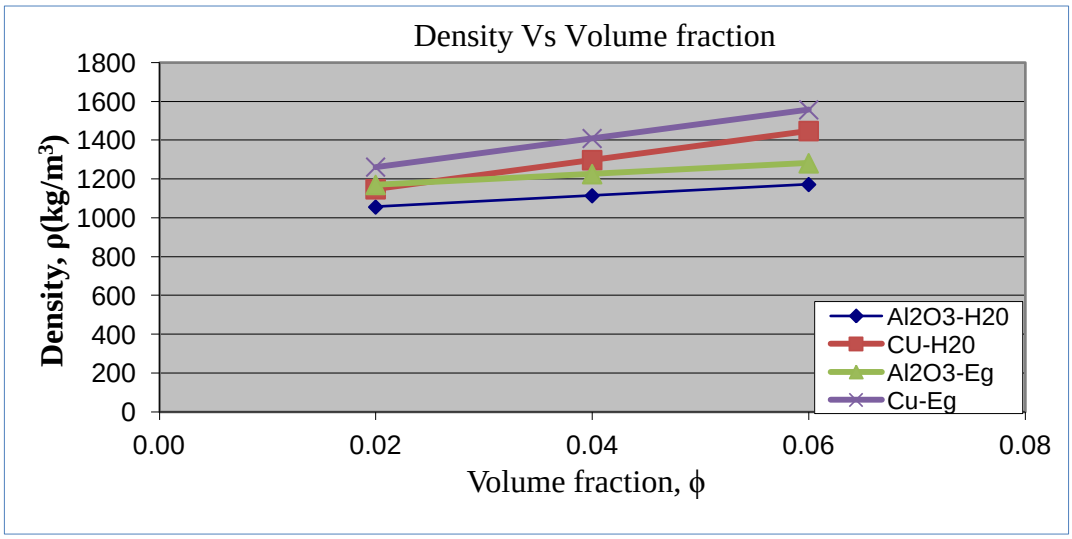


Figure 4.1: Density for nanofluids

Table 4.1: Percentage of density increment for nanofluid.

| Nanofluid | Volume fraction, ϕ | % Increment of k |
|---|---|---|
| $Al_2O_3$-$H_20$ | 0.2 | 6 |
| | 0.4 | 12 |
| | 0.6 | 18 |
| Cu-$H_2O$ | 0.2 | 15 |
| | 0.4 | 30 |
| | 0.6 | 45 |

Table 4.1: Continued

| | | |
|---|---|---|
| $Al_2O_3$-Eg | 0.2 | 5 |
| | 0.4 | 10 |
| | 0.6 | 15 |
| Cu-Eg | 0.2 | 13 |
| | 0.4 | 26 |
| | 0.6 | 39 |

4.1.3 Viscosity

Equation (3.3) is used to determine viscosity of nanofluid for with various volume fractions. Figure 4.3 show various result of nanofluids with varies of volume fractions. Increment of nanoparticle show an increment result of viscosity in nanofluids. Entire nanofluids show same percentage of increment. Table 4.3 show result for increment of nanofluids. Even do entire result show same increment percentage, Higher value of viscosity is result in nanofluid Cu-Eg and $Al_2O_3$ – Eg compare to $AL_2O_3$-$H_2O$ and Cu-$H_2O$.

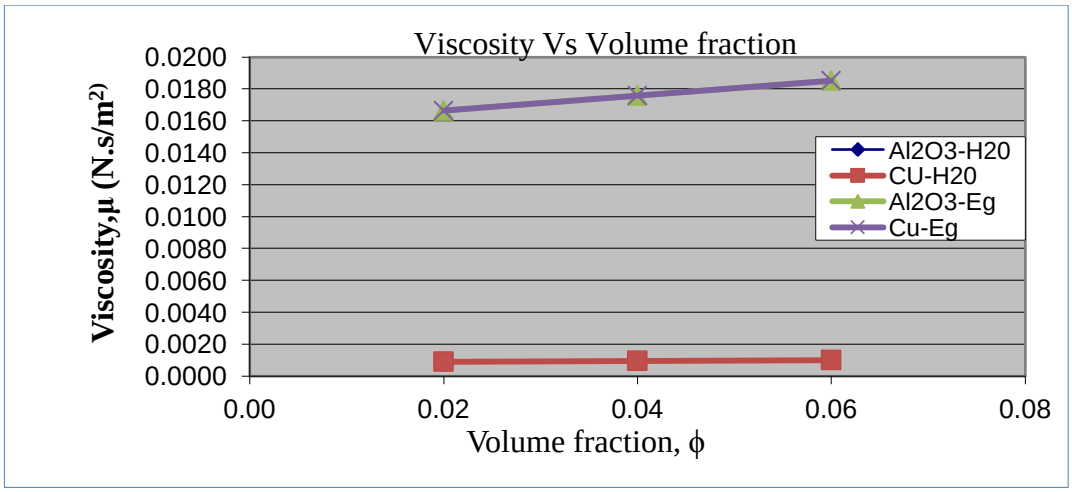


Figure 4.2: Viscosity for nanofluids

Table 4.2: Nanofluids viscosity

| Nanofluid | Volume fraction, ϕ | % Increment of k |
|---|---|---|
| $Al_2O_3$-$H_20$, Cu-$H_2O$, $Al_2O_3$-Eg, Cu-Eg | 0.2 | 6 |
| | 0.4 | 12 |
| | 0.6 | 18 |

4.1.4 Specific heat

Equation (3.4) is used to determination specific heat of nanolfuids for various volume fractions. Figure 4.4 show various result of nanofluids with various volume fraction. Nanofluids show reducing result in specific heat with increment of nanoparticle. Entire result for reducing nanofluid specific heat is show in table 4.4. Specific heat for nanofluids with various volume show same percentage value of reducing. Nanofluids with water as base fluid show higher specific heat value compare to nanofluids with ethylene glycol.

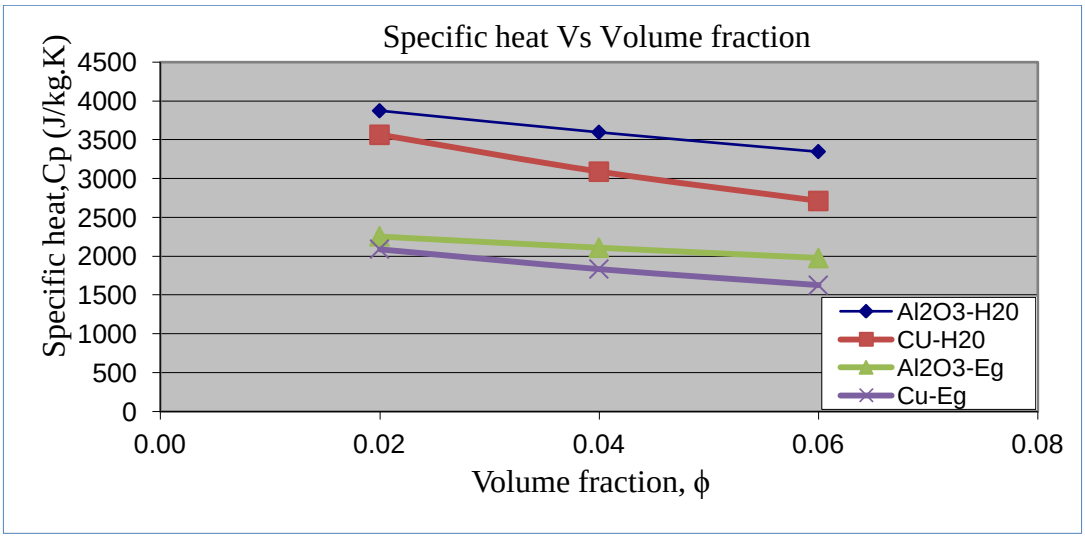


Figure 4.3: Specific heat for nanofluids

Table 4.3: Specific heat for nanofluids

| Nanofluid | Volume fraction, $\phi$ | % reducing of Cp |
|---|---|---|
| $Al_2O_3$-$H_20$ | 0.2 | 7 |
| | 0.4 | 14 |
| | 0.6 | 20 |
| Cu-$H_2O$ | 0.2 | 15 |
| | 0.4 | 26 |
| | 0.6 | 35 |
| $Al_2O_3$-Eg | 0.2 | 7 |
| | 0.4 | 13 |
| | 0.6 | 18 |
| Cu-Eg | 0.2 | 13 |
| | 0.4 | 24 |
| | 0.6 | 33 |

4.1.5 Heat capacity and heat transfer parameter

Equation (3.16) and (3.14) are used to determine heat transfer parameter and heat capacity for nanofluids. Figure 4.5 and figure 4.6 show result of heat transfer parameter with different Reynolds number. Both nanofluids show reducing result of heat transfer parameter with increasing Reynolds number. For heating capacity, results are shown in figure 4.7 and figure 4.8 again Reynolds number. For both nanofluids, heating capacity is reducing with increasing Reynolds number.

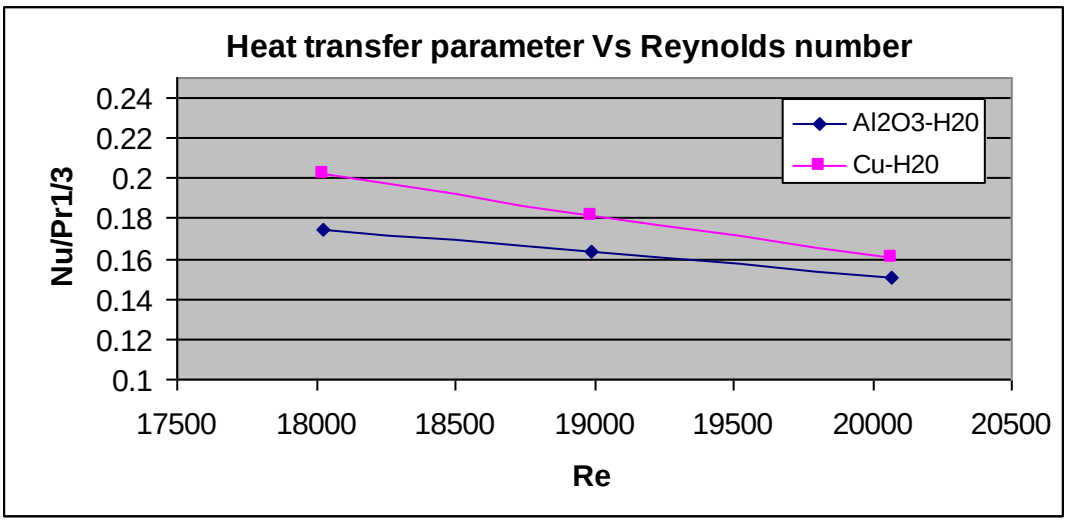


Figure 4.4: Heat transfer parameter for water base nanofluids

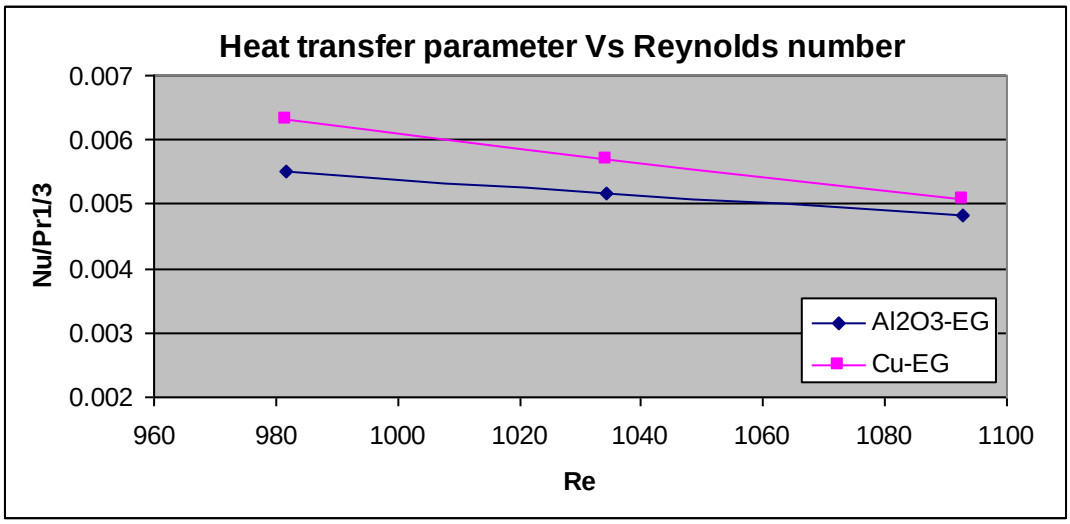


Figure 4.5: Heat transfer parameter for Ethylene glycol base nanofluids

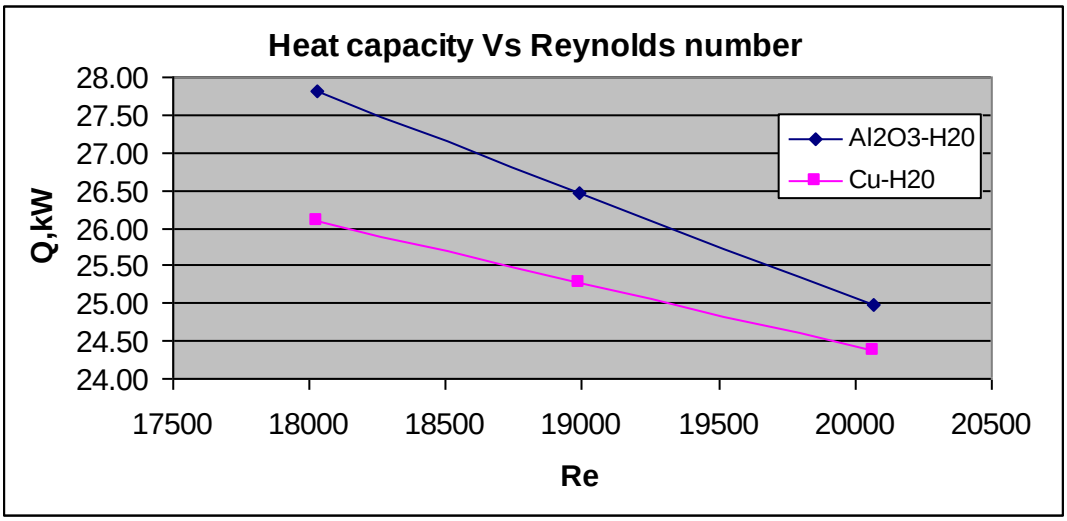


Figure 4.6: Heat capacity for water base nanofluids

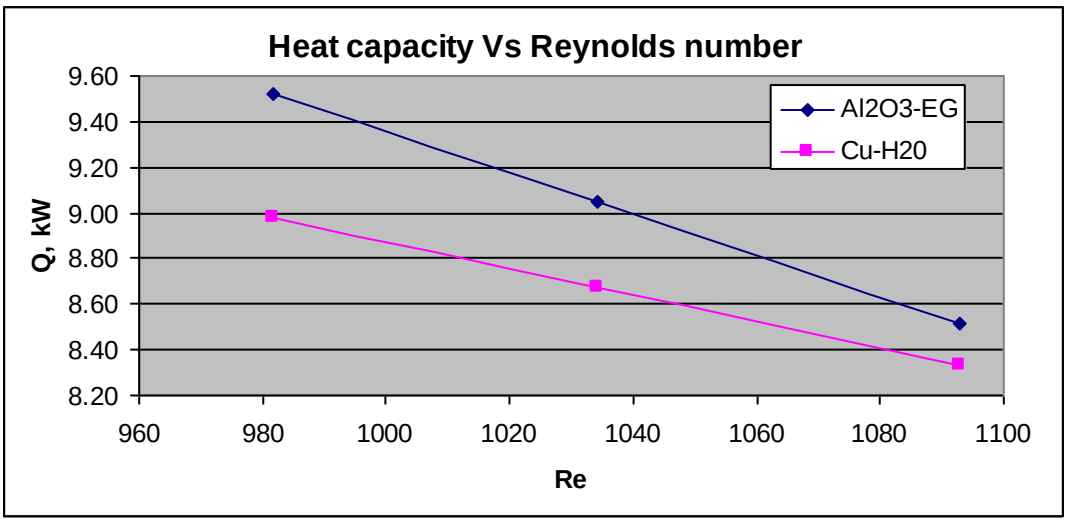


Figure 4.7: Heat capacity for water base nanofluids

4.1.6 Different pressure

Equation (3.11) is used to determine different pressure for nanofluids. Figure 4.9 and figure 4.10 show result for different nanolfuids different pressure. Entire nanofluids show reduction in linear with increasing of Reynolds number.

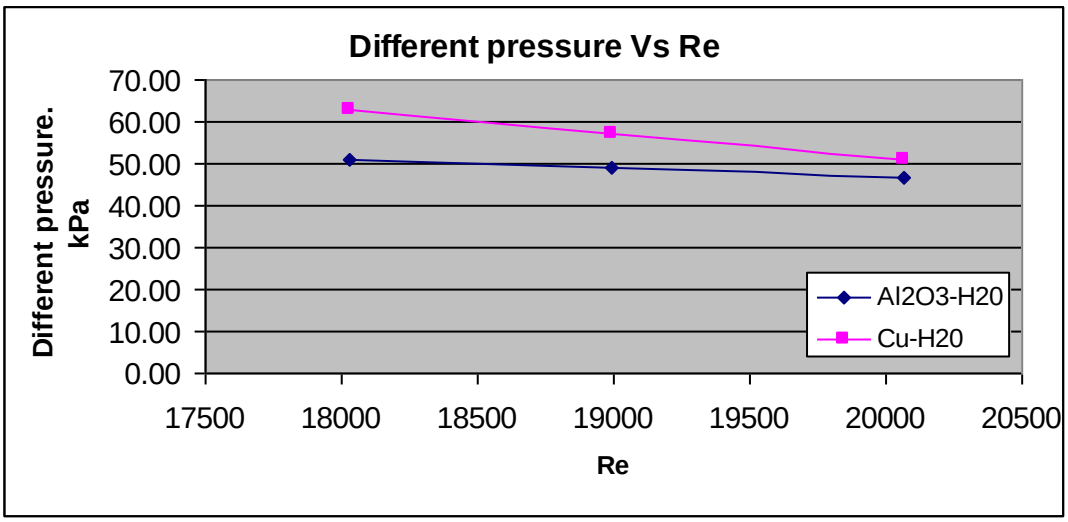


Figure 4.8: Different pressure for water base nanofluid.

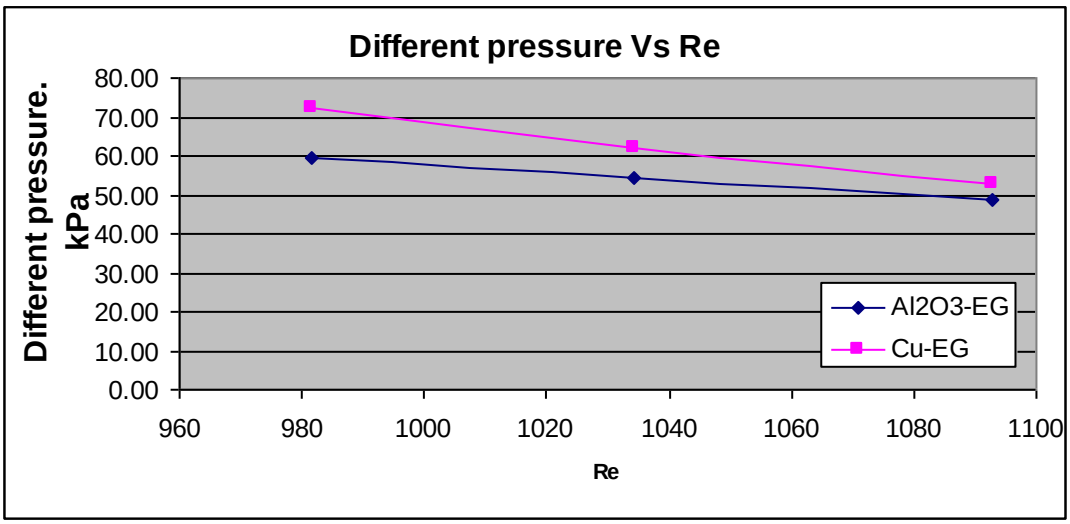


Figure 4.9: Different pressure for ethylene glycol base nanofluid.

4.1.7 Mass flow rate

Mass flow rate is one the important parameter to determine energy ratio. Figure 4.11 show mass flow rate result with energy ration. For same volume fraction, increasing mass flow rate will reduce energy ratio. Same effect also observed to nanofluids with volume fraction of 0.4 and 0.6. For same mass flow, increasing volume fraction shown and increment result for energy ratio. Increment for energy ratio is in linear for entire nanofluids and volume fraction.

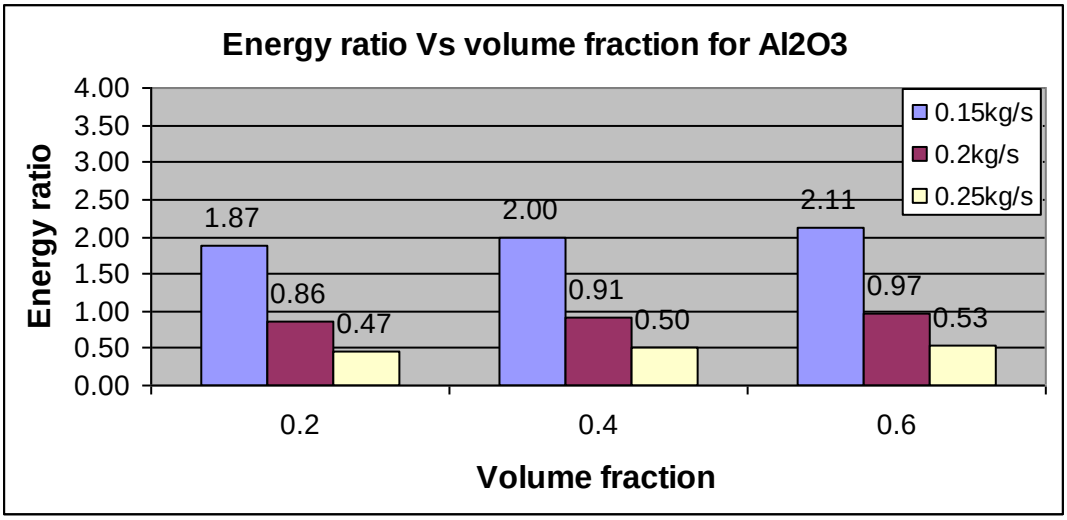


Figure 4.10: Mass flow rate impact to energy ratio

4.1.8 Tube diameter

In heat exchanger, coil which consist tube diameter is a important parameter for determination heat capacity and energy ratio. Figure 4.12 show various volume fraction again different tube coil diameter. For same volume fraction, energy ratio is increasing by increasing coil diameter. Linear trend of increasing energy ratio is observed. For same tube diameter, increasing volume fraction yields and increment result of energy ration. Entire tubes which are 7 mm, 10 mm and 12.5 mm show same result trend.

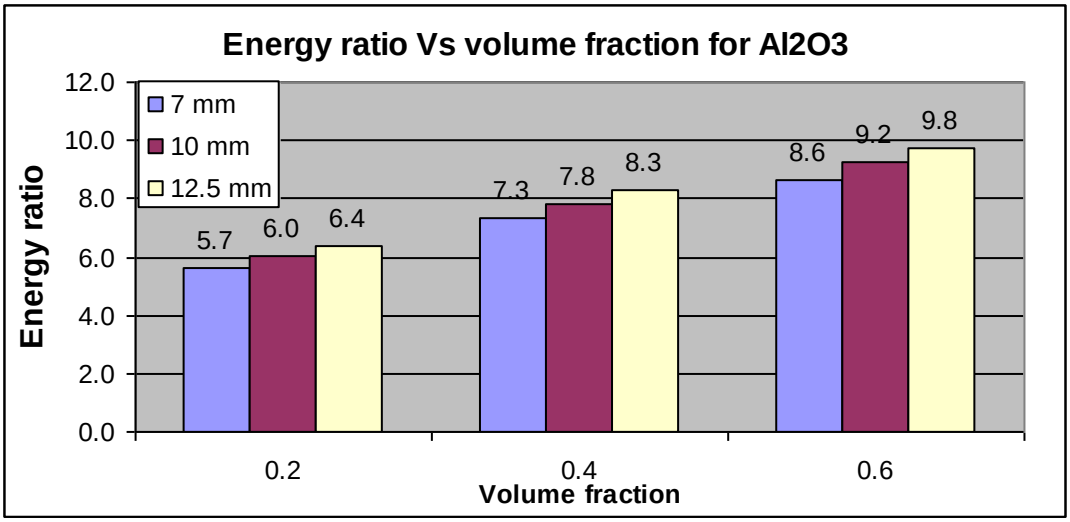


Figure 4.11: Heat exchanger tube diameter impact to energy ratio

4.1.9 Energy saving for air conditioning operated with nanofluids

Energy saving for air conditioning system which operated with nanofluids application graph is plot in figure 4.13 and figure 4.14. Figure 4.13 is comparing result of energy ratio for water base nanofluids application and figure 4.14 is comparing result for ethylene glycol base fluid of nanofluids. For alumina nanofluid and copper nanofluids, result shown and increment of energy ratio. Even with increment of volume fraction, both nanofluids still showed a positive result which is an increment compare to base fluids. For ethylene glycol base fluids, adding nanoparticle such as alumina show an increment result. Anyhow, with copper nanoparticle, this nanofluid shows a reduction of energy ratio result. A reduction is observed at 0.2 and 0.4 volume fraction

of nanoparticle. Anyhow, 0.6 volume fraction show better result which nanofluids and base fluids yields same result for energy ratio.

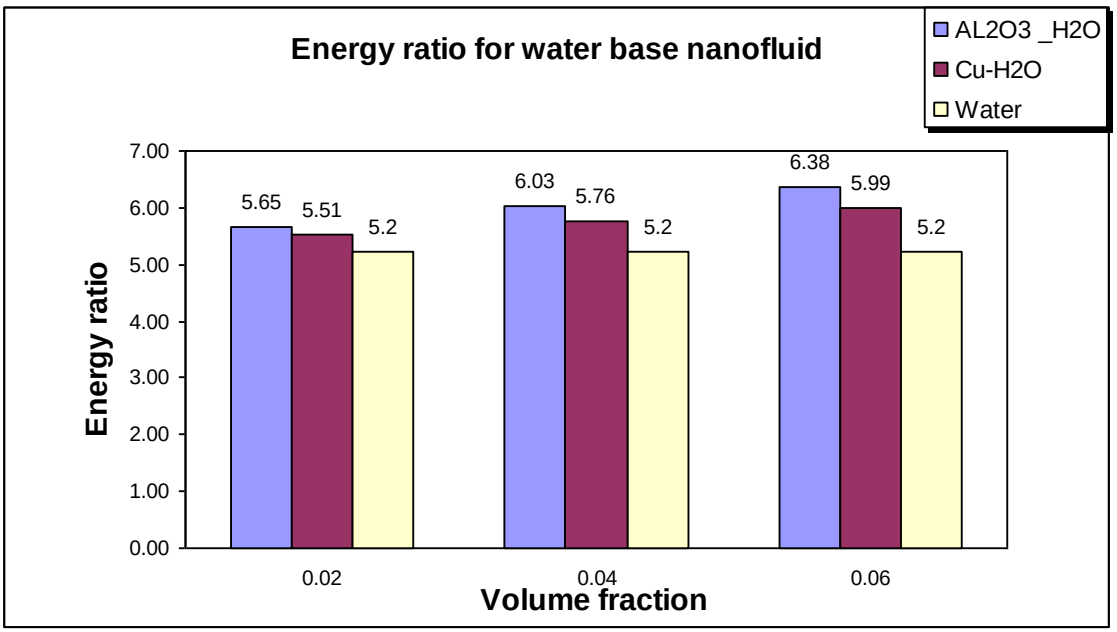


Figure 4.12: Energy ration for water base nanofluids

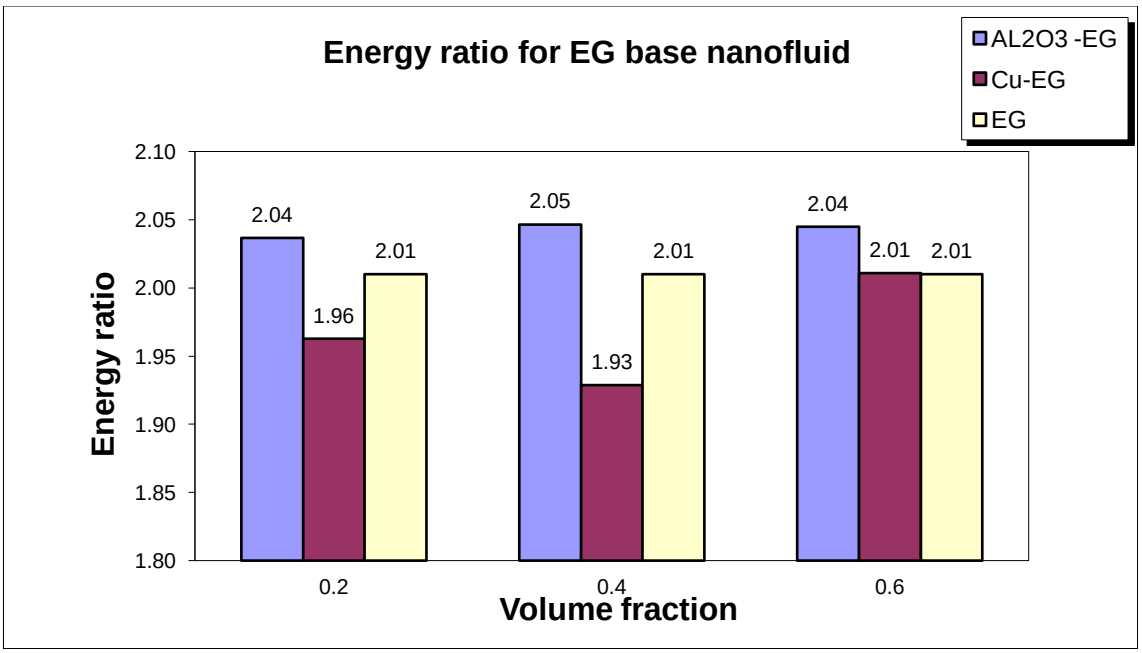


Figure 4.13: Energy ration for ethylene glycol nanofluids

As summarize, for entire volume fraction, $AL_2O_3$-$H_2O$ give the highest energy saving percentage. Second highest and third highest are observed for Cu-$H_20$ and $Al_2O_3$-Eg The lowest energy saving is on Cu-Eg which in minus**.**

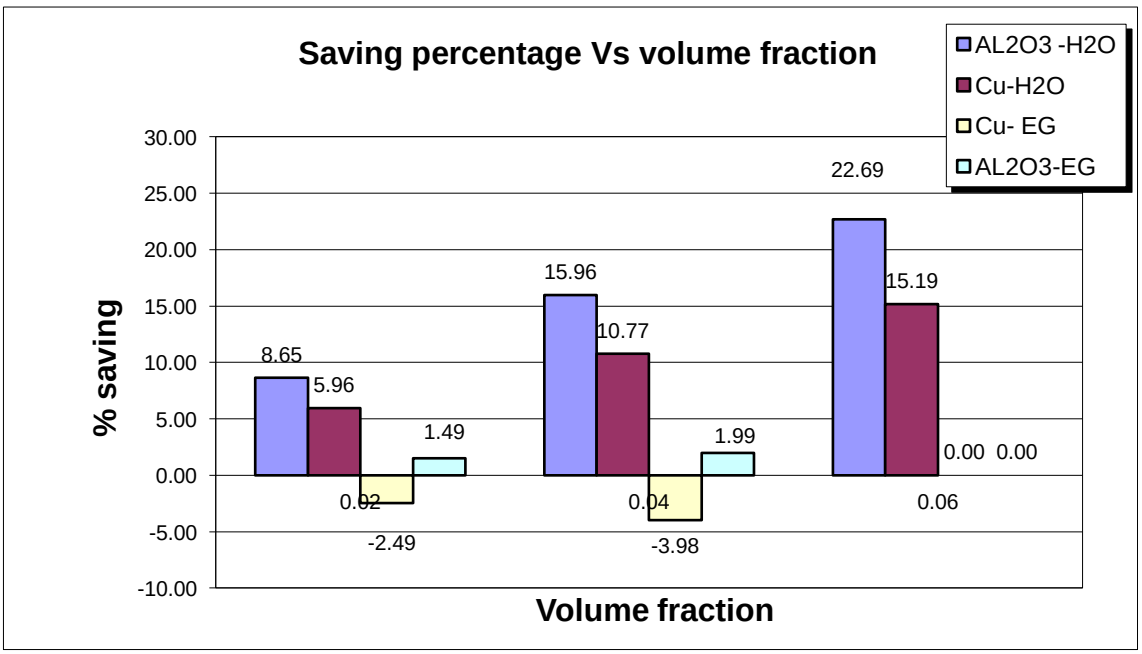


Figure 4.14: Percentage of energy saving with nanofluids

## 4.2 DISCUSSION

### 4.2.1 Thermal properties discussion.

Thermal physical properties show an increment and reducing result with additional of nanoparticle into base fluilds. Thermal conductivity, density and viscosity show an increment result with increment of volume fractions. Different form above properties, specific heat shows a reducing result with increasing of nanoparticle into base fluids. Transition heat amount is increasing with nano particle in base fluids. Brownian motion and crystalline solid interface are the factor that increase heat transfer amount. On top of that, particle in nanofluids are closed together and promote the coherent phonon heat flow among the particle which lead to increment of amount of transmission heat. Motion of nano particle in liquid and collide with each other is define as Brownian motion. Temperature, interfacial layer and nanoparticle play role in

Brownian motion. Incorporation attribute by those make effect on static and kinematic mechanisms. Kinematic effect is take place during collision. Heat transfer is transmitting with direct solid – solid heat exchange which ultimately increases thermal conductivity of nanofluids. Brownian motion-based dynamic mechanism is also significant for nanofluids with smaller-size and low concentration of nanoparticles. It can be inferred that the thermal conductivity of nanofluids. (S. M. Sohel Murshed 2011)

Effective of Brownian motion is measure by comparing time scale of nanopartile and solid motion with heat diffusion in the liquid. Comparison of nano particle to move with distance equal to sizes in the base fluids and bulk liquid of heat diffusion by the same distance is a method of measuring Browian motion. By adding nanoparicle into base fluids, Brownian motion is increase which lead to increment of thermal conductivity. Result is been support by increment of thermal conductivity in nanofluids which have higher volume fraction. Nano particle is in crystalline solid interface with base fluids layer. Interface of crystalline solid enhance thermal conductivity by which liquid layer atomic structure is more ordered compared to bulk liquid. As result, thermal transport is better with crystallizing solids interface compare to liquids. In solid, crystalline solid interface is performance is same. This lead to larger effective volume of the particle layered liquid structure. Larger layer give higher thermal conductivity to nanofluids. In base fluids, propagating lattice vibration with nanoparticle as crystalline solid state carried heat by phonons. Heat is transports in phonons are random. Direction of propagate also in random and scattered by each other or by default. Nanoparticle is relatively closed to each even with low volume fraction. Due to Brownian motion, particle moving in nanofluids is constant. By then, nanoparticle in nanofluids are closer and thus enhance coherent phonon heat flow among particle.

`4.2.1 Energy saving discussion

Energy ratio is calculated by using equation (3.15) and energy saving is calculated using equation (3.17). Base on figure 4.15, $Al_20_3$- $H_20$ give the highest percentage of increment of energy saving. For 0.2 volume fraction, increment is 8.65 % compare to base fluids. Result for 0.4 volume fractions is 15.96 % and for 0.6 volume fraction is 22.69 %. Second highest energy saving is occurring in Cu-$H_2O$ nanofluids which is 5.96 % for 0.2 volume fraction, 10.77 % for 0.4 volume fraction and 15.99 % for 0.6 volume fraction. For $AL_2O_3$-Eg, for 0.4 and 0.2 volume fraction, result of energy saving is 1.49 % and 1.99 %. Anyhow for O.6 volume fraction, result of increment is none or 0 %. For Cu-Eg, energy saving is minus which mean energy uses is not efficient and effective. For 0.2 and 0.4 volume fraction, energy saving are -2.49 % and -3.98 %. For 0.6 volume fraction, energy saving is 0 %.

For $Al_2O_3$-$H_20$, energy saving is higher since friction factor show reduction and thermal heat transfer parameter show an increment. 0.6 volume fractions show the highest energy saving for alumina oxide nanofluids. Friction factor is function of Reynolds number, viscosity and density. Incresing of Reynolds number shows reduction result for friction factors(Vajjha, Das et al. 2010). High volume fraction may achieve by two ways, either by adding more particle into base fluids or increase particle size. Should increasing particle size is the selection to prepare nanofluids, it lead to reducing viscosity to nanofluids. Benefit of reducing viscosity make nanofluids fluids is easier to move during pumping around the coil or tube. Inside tube or coil, less viscose fluid will have lower friction factor. Increment of fraction factor lead to additional power required for pump to circulated water in heat exchanger. Heat transfer parameter is in function of Nusselt number and Prandit number. For $Al_2O_3$-$H_20$, heat transfer parameter show an increment since thermal conductivity show an increment compare to base fluids. Increasing volume fractions show an increment of thermal conductivity because

collision rate of nanopartilce inside nanolfuids is higher. During collision, heat is transferring form one solid to other solid.

For Cu-EG, energy saving show a reduction since friction factor yield higher result compare for base fluids. Increment of friction factor is because of additional of nanoparticle into base fluid yield increment of viscosity and density. Both parameters make fluids is more difficult to move. In order to move fluids as required mass flow rate, higher pumping power is required. Increment pumping power lead to energy saving is not effective for air conditioning to operate with Cu-Eg nanofluids. 0.6 volume fraction of Cu-EG nanolfuids yields same energy saving as ethylene glycol fluids. This because thermal conductivity is higher, thus can compensate increment power required by pump.

For heat exchanger parameter such tube diameter and mass flow rate, both parameter show an enhance result of energy ratio by increase tube diameter and mass flow rate. Increasing tube diameter reduces friction factor value inside tube and makes nanofluids make easier to flow inside tube.  Result for increment of tube diameter show in figure 4.16.

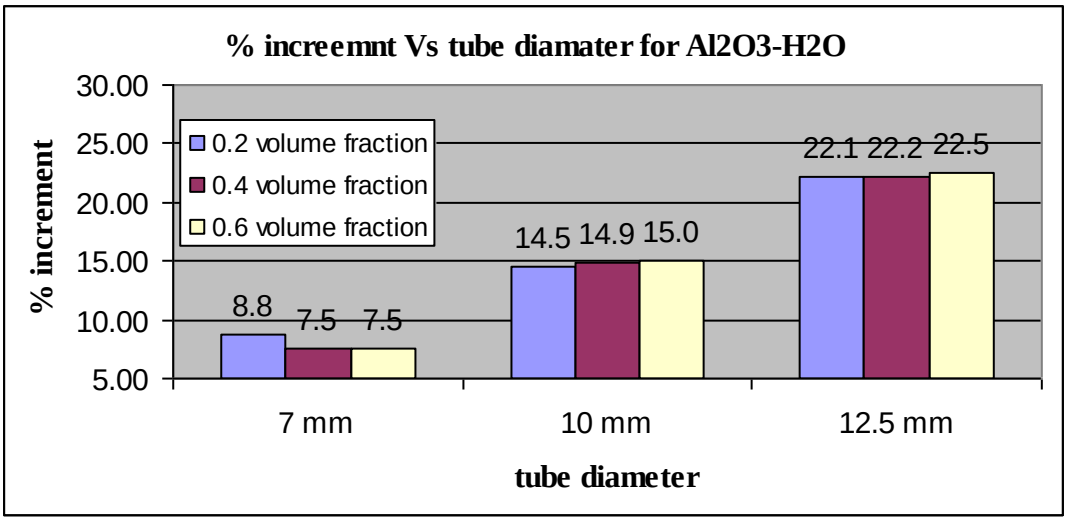


Figure 4.15: Percentage increment for different tube.

For same volume fraction and tube diameter (figure 4.11), increasing mass flow rate reduces energy ratio. They lowest energy ratio observed is on 0.2 volume fraction

and 0.15 kg/s which is 0.47 and the highest energy ratio recorded is on 0.6 volume fraction and 0.15kg/s  which yield result 2.11. Result shows that, increment of volume fraction at same mass flow increase energy ratio. For same volume fraction, increasing mass flow rate show reduction of energy ratio. Energy ratio is reducing since pumping power required is higher.

# CHAPTER 5.0 CONCLUSION AND RECOMENDATION

## 5.1 Conclusion

The analysis of energy saving for air conditioning operate with nanofluids as medium for heat transfer was analysis with different heat exchanger tube diameter, different volume fraction of nanofluids and different mass flow rate.

For air condition system, energy saving can be achieved with proper selection of nanofluids. Nanofluids with higher thermal conductivity are the most suitable selection. Result shown, alumina particle with water base fluid is the highest energy saving can be achieved compare to other nanofluids. Highest energy saving is 22.69 % of increment result yield for alumina particle with water as base fluids. Result is occurring at 0.6 volume fraction. For this type of nanofluids, increment of energy saving is increase linearly with volume fraction increment. Lowest energy saving is recorded for copper particle with ethylene glycol base fluids which show reduction of 3.98 % of energy saving. This occurs at 0.4 volume fraction of nanolfuids. For this nanofluid, energy saving is not beneficial since maximum energy saving only 0 % and occur at 0.6 volume fraction. Tube diameter for heat exchanger also play important roles in determine energy saving. Increase tube diameter size shall increase energy saving for air conditioning. 0.6 volume fraction of nanofluid and 12.5 mm tube diameter show highest increment if energy saving percentage which is 12.99 %. Mass flow also play important roles during determine energy saving. Result show that with increment of mass flow, energy saving is reduce by 75 %. This result happened at 0.25 kg/s of mass flow rate of nanofluids. Percentage reduction is consistence for other volume fraction.

## 5.2 Recommendation

Further analysis on different nanofluids is a must since present day many nanofluids materials is being engineered without been utilization into air condition as working fluids. Nanofluids have special characteristic which thermal physical properties

can be customize base on the manufacturing process, nanopartilce size and shape. On top of that, combination of these particle and base fluids may create new thermal physical properties.

In engineering term, internal heat transfer is equal with external heat transfer. Actual application for heat exchange device may have impurities which may lead to reduce energy transfer from working fluids to coil. Further analysis should be study on effect of impurities on tube surface to air conditioning which operates with nanofluids.

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