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# HEAT TRANSFER CHARACTERICSTIC OF A CONDENSERWITH $Al_2O_3$ REFRIGERANT BASED NANOFLUIDS AS WORKING FLUID

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**ADMISSION**

"I admit this report has been written by me myself except for some quotation that has been noted well for each of them"

Signature :…………..……………………

Author Name :…………..……………………

Date :……………………………….

## DEDICATION

This report is dedicated to my beloved parents

Mujah @Tumbin ak Enjawan

and

Rosemina ak Outram

## APPRECIATION

First of all, thanks God for His almighty that I can complete this report. Thus, thanks also to my beloved parents that always support me although they are far away from me. Special thanks to my supervisor, Pn. Fadhilah bt Shikh Anuar in guiding me along this report writing and project computation.

To all my friends especially my course mates who never give up in supporting me towards the completion of this report. I am appreciating all the helps and supports.

**ABSTRACT**

Refrigeration systems have become very important in various applications. Almost all buildings and houses in Malaysia have the air conditioning system regarding the hot temperature in this country. However, the use of the air conditioners consumes a lot of electricity. Scientist and researchers are trying to find a new kind of working fluid that can enhance the thermal conductivity and the pressure drop of the conventional base fluid, thus increasing the heat transfer rate and the energy consumption could be reduced. By introducing a base fluid suspended with nanoparticles which have been developed in recent years, this might happen. In this project, the effect of the suspended nanoparticles, $Al_2O_3$, in the base fluid; conventional refrigerant, Tetraflurocarbons, R-134a, called as nanorefrigerant, is being investigated through mathematical modeling to investigate the thermal conductivity, pressure drop and heat transfer of nanorefrigerant with different volume fraction of nanoparticles from 0.2% - 1.0%. CFD simulation is needed in this project to verify the results of mathematical modeling. Based on the calculation, the percentage of thermal conductivity improvement of nanorefrigerant as compared to conventional refrigerant is 1256.125% and 16 – 48% enhancement with 0.2% to 1.0% volume fraction of nanoparticles. Meanwhile the pressure drop showed the enhancement about 61.8% and heat transfer enhancement is about 2.09%. The results of mathematical modeling are higher as compared to simulations result. These showed that with additive of nanoparticles, the properties of conventional refrigerant can be improve for better cooling process.

# ABSTRAK

Sistem penyejukan adalah amat penting didalam banyak aplikasi. Di Malaysia sahaja, ia boleh dilihat hampir setiap bangunan dan rumah memandangkan keadaan suhu yang agak panas di negara ini. Walaubagaimanapun, penghawa dingin menggunakan banyak tenaga elektrik. Para saintis dan penyelidik masih sedang mencari satu bendalir kerja yang baru untuk meningkatkan kekonduksian terma dan penurunan tekanan bendalir asas konvensional, sekali gus meningkatkan kadar pemindahan haba dan penggunaan tenaga dapat dikurangkan. Dengan potensi nanopartikel yang telah dibangunkan sejak beberapa tahun kebelakangan ini, impian mungkin menjadi kenyataan. Dalam projek ini, kesan nanopartikel, $Al_2O_3$ yang dimasukkan ke dalam bendalir penyejuk yang biasa, yang boleh dipanggil sebagai nanorefrigerant, sedang disiasat menggunakan pemodelan matematik dari segi kekonduksian terma, penurunan tekanan dan kadar pemindahan haba daripada nanofluids dengan menggunakan kepekatan nano partikel 0.2–1.0%. Simulasi diperlukan dalam projek ini untuk mengesahkan keputusan pemodelan matematik kerana ia adalah lebih tepat. Berdasarkan pengiraan, peratus kekonduksian terma bagi nanorefrigerant meningkat jika dibandingkan dengan bendalir asalnya iaitu1256.125% dan 16 – 48%peningkatan dengan 0.2 – 1.0%kepekatan nanopartikel. Sementara itu penurunan tekanan juga menunujukkan peningkatan sebanyak 61.8% dan peningkatan kadar pemindahan haba sebanyak 2.09%. Keputusan agi permodelan matematik adalah lebih tinggi jika dibandingkan dengan keputusan simulasi. Ini menunujukan dengan menambahkan nanopartikel, sifat bendalir asal boleh ditingkatan untuk proses penyejukan yg lebih baik.

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## NOMENCLATURE

| | |
|---|---|
| $A$ | Area($m^2$) |
| $B_{2x}$ | Depolarization factor along x- symmetrical axis |
| $c$ | constant |
| $C_p$ | Heat capacity( $J/kg.K$ ) |
| $d$ | Diameter (m) |
| $f$ | friction |
| $h$ | Heat transfer coefficient($W/m^2K$) |
| $k$ | Thermal Conductivity ($W/m.K$) |
| $k_{33}^c$ | Longitudal equivalent thermal conductivity |
| $k_{11}^c$ | Transverse equivalent thermal conductivity |
| $L$ | Length (m) |
| $Nu$ | Nusselt number |
| Pr | Prandtl number |
| Re | Reynold number |
| $r$ | Radius (m) |
| $T$ | Temperature ($^oC$ or K) |
| $\Delta T$ | Temperature difference |
| $U$ | Overall heat transfer coefficient ($W/m^2K$) |

**Greek Symbols**

| | |
|---|---|
| $\alpha$ | Volume ratio |
| $\beta$ | Particle motion |
| $n$ | Shape factor |
| $\rho$ | Density ($kg/m^3$) |
| $\phi$ | Volume Fraction |
| $\gamma$ | Ratio of nano layer |
| $\lambda$ | Elliptical complex nanoparticles |
| $v$ | Velocity($m/s$) |
| $\mu$ | Viscosity($Pa.s$) |
| $\psi$ | Particle sphericity |

**Subscripts**

| | |
|---|---|
| $p$ | Nanoparticles |
| $b$ | Base fluid |
| $eff$ | Effective |
| $pe$ | Modified |
| $in$ | Inlet |
| $out$ | Outlet |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background Study

An air conditioner is a mechanism designed to extract heat from an area. The whole process is done using the refrigerant cycle. The process consists of heating, ventilation and air conditioning or usually referred as HVAC. HVAC is a form of air treatment whereby temperature, ventilation and cleanliness are all controlled within limits determined by the requirements of the air conditioned enclosure. In the HVAC system, refrigerant is used.

A refrigerant is a substance used in air conditioning system. Usually, fluorocarbons, especially chlorofluorocarbons, were used as refrigerants, but now they are illegal because of their ozone depletion effects. Other common refrigerants used in various applications are ammonia, sulfur dioxide, and non-halogenated hydrocarbons such as methane.

In heat transfer, condenser is a device to condense gas state to liquid state, typically by cooling it. Thus, and because of that, the latent will transfer to the coolant. Condensers is actually a typical heat exchangers, which are used in so many industrial needs.. For example, a refrigerator uses a condenser to get rid of heat extracted from the interior of the unit to the outside air. Condensers are used in air conditioning, industrial chemical processes such as distillation, steam power plants and other heat-exchange systems. Use of cooling water or surrounding air as the coolant is common in many condensers.

Nanorefrigerant might still a new technology out there. However, this technology has a big potential to be commercialized as the result to its advantages. One of the applicable nanotechnologies is nanofluid. Nanofluid is a mixer between nanoparticles and based fluid. Examples of nanoparticles such as aluminum oxide, cooper oxide and carbon nanotubes. While base fluids are such as DI water, ethylene glycol, and oil. The nanoparticles suspense into any refrigerant called as nanorefrigerant in the refrigerant system. This is regarding its benefits to enhance the performance of the refrigeration system. When a substance in nano sized, it‟s actually change its properties and somehow, it can benefit air conditioning system. Thus, because of that, nanofluid can actually revolutionize the air conditioning system by introducing nanorefrigerant as the new working fluid to replace the conventional base fluids.

## 1.2 Objectives

1) To investigate the effect of aluminum oxide nanoparticles with volume fraction from 0.2 to 1.0 vol % on thermal conductivity of nanorefrigerant.
2) To study the effect of the nanoparticle volume fraction on pressure drop of the nanorefrigerant.
3) To investigate the heat transfer rate of nanofluids in a condenser

## 1.3 Scope

This study will use mathematical modeling to investigate and determine the thermal physical properties of the nanorefrigerant. The parameters such as size of nanoparticles, types of refrigerant, nanorefrigerant velocity, and mass flux, heat flux are constants. The only variable in this study is only the nanoparticle volume fraction.

## 1.4 Problem Statement

Air Conditioning is very important nowadays. At current moment, refrigerant fluids are used in the system. For example is R134a. Meanwhile, experts/scientists believe that nanoparticles have great potential in enhancing the thermal conductivity of the whole refrigeration system. The method is by mixing the nanoparticles with base fluids to create nanorefrigerant.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Refrigeration System

The refrigeration cycle is the series of events that occur to allow the refrigerant to both absorb and release heat energy. The refrigeration system is divided into low-pressure side and high-pressure side. There are two specific points within the refrigeration system where the system divides: the compressor and the metering device. The high side of the system begins with the compressor outlet and includes the condenser and associated lines and ends at the metering device inlet. The low side of the system begins at the outlet of the metering device and includes the evaporator and associated lines and end sat the compressor (Cengel, 2006).

The compressor draws in low-pressure vapor from the suction line. In the compressor, the refrigerant is pressurized, causing the temperature to increase relative to the pressure applied. High-pressure, high-temperature refrigerant vapor exits the compressor and travels through the discharge line to the condenser. (Cengel, 2006)

When the refrigerant reaches the condenser inlet, it is almost 100 percent vapor. A small amount of liquid may remain. As the refrigerant moves from the top of the condenser, it passes through the tubes. Much of the heat that is present within the vapor is transferred to the tubes and fins of the condenser. As air moves across the surface of the fins and tubes, heat is dissipated into the atmosphere. This process is aided by a ram air effect provided by the movement of the vehicle and the operation of the cooling fan. As the refrigerant moves down through the tubes on the condenser, much of the latent heat stored in the vaporized refrigerant is released, causing the vapor to condense into a liquid. (Carrigan et. al, 2006)

High-pressure liquid refrigerant exits the condenser into the liquid line, where it is transported to the metering device. The metering device acts as a restriction, reducing the amount of refrigerant pressure and volume. As the liquid passes through the metering device, the pressure is reduced by approximately 75 percent or more. Because pressure and temperature are relative to one another, the temperature of the refrigerant is significantly reduced as the refrigerant exits the metering device. The refrigerant exits the metering device as a low-pressure, low-temperature liquid. (Carrigan et. al, 2006)

Low-pressure, low-temperature liquid refrigerant enters the evaporator core. As air is forces across the surface of the evaporator, heat that resides within the air is absorbed by the evaporator core and into the refrigerant, causing the refrigerant to vaporized, thus reducing the air temperature. As the air is cooled, moisture present in the air molecules condenses on the surface of the evaporator. Refrigerant exits the evaporator as a low-pressure, low-temperature vapor. The refrigerator cycle continues as the low-pressure, low-temperature vapor refrigerant enters the compressor suction hose and is transported to the compressor. At this point, the cycle starts over (Carrigan et. al, 2006).

## 2.2 Component of Refrigeration System – Condenser

The condenser is the next destination for the refrigerant after it leaves the compressor. When the refrigerant leaves the compressor and enters the condenser, it does so as a high-pressure, high-temperature vapor. The purpose of the condenser is to remove enough heat from the gaseous refrigerant to cause a change of state into a high-pressure liquid (Cengel, 2006).

The condenser is a heat exchanger is physically located at the front of the vehicle and install in front of the radiator. The placement of the condenser allows for maximum airflow to pass the condenser to provide maximum heat transfer (Cengel, 2006).

The condenser is constructed of a series of tubes that transport refrigerant. Between each tube is a set of fins that provide surface area in which heat can be dissipated. The basic design and operation is similar to that of a radiator. Refrigerant enters at the top of the condenser and flows toward the outlet located at the bottom of the core. As high-pressure refrigerant is force through the condenser, the heat that is present within the refrigerant is transferred to the tubes and fins through the process of conduction. As air is forced across the surfaces of the condenser, heat from the tubes and fins is transferred into the atmosphere by convection. Sufficient heat is removed from the refrigerant to cause the refrigerant to condense into a liquid refrigerant; hence the name condenser (Cengel, 2006).

## 2.3 Nanorefrigerant

Refrigeration is very important nowadays especially in a country like Malaysia. Since Malaysia is considered as hot country, thus chilling system is a must in their households, offices and etc. However, the use of refrigeration system is quite a waste in terms of energy. This is because, a refrigeration cycle required a lot of energy compared to any electrical items such as lamps, and fans.

Refrigerants are the transport fluids which convey the heat energy from the low-temperature level to the high-temperature level, where it can, in terms of heat transfer, give up its heat. In the broad sense, gases involved in liquefaction processes or in gas-compression cycles go through low-temperature phases and hence may be termed "refrigerants," in a way similar to the more conventional vapor-compression fluids.

Refrigerants are designated by number. The identifying number may be preceded by the letter R, the word "Refrigerant," or the manufacturer"s trademark or trade name. The trademarks or trade names shall not be used to identify refrigerants on equipment or in specifications. In the previous time, chlorofluorocarbon (CFC) and hydro chlorofluorocarbon (HCFC) are use as refrigerant in air conditioning system. However, due to the "greenhouse effect", these refrigerants have been phase out.

Nowadays, new refrigerants, primarily hydrofluorocarbon, HFCs, have been commercialized to replace them. There has also been a renewed interest in non halocarbon refrigerants such as ammonia and carbon dioxide.

Recently, the issue regarding refrigerant become hype topic once more. This time is regarding the performance of heat transfer of the refrigerant itself. Various techniques and development have been proposed to improve the heat transport properties of fluids. At the beginning, researchers tried to blend or suspend the base fluid with solid particles of micrometer, even millimeter magnitudes to increase the thermal conductivity of the base fluid since the thermal conductivity of solid is typically higher than that of liquids (Xiang and Mujumdar, 2006). Based on their research, they able to increase the thermal conductivity of cooper up to 401 W/m.K and aluminums up to 237 W/m.K. Those are metallic materials. For non-metallic, silicon and alumina, $Al_2O_3$, the thermal conductivity increase up to 148 W/m.K and 40 W/m.K respectively. Others are metallic liquid such as sodium and non-metallic liquid such as water, which were also enhanced in terms of its thermal conductivity. However due to its large density and size, practically it the applications are limited. Furthermore, by using micro particles, it may cause abrasion of the surface, clogging the micro channels and increasing the pressure drop (Zenghu Han et al, 2008).

Regarding this issues, researchers and scientists put one step forward. This time they consider nanotechnology. Thus, it is leading to process and produce materials with average crystallite sizes below 50 nm. Fluids with nanoparticles suspended in them are called nanofluids, a term proposed by Choi in 1995 at the Argonne National Laboratory, U.S.A. (Choi et al.1995).

Basically, nanofluids are formed by dispersing nanometer-sized particles (1-100nm) or droplets into heat transfer fluid, HTFs usually use as refrigerant. The specialty of nanofluids are they have unique properties, such as large surface area to volume ratio, dimension-dependent physical properties, and lower kinetic energy, which can exploits by the nanofluid. Furthermore, its large surface area makes nanoparticles better and more stably dispersed in base fluids. Compared with micro-fluids or milli-fluids, nanofluids stay more stable, so nanofluids are promising for practical applications. Nanofluids will keep the fluidic properties of the base fluids, behave like pure liquids and incur little penalty in pressure drop due to the fact that the dispersed phase (nanoparticles) are extremely tiny, which can be very stably suspended in fluids with or even without the help of surfactants ( Xuan and Li, 2003).

Researchers usually use nanoparticles such as aluminum oxide, $Al_2O_3$ and Cooper oxide, CuO in their research. Figure 2.1 and Figure 2.2 are the pictures of those particles that mentioned above;

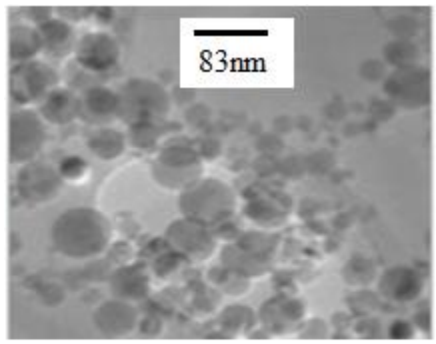


Figure 2.1 Aluminum oxide particles, $Al_2O_{3.}$(Xuan et. al 2003).

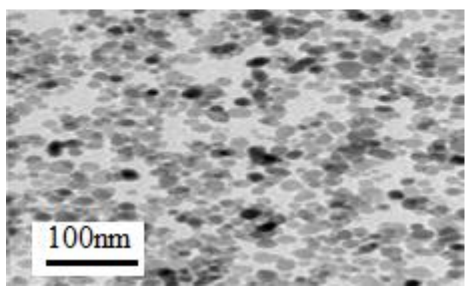


Figure 2.2 Cuprum oxide particles, CuO (Vegalapudi, 2008).

Refrigerant-based nanofluids have been investigated as the potential application as a new kind of working fluid in refrigerant systems (Bi et al. 2008). The term "Nanorefrigerant" appeared by Ding et. al, (2009). The special about this discovery is that, it has higher thermal conductivity than conventional refrigerant which is for example FTCs (fluorocarbon). Other researcher such as Wang et. al , (2003) and Bi et al. (2008) show that by using nanoparticles in mineral oil in the refrigerant, the performance of the whole refrigeration system better than the conventional refrigerant.

Based on Wu et al. (2008) investigation on the boiling heat transfer characteristics of nanorefrigerant are focused only on the pool boiling heat transfer and there are no published researches on the flowing boiling heat transfer characteristics of nanorefrigerant according to Peng et al. (2009).

In recent years, Park and Jung (2007 a, b) conducted an experiment on the pool boiling heat transfer of CNT‟s/R22, CNT‟s/R123 and CNT‟s/R134a using horizontal smooth tube. The result was quite shocked because at lower heat flux, the enhancement of the heat transfer coefficients became clearer and the maximum enhancement could reach 36.6%. The results of the experiment also showed that the pool boiling heat transfer coefficients of refrigerants improved by using CNT‟s.

Meanwhile, from the experiment that was conducted by Trisaksri and Wongwises (2009), they used a cylindrical copper tube to investigate the pool boiling heat transfer of TiO2/HCFC 141b nanofluid. Their results were that, with the increments of the concentrations of nanoparticles, the nucleate pool boiling heat transfer will decreased, especially at high heat fluxes.

## 2.5 Thermal Conductivity of Nanorefrigerant

Generally, thermal conductivity is the property of a material which is its ability to conduct heat. Heat transfer by conduction involves transfer of energy within a material without any motion of the material as a whole. Conduction happened when a temperature difference exists in a solid medium. Conductive heat flow occurs when temperature is decreasing because higher temperature generates higher molecular energy or more molecular movement. Energy is transferred from the more energetic to the less energetic molecules when neighboring molecules collide among themselves. In terms of unit, in International System of Units (SI), thermal conductivity measured by watts per meter Kelvin (W/m .K).

Murshed et al. (2007) stated that the thermal conductivity of nanofluids varies with three attributes; size, shape and material of nanoparticles. For example, nanofluids that are suspended with metallic nanoparticles were found to have a higher thermal conductivity than nanofluids that are suspended with non-metallic (oxide) nanoparticles. Furthermore, nanofluids that are suspended with nanoparticles that are spherical in size increased only a smaller value of thermal conductivity compared with the nanofluids having cylindrical (nano-rod or tube) nanoparticles.

The less expensive nanoparticles that are usually used by researchers in their experiment are Alumina ($Al_2O_3$) and Copper oxide (CuO) based on Xiang and Mujumdar (2006). Even though the size of nano particles and refrigerants are different, but still the thermal conductivity of the nanofluids till enhanced. There is another experiment conducted by Eastman et al. (1997), showed that the thermal conductivity of nanofluids that contains CuO, $Al_2O_3$ and Cu nanoparticles with two different base fluids; water and HE 200 oil was measured.