UNIVERSITI TEKNIKAL MALAYSIA MELAKA

STUDY ON HEAT TRANSFER AND PRESSURE DROP CHARACTERISTICS OF NANOFLUID FLOWING IN HEAT EXCHANGER

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (REFRIGERATION AND AIR-CONDITIONING SYSTEMS) WITH HONOURS

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DECLARATION

I declare that this Choose an item. entitled " Study On Heat Transfer And Pressure Drop Characteristics of Nanofluid Flowing In Heat Exchanger " is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 16/1/2022

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems) with Honours.

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DEDICATION

Foremost, I would like to express my sincere gratitude to my supervisor Ts.Siti Nor'Ain Binti Mokhtar for the continuos support of my study and research, for her patience, motivation, enthusiasm, and immense knowledge. Her guidance helped me in all the time of research and writting of this research. I could not have imagined having a better supervisor and mentor for my Degree study. Last but not least, I would like to thanks my family for supporting spritually throughout my life

ABSTRACT

Microchannel heat sinks (MCHS) are generally utilized as a part of electronic gadgets for cooling system. In this study, the pressure drop in straight microchannel heat sink (MCHS) is examined repectively, using different concentration (1%, 2%, 3%, 4%, and 5%) of Water-CuO nanofluids are used as working fluids. For this purpose, a computational fluid dynamics (CFD) evaluated the performance of the nanofluids through microchannel heat sink. The evaluated microchannel performance was shown in terms of pressure drops, temperature, velocity, surface Nusselt number, surface heat transfer coefficient contours. The thermo-physical properties of nanofluid are evaluated to study its effect on the flow and heat transfer at a reference inlet velocity 2 m/s. The heat flux generated at the bottom surface of the microchannel used was 160000 (W/m^2). The results show that increasing the temperature decreases the pressure drop. Generally, increasing the velocity rate results in a decrease in the pressure drop. The increased volume concentration of the nanofluid results in increased viscosity, which results in an increased pressure drop. Increases in fluid temperature directly affect viscosity, which results in a decrease in pressure drop. Overall, the comparison of all concentrations of Water-CuO nanofluids demonstrates unequivocally that Water-CuO 1% is the best for cooling because it exhibits the lowest pressure drops compared to the other nanofluids. This physical characteristics concentration of Water-CuO 1% can fully exploit the advantages of increasing flow velocity, enhancing heat transfer, and lowering pressure drop.

ABSTRAK

Sinki haba saluran mikro (MCHS) biasanya digunakan sebagai sebahagian daripada alat elektronik untuk sistem penyejukan. Dalam kajian ini, penurunan tekanan dalam sink haba mikrosaluran lurus (MCHS) diperiksa secara bergantian, menggunakan kepekatan berbeza (1%, 2%, 3%, 4%, dan 5%) cecair nano Air-CuO digunakan sebagai cecair kerja. Untuk tujuan ini, dinamik bendalir pengiraan (CFD) menilai prestasi cecair nano melalui sink haba saluran mikro. Prestasi saluran mikro yang dinilai ditunjukkan dari segi penurunan tekanan, suhu, halaju, nombor Nusselt permukaan, kontur pekali pemindahan haba permukaan. Sifat termofizikal bagi bendalir nano dinilai untuk mengkaji kesannya terhadap aliran dan pemindahan haba pada halaju masukan rujukan 2 m/s. Fluks haba yang dihasilkan pada permukaan bawah saluran mikro yang digunakan ialah 160000 (W/m^2). Keputusan menunjukkan bahawa peningkatan suhu mengurangkan penurunan tekanan. Secara amnya, peningkatan kadar halaju menyebabkan penurunan tekanan. Peningkatan kepekatan isipadu cecair nano menyebabkan kelikatan meningkat, yang mengakibatkan penurunan tekanan meningkat. Peningkatan suhu bendalir secara langsung menjejaskan kelikatan, yang mengakibatkan penurunan penurunan tekanan. Secara keseluruhannya, perbandingan semua kepekatan cecair nano Air-CuO menunjukkan dengan jelas bahawa Air-CuO 1% adalah yang terbaik untuk penyejukan kerana ia menunjukkan penurunan tekanan yang paling rendah berbanding dengan cecair nano yang lain. Kepekatan ciri fizikal Air-CuO 1% ini boleh mengeksploitasi sepenuhnya kelebihan meningkatkan halaju aliran, meningkatkan pemindahan haba, dan menurunkan penurunan tekanan.

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LIST OF SYMBOLS AND ABBREVIATIONS

W - Microchannel heat sink width
L - Microchannel heat sink length
H - Microchannel heat sink height
Dh - Channel height
w - Channel width
$\dot{m}$ - Mass flow rate
Nu - Nusselt number
ΔP - Pressure drop across the microchannel
q - Heat flux
ρ - Density
κ - Conductivity
μ - Viscosity
ϕ - Concentration of nanofluid
C_p - Specific heat capacity
CFD - Computational Fluid Dynamics
HTC - Heat Transfer Coefficient
MCHS - Microchannel Heat Sink
SIMPLE - Semi-Implicit Method for Pressure Linked Equation

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CHAPTER 1

INTRODUCTION

1.1 Background

With the advancement of the electronics industry, adequate cooling of electronic devices has become a critical criterion for their correct operation since heat flux created by electronic chips has exceeded 100 W/cm2 (Xie et al., 2007). Since a result, an optimum cooling solution was required to remove this excessive heat for optimal performance and life, as air cooling had become inadequate for high heat removal ability. Due to air restrictions, researchers' focus shifted to smart liquid cooling approaches. Nanofluids with dispersed nanoparticles have shown to be a potential choice for heat removal applications.

(Chein & Chuang, 2007) established the thermal superiority of CuO-H_2O nanofluids against base fluid experimentally. They employed silicon microchannel heat sinks with four different concentrations of CuO-H_2O nanofluids. They discovered that nanofluids with low flow rates were more effective and correlated with the analytical model. Additionally, they observed a decrease in particle agglomeration at elevated mean temperatures. Additionally, (Chein & Huang, 2005) employed various concentrations of Cu/H_2O nanofluids in two distinct microchannels. They discovered that nanofluids had no additional pressure loss due to their low volumetric concentration and small particle size.

1.2 Problem Statement

In recent years, a surge in interest in heat transfer improvement employing nanofluids in straight channels as existing technologies shrinks in size and performance. However, the devices will develop hot spots and generate additional heat when their performance improves, and the current heat sink cannot remove the heat. As a result, several researchers have investigated the development of microchannel heat sinks by using water as a working fluid, making it very low in thermal conductivity and having a minor effect on the pressure drop values in the channel. Consequently, it would be an excellent opportunity to examine the impact of using a different concentration of nanofluid, such as Water-CuO, in the microchannel heat sink, which may increase the rate of pressure drop outcomes.

1.3 Research Objective

The main aim of this research is to demosntrate the effectiveness of nanofluid in pressure drop in mircochannel. Specifically, the objectives are as follows:

a) To study the pressure drop in microchannel heat sink using different concentrations of Water-CuO nanofluid.

b) To perform a CFD simulation related to pressure drop in ANSYS Fluent using different concentrations of Water-CuO nanofluid.

c) To analyze the effect in pressure drop using different concentrations of Water-CuO nanofluid in CFD simulation.

1.4 Scope of Research

The scope of this research are as follows:

- The CFD simulation will be conducted in ANSYS Flow Fluent software.
- The type of nanofluid will be used Water-CuO, with a concentration of 1% - 5%.
- Temperature of the fluid at inlet around 20°C.
- Laminar flow will be used in this study.
- Heat Flux will be at 100000 w/m^2 at the heated source surface.
- The channel which will be used is a straight channel and the material of the channel is aluminum.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Since 1931, researchers have investigated methods of regulating the heat flux created by electrical devices and providing higher heat transfer rates by using various tactics to improve heat transfer in mini and micro cooling systems. Because of fast improvements in electronic and electrical devices and systems that are becoming tinier in size, light in weight, but high in heat transfer dissipation needs, the effect of heat transfer and fluid flow has grown more intriguing and demanding at the same time. However, another strategy to improving cooling system heat performance is to increase the thermophysical characteristics of the coolants, such as by producing nanofluids (Al-asadi et al., 2017). Alternatively, the heat sink shape may be modified to increase heat transmission, for example, by altering the pins in PHSs or the channels in PFHSs. The usage of micro-channels is a particularly effective solution for air applications.

2.2 Nanofluid Overview

In recent years, research on nanofluids has seemed to be growing in terms of publications, as seen in Figure 1, which presents the total number of publications in the nanofluid area since 2010. Some of these research cover issues pertaining to their production, characterization, and measurement of their physical characteristics as well as their use in a wide variety of applications. In **Figure 2.1**, the data was found by searching the term “nanofluids” in the Scopus database for content types that include the phrases “title,” “abstract,” and “keyword” for the period in question (Okonkwo et al., 2020).

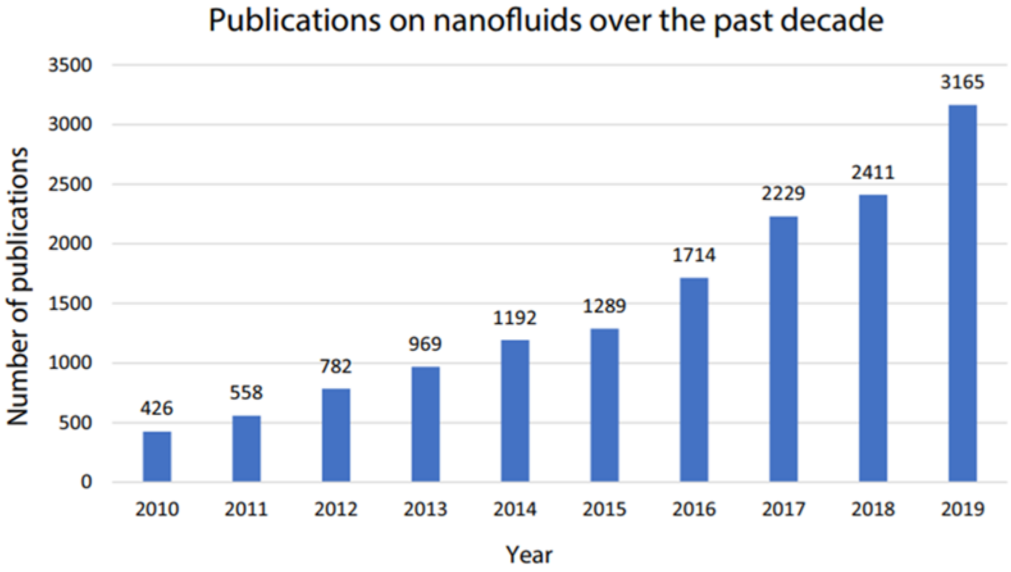

Figure 2.1: Nanofluids over the year

The search highlights that as of January 2019, around 3,165 articles were published per year, and this tendency is anticipated to rise in the years ahead. The article also mentions a few new review articles on heat transfer qualities and the use of nanofluids in 2019. Solar collector applications (Wahab et al., 2019), nanofluids review in heat exchangers (Sajid & Ali, 2019), a review of nanofluids in heat pipes (Nazari et al., 2019), radiator cooling (Virendra R.Patil, 2017), electronic cooling (Murali Krishna & Sandeep Kumar, 2019), and a review of different thermophysical features of nanofluids are all included in the reviews (Ramezanizadeh et al., 2019), and (Sezer et al., 2019). The progress and measures taken in 2019 on nanofluids in heat transfer devices need to be holistically assessed. This research examines the year 2019 in retrospectively. The paper intends to inform readers on current advances in the use and use of nanofluid syntheses. It also aims to emphasize the problems and potential of nanofluids as the heat transfer medium for the future generation.

2.3 Microchannel Concepts

According to (Gunnasegaran et al., 2010), water and heat transfer in microchannels are studied numerically for a range of Reynolds numbers from 100 to 1000. The finite volume method solves the three-dimensional steady, laminar flow, and heat transfer equations. For this example, we will say that the computational domain is the whole heat sink. This includes the inlet and outlet ports, the wall plenums and the small channels. Heat sinks in this study come in three different shapes: rectangular, trapezoidal, and triangular. They are all looked at. Each shape of the heated microchannel is looked at in three ways to see how water moves and heat moves through it. In this example, the averaged fluid temperature and heat transfer coefficient in each heat sink shape was used to measure the fluid flow and temperature distributions. It was found that better uniformities in heat transfer coefficient and temperature can be achieved in heat sinks with the smallest hydraulic diameter. Also, it is thought that the heat sink with the smallest hydraulic diameter performs better than other heat sinks in terms of pressure drop and friction factor than the other heat sinks.

According to (Weilin et al., 2000), the flow properties of water via trapezoidal silicon microchannels with hydraulic diameters ranging from 51 to 169 µm were investigated in experiments. The tests determined the flow rate and pressure drop through the microchannels at steady states. The experimental results were compared to the traditional laminar flow theory predictions. There was a significant discrepancy between the experimental findings and theoretical expectations. The pressure gradient and flow friction in microchannels are greater than those predicted by standard laminar flow theory. The observed increased pressure gradient and flow friction might result from the microchannels' surface roughness. The experimental data are interpreted using a roughness viscosity model.

According to (Tiselj et al., 2004), the heat transfer properties of water flowing through triangular silicon microchannels with a hydraulic diameter of 160 µm were evaluated experimentally and numerically across the Reynolds number range of Re 14 3:2–64. It was demonstrated that the bulk water temperature and the heated wall do not change linearly along the channel. The temperature distribution on the heated wall was consistent with the numerical projections. The Nusselt number's behaviour along the channel is solitary. The difference in temperature between the wall and the bulk water turns negative at this point, and the flux switches direction and is directed from the fluid to the wall. Increasing the Reynolds number, the unique point moves closer to the channel outlet. It was demonstrated that under the parameters of this investigation, heat transport might be represented using both standard Navier– Stokes and energy equations.

According to (Hong & Cheng, 2009), this study showed a numerical analysis of laminar forced convection of water in offset strip-fin microchannel network heat sinks for microelectronic cooling. Numerically solved is a three-dimensional mathematical model consisting of N–S equations and an energy conservation equation that considers conjugate heat transfer between the heat sink base and liquid coolant. We investigate the heat transfer and fluid flow properties of offset strip-fin microchannel heat sinks and describe the process of heat transfer enhancement. In addition, the effects of strip-fin geometry on heat sink performance are examined. It is discovered that an ideal strip-fin size exists for minimizing pressure drop or pumping power under the constraint condition of maximum wall temperature and that this optimal size is dependent on the input heat flux and maximum wall temperature. The findings of this paper apply to the design and optimization of offset strip-fin microchannel heat sinks used in microelectronic cooling.

According to (Chai et al., 2013), the heat transfer enhancement of microchannel heat sinks with periodic expansion-contraction cross-sections is examined. Each heat sink is composed of ten parallel microchannels measuring 0.1 mm wide and 0.2 mm deep in constant cross-section segments, with each microchannel containing an array of periodic expansion-contraction cross-sections. Three-dimensional laminar numerical simulations of pressure drop and heat transfer in these microchannel heat sink under identical experimental circumstances are produced using the Navier–Stokes equations and the energy equation. Consideration is given to the multi-channel effect, the entrance effect, conjugate heat transfer, viscous heating, and temperature-dependent features. The apparent friction factor and Nusselt number numerical predictions are in good agreement with experimental results. In that order, the authors address the effects of periodic expansion-contraction cross-sections on pressure drop, heat transfer, and thermal resistance. The authors analyse the impact of the entrance and exit plenum areas and the lateral portions of the silicon wafer on fluid flow and heat transmission. Particular emphasis is placed on analysing the fluctuation of thermal resistance with pumping power for each term, corresponding to three phases of heat release at the heat sink's substrate.

In this paper from (Wang et al., 2015), describes a chip cooling microchannel heat sink (MCHS) with microscale ribs and grooves. To increase heat transfer, micro-scale ribs and grooves were formed on the heated wall of the MCHS using a variety of surface-micromachining micro-electro-mechanical system (MEMS) methods. Through experimental and numerical comparisons, the cooling performance of rib-grooved microchannels is compared to that of typical smooth rectangular microchannels for Reynolds numbers ranging from 100 to 1000. The results reveal that rib-grooved microchannels can have a Nusselt number of 1.11e1.55 times that of smooth microchannels. Meanwhile, the use of micro-scale ribs and grooves results in a significant increase in pressure drop. The