UNIVERSITI TEKNOLOGI MARA

HEAT TRANSFER OF ADVANCED COOLANT DISPERSED WITH HYBRID OXIDES NANOPARTICLES IN PEMFC COOLING PLATES

SAIFUDDIN BIN KHALID @ CHIK

MSc

August 2020

AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of University Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

Name of Student	:	Saifuddin bin Khalid @ Chik
Student I.D. No.	:	2017948091
Programme	:	Master of Science (Mechanical Engineering) – EM750
Faculty	:	Mechanical Engineering
Thesis Title	:	Heat transfer of advanced coolant dispersed with hybrid oxides nanoparticles in PEMFC cooling plates
Signature of Student	:	……..
Date	:	August 2020

ABSTRACT

Thermal management analysis has always been a major concern in the energy-based sector. Thermal management in Proton Exchange Membrane Fuel Cell (PEMFC), as one of the leading green energy converter, is extremely important to ensure efficient heat extraction from the system. The low operating temperature of PEMFC has been known to reduce the rate of heat transfer which contribute to large volume space consumption for the cooling mechanism. The low electrical conductivity requirement of the system also limited the implementation of the well-established nanofluids as a coolant in PEMFC. This research aims to study the effect of hybrid nanofluids Al_2O_3-SiO_2 with 0.5% volume concentration dispersed in base fluid water to heat transfer enhancement in PEMFC. Nine different ratios of hybrid Al_2O_3-SiO_2 nanofluids were investigated, starting from 10:90 (Al_2O_3:SiO_2) to 90:10. Three thermophysical characteristics affecting heat transfer of fluids were analyzed namely thermal conductivity, electrical conductivity and dynamic viscosity of each sample. Correlation between properties was investigated using property enhancement ratio (PER) of thermo-electrical and thermo-hydraulic of each sample. Investigations made on two different cooling plates which are Serpentine-type and Distributor-type to obtain Nusselt number and pumping power requirement through the adoption of hybrid nanofluids in PEMFC. At the end of the experiment, the most feasible nanofluids ratio and cooling plate type for PEMFC application was selected. The Al_2O_3-SiO_2 hybrid nanofluids with ratio R1 (10:90) is shown as the most prominent ratio among all samples of Al_2O_3-SiO_2 hybrid nanofluids. Ratio R1 (10:90) exhibits the highest convective heat transfer coefficient and Nusselt number but show higher pumping power requirement as compared to the other ratios. Serpentine-type cooling plate shows the most feasible cooling plate with the highest convective heat transfer and Nusselt number at all ratios. It also shows a lower value in pumping power as compared to Distributor-type plate.

ACKNOWLEDGEMENT

Firstly, I wish to escalate my thanks to the Almighty for giving me the opportunity to embark on my life journey in pursuing Master of Science (Mechanical Engineering). My gratitude and thanks go to my supervisor, Ir Dr Irnie Azlin Zakaria, my co-supervisors, Prof Madya Dr Wan Ahmad Najmi and Prof Madya Dr Wan Azmi for their relentless help and support in my research. I would also like to express my gratitude to my fellow researches in University Malaysia Pahang (UMP) especially Dr Kamariah, Mr Anwar and Mr Sharif for providing facilities, assisting me in completing my experiments, and becoming such a good companions' day and night throughout a few months I am staying in UMP

My appreciation goes especially to my dear partner in life, Intan Sofia bt Omar, for undying support and love that has encouraged me to confidently pursue this path. Life has been hectic for us, but your courage and patience made me stronger to bring it to the end. Not to forget, my son, Khalid Umar and my daughter, Sofeeyya Aleena who are always there to cure my tiring days and stresses.

Finally, I dedicated this thesis to my very dear late father, Khalid bin Mohd Idris and my mother, Mariah bt Paimin for all their love and gifts to make me who I am today. Also my ten brothers who has always been there when I needed them to. I am here because all of you. Alhamdulillah.

TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	**ii**
AUTHOR'S DECLARATION	**iii**
ABSTRACT	**iv**
ACKNOWLEDGEMENT	**v**
TABLE OF CONTENTS	**vi**
LIST OF TABLES	**ix**
LIST OF FIGURES	**x**
CHAPTER ONE: INTRODUCTION	
1.1 Background Study	1
1.2 Problem Statement	5
1.2.1 Research Questions	6
1.2.2 Research Objectives	6
1.2.3 Scope and Limitations of the Study	6
1.3 Significance of the Study	7
CHAPTER TWO: LITERATURE REVIEW	
2.1. Introduction	9
2.2. Basic Structure and Working Principle	9
2.3. Thermal Management Issue of PEMFC	13
2.4. Cooling Strategies for PEMFC	14
2.4.1. Air Cooling Method	15
2.4.2. Liquid Cooling Method	16
2.5. The Application of Nanofluids in PEMFC Liquid Cooling Strategies	17
2.5.1. Overview	17
2.5.2. Preparation	19
2.5.3. Stability	22