UNIVERSITI TEKNOLOGI MARA

THERMOSOLUTAL MARANGONI CONVECTIVE BOUNDARY LAYER EQUATIONS

NORAINI BINTI AHMAD

Thesis submitted in fulfillment
of the requirements for the degree of
Master of Science

Faculty of Computer and Mathematical Sciences

December 2013

ABSTRACT

Prandtl velocity boundary layer has conceptualized the mathematical description of boundary layers that led to wide applications in engineering processes. In coupled dissipative boundary layer, the surface tension gradient play an important role at the interface in determining the characteristics of the boundary layer flow. In this study, the surface tension is assumed to depend linearly or quadratically on temperature and/or concentration gradients. Four mathematical models are formulated for the steady dissipative boundary layer flows. The systems of the steady boundary layer equations in form of system of partial differential equations (PDE) are transformed to system of ordinary differential equations (ODE) by similarity transformation. The ODE systems are solved numerically by using the Runge-Kutta-Fehlberg with shooting technique. The first problem considered the linear dependence of surface tension on temperature and solute concentration on the momentum and heat and mass transfer of MHD mixed convection boundary layers with suction or injection. The results show that as thermal and solutal Marangoni parameters increase the velocity, thermal and concentration boundary layer thickness for buoyancy-opposed flow increases but their thickness reduce for buoyancy-assisted flow. In the second problem, the combined effects of power law temperature and solute concentration on the surface tension, species concentration and pressure gradient are considered. The results shows thermosolutal surface tension ratio increases the velocity boundary layer thickness but decrease the temperature and concentration boundary layer thickness. The effect of porosity is considered in the third problem and significant effect of porosity can be observed in the momentum boundary layer but less impact on the rate of heat and mass transfer. In the fourth problem, the flow and temperature patterns on thermal Marangoni convection are studied. The effect of magnetic field, porous medium and permeable surface with the quadratic temperature dependence surface tension are considered. The results show the increase of thermocapillary or Marangoni effects and weaker magnetic field strength lead to stronger reverse flow.

ACKNOWLEDGEMENT

Alhamdulillah. Praise to Allah S.W.T for giving me the strength and patient to complete this study.

First and foremost I would like to express my deepest gratitude to my supervisor Associate Professor Dr. Seripah Binti Awang Kechil for her valuable guidance, advice, encouragement and insightful comments that enable me to complete this study. This wonderful and challenging journey will be cherished and will definitely guide me in my future endeavours.

I am also thankful to my second supervisor Puan Norma Binti Mohd Basir for her support and opinion. I am also indebted to the Universiti Teknologi Mara (UiTM) and Ministry of Higher Education for the financial support under the young lecturers scheme (TPM). I am most grateful to my beloved family and my lovely husband and thanks for all their sacrifices, support, pray and hope that provided me the strength to complete this study.

I owe many thanks to my classmate and all of my friends who always provide support and care during my time of needs. They always help me in any activities of brainstorming discussion and exchanging ideas and thus give me an enjoyable studying environment. They made my life at UiTM a truly memorable experience and their friendships are invaluable. Last but not the least, I would like to thank all the UiTM lecturers for all the valuable knowledge. May god bless us all always. Amin

TABLE OF CONTENTS

	Page
AUTHOR'S DECLARATION	ii
ABSTRACT	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	vii
LIST OF FIGURES	ix
LIST OF NOMENCLATURE	xii

CHAPTER ONE: INTRODUCTION

1.1 General Introduction 1
1.2 Research Background 2
1.3 Problem Statement 4
1.4 Objectives of the Study 4
1.5 Scope of the Study 5
1.6 Significance of Research 5
1.7 Thesis Organization 6

CHAPTER TWO: LITERATURE REVIEW

2.1 Marangoni Convection Boundary Layer 8
2.2 Magnetic Field and Mass Fluxes 11
2.3 Boundary Layer Equations 13
2.3.1 Development of Velocity, Thermal and Concentration Boundary Layers on Flat Surfaces 13
2.3.2 Derivation of Velocity Boundary Layer Equations 15
2.3.3 Thermal Boundary layer Equations 22

2.3.4 Concentration Boundary layer Equations 26

2.4 Method of Solution 28

2.4.1 Similarity Transformations 29

2.4.2 Runge-Kutta-Fehlberg Method (RKF45) and shooting technique 35

CHAPTER THREE: MATHEMATICAL MODELS AND SOLUTIONS OF MARANGONI CONVECTION BOUNDARY LAYER FLOWS

3.1 Thermosolutal MHD Marangoni Mixed Convection in the Presence of Suction or Injection 37

3.1.1 Model Formulation 38

3.1.2 Nondimensionalization 40

3.1.3 Similarity Transformation 46

3.1.4 Results and Discussion 52

3.2 Effects of Suction or Injection on Marangoni Boundary Layers with Power Law Surface Temperature and Concentration 61

3.2.1 Model Formulation 61

3.2.2 Nondimensional Governing Equations 68

3.2.3 Results and Discussion 68

3.3 Thermosolutal MHD Marangoni Convection over a Flat Permeable Surface in a Porous Medium with Internal Heat Generation and a First Order Chemical Reaction 74

3.3.1 Model Formulation 74

3.3.2 Boundary Layer Equations 76

3.3.3 Results and Discussion 80

3.4 Concluding Remarks 88

CHAPTER FOUR: THE FLOW AND TEMPERATURE PATTERNS OF MHD MARANGONI CONVECTION IN LIQUID LAYER