



UNIVERSITI PUTRA MALAYSIA

**UNSTEADY STAGNATION POINT FLOW AND HEAT
TRANSFER OVER A STRETCHING OR SHRINKING SHEET**

MELINI SUALI

FS 2012 76

**UNSTEADY STAGNATION POINT FLOW AND HEAT
TRANSFER OVER A STRETCHING OR SHRINKING
SHEET**

By

MELINI SUALI

Thesis Submitted to the School of Graduate Studies, Universiti Putra
Malaysia, in Fulfilment of the Requirements for the Degree of Master
of Science

July 2012

DEDICATIONS

To God, my parents, my siblings, my best friend and my supervisor.

*I might not know where the life's road will take me, but walking with You, God,
through this journey has given me strength.*

*Mom, you have given me so much, thanks for your faith in me, and for teaching
me that I should never surrender.*

Daddy, you always told me to reach for the stars. I think I got my first stars.

Thanks for inspiring my love for transportation.

*To my siblings and my best friend, you are everything for me, without your love
and understanding I would not be able to make it.*

To my supervisor, thanks for your timely and wise advice.

Thanks for teaching me well,

for giving me many chances to prove myself.

For many kind acts, for knowing what to say,

how to say it and when to say it.

Thanks for the many stories and lessons.

We made it...

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in
fulfilment of the requirement for the degree of Master of Science

UNSTEADY STAGNATION POINT FLOW AND HEAT TRANSFER OVER A STRETCHING OR SHRINKING SHEET

By

MELINI SUALI

July 2012

Chair: Associate Professor Nik Mohd Asri Nik Long, PhD

Faculty: Faculty of Science

The study is focused on investigating the effects of unsteady stagnation point flow and heat transfer over a stretching/shrinking sheet. The problem is modelled as a mathematical formulation that involves a system of partial differential equations. The governing partial differential equations are then transformed into non-linear ordinary differential equations using the similarity transformations. The obtained non-linear ordinary differential equations are solved numerically using the shooting method. For the problem of unsteady stagnation point flow and heat transfer over a stretching/shrinking sheet with prescribed heat flux, the unsteadiness parameter A increases the skin friction $f''(0)$ and the local Nusselt number $\frac{1}{\theta(0)}$. As the values of ratio of stretching/shrinking velocity ε and Prandtl number Pr increase, the velocity and temperature profiles increase but the surface temperature decreases. For the problem of unsteady stagnation point flow and heat transfer over a stretching/shrinking sheet with suction/injection, the temperature and velocity profiles increase as the values of f_0 increases. As the injection/suction parame-

ter increases the thermal boundary layer thickness increases, thus reduce the heat transfer rate at the surface. For the case of injection, the solutions exist for a certain interval of ε , whereas for the suction, there is no such interval appears. For the problem of thermal radiation effects on unsteady stagnation point flow and heat transfer over a stretching/shrinking sheet, the skin friction coefficient $f''(0)$ and the local Nusselt number $-\theta'(0)$ increase as the values of the unsteadiness parameter A increases, and the increase of the radiation parameters Nr and ε lead to an increase of the temperature profiles. From the results, it is noticed that the unsteadiness, thermal radiation, suction/injection, ε and Pr parameters can control the behaviour of the unsteady stagnation point flow and heat transfer over a stretching/shrinking sheet.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**ALIRAN TITIK GENANGAN TAK MANTAP DAN
PEMINDAHAN HABA TERHADAP HELAIAN MEREKANG
ATAU MENGE CUT**

Oleh

MELINI SUALI

Julai 2012

Pengerusi: Profesor Madya Nik Mohd Asri Nik Long, PhD

Fakulti: Fakulti Sains

Kajian ini ditumpukan kepada penyiasatan kesan aliran titik genangan tak mantap dan pemindahan haba ke atas helaian meregang/mengecut. Masalah ini dimodelkan sebagai formulasi bermatematik yang melibatkan sistem persamaan pembezaan separa. Persamaan pembezaan separa mentadbir kemudiannya dijemakan kepada persamaan pembezaan biasa tak linear dengan menggunakan penjelmaan keserupaan. Persamaan pembezaan biasa tak linear yang diperolehi diselesaikan dengan menggunakan kaedah tembakan. Bagi masalah aliran titik genangan tak mantap dan pemindahan haba ke atas helaian meregang/mengecut dengan fluks haba permukaan ditetapkan, parameter ketakmantapan A meningkatkan pekali geseran kulit $f''(0)$ dan nombor Nusselt tempatan $\frac{1}{\theta(0)}$. Apabila nilai nisbah diantara meregang/mengecut ε dan nombor Prandtl Pr meningkat, profil halaju dan profil suhu meningkat tetapi suhu permukaan menurun. Bagi masalah aliran titik genangan tak mantap dan pemindahan haba ke atas helaian meregang/mengecut dengan semburan/sedutan, profil suhu dan profil halaju meningkat apabila ni-

lai f_0 bertambah. Apabila parameter semburan/sedutan meningkat, ketebalan lapisan sempadan juga meningkat, dan seterusnya mengurangkan kadar pemindahan haba pada permukaan. Bagi kes semburan, penyelesaian wujud pada selang ε tertentu, manakala bagi kes sedutan selang tersebut tidak wujud. Bagi masalah kesan radiasi terma pada aliran titik genangan tak mantap dan pemindahan haba ke atas helaian meregang/mengecut, pekali geseran kulit $f''(0)$ dan nombor Nusselt tempatan $-\theta'(0)$ meningkat apabila parameter ketakmantapan meningkat, dan peningkatan nilai parameter radiasi Nr dan ε membawa kepada peningkatan profil suhu. Hasil daripada keputusan kajian, adalah diperhatikan bahawa parameter ketakmantapan, radiasi terma, semburan atau sedutan, ε dan Pr mengawal telatah aliran titik genangan tak mantap dan pemindahan haba terhadap helaian merengang/mengecut.

ACKNOWLEDGEMENTS

First and foremost I would like to thank God, for my life through all tests in the past two years and for making this Master thesis entitled unsteady stagnation point flow and heat transfer over a stretching/shrinking sheet success. I could never have done this without the faith I have in You, the Almighty. I would like to thank all people who have helped and inspired me during my study.

I especially thanks my supervisor, Associate Professor Dr. Nik Mohd. Asri Nik Long, who has supported me throughout my work with his patience and knowledge whilst allowing me to work on my own way. I attribute the level of my Masters degree to his encouragement and effort and without him this thesis, would not have been completed. One simply could not wish for a better or friendlier supervisor. My gratitude also goes to Professor Dr. Anuar Mohd. Ishak and Associate Professor Dr. Norihan Binti Md. Arifin as my co-supervisors for their valuable knowledge, encouragement, time and advise to make this thesis possible. I would also like to extend my most sincere thanks to Puan Norfifah Binti Bachok for her time, continuous support, with her kind and helpful attitude to my questions throughout this research.

In my daily work I have been blessed with a friendly and cheerful group of fellow students. Koo Lee Feng, who has helped me to get on the road to LATEX and provided an experience ear for my doubts about writing a thesis. In many ways I have learnt much about LATEX because of her and Mohd. Hafizi has impressed me with his willingness to teach me on the shooting method. Thank you so much for the helps that I have received from both of you. To my best friend, Alex you have given me so much support when I was down on myself. Thanks for being a

great friend.

My deepest gratitude goes to my family for their unflagging love and support throughout my life, this dissertation is simply impossible without them. I am indebted to my parents for their advise, love, care and confidence have always motivated me and gave me hope through the good times and in those more difficult moments. Not to forget their financial support, from the moment I started my study. I have no suitable word that can fully describe their everlasting love to me. To my sister, Emma you have been a role model for me to follow unconsciously when I was a teenager and has always been one of my best counsellors.

Last but not least, I would like to thank the staff and lecturers of Universiti Putra Malaysia, for their great assistance and continuous help through out my study and Biasiswa Kerajaan Negeri Sabah (BKNS) for the financial support. Thank You.

I certify that a Thesis Examination Committee has met on **16 July 2012** to conduct the final examination of Melini binti Suali on her thesis entitled “Unsteady Stagnation Point Flow and Heat Transfer Over a Stretching or Shrinking Sheet” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Zanariah binti Abdul Majid, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Chairperson)

Leong Wah June, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Norazak bin Senu, PhD

Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Ahmad Izani bin Md. Ismail, PhD

Associate Professor
School of Mathematical Sciences
Faculty of Science
Universiti Sains Malaysia
Malaysia
(External Examiner)

SEOW HENG FONG, PhD

Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Nik Mohd Asri bin Nik Long, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Chairperson)

Norihan Md. Arifin, PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

Anuar Mohd Ishak, PhD

Professor
School of Mathematical Sciences
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD

Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

The logo of Universiti Putra Malaysia (UPM) is a shield-shaped emblem. It features a red and white design with a central vertical element and a book icon at the top right. The letters 'UPM' are prominently displayed in the upper left corner of the shield.

MELINI BINTI SUALI

Date:16 July 2012

TABLE OF CONTENTS

| | Page |
|--|-----------|
| DEDICATIONS | i |
| ABSTRACT | ii |
| ABSTRAK | iv |
| ACKNOWLEDGEMENTS | vi |
| APPROVAL | viii |
| DECLARATION | x |
| LIST OF TABLES | xiii |
| LIST OF FIGURES | xiv |
| LIST OF ABBREVIATIONS | xvi |
| | |
| CHAPTER | |
| 1 INTRODUCTION | 1 |
| 1.1 Motivation | 1 |
| 1.2 Heat Transfer | 3 |
| 1.3 No Slip Condition | 3 |
| 1.4 Reynolds Number | 4 |
| 1.5 Boundary Layer Approximation | 4 |
| 1.5.1 Velocity Boundary Layer | 10 |
| 1.5.2 Thermal Boundary Layer | 11 |
| 1.6 Objectives and Scope | 15 |
| 1.7 Thesis Outline | 16 |
| | |
| 2 MATHEMATICAL FORMULATION, METHODS AND LITER- ATURE REVIEW | 17 |
| 2.1 Problem Formulation | 17 |
| 2.1.1 Equation of Continuity | 17 |
| 2.1.2 Navier-Stokes Equations | 18 |
| 2.1.3 Energy Equation | 19 |
| 2.1.4 Basic Equations | 19 |
| 2.1.5 Similarity Transformation | 20 |
| 2.2 Numerical Method | 20 |
| 2.2.1 Shooting Method | 20 |
| 2.2.2 Runge Kutta Fehlberg Method | 21 |
| 2.3 Literature Review | 21 |

| | | |
|----------|--|-----------|
| 3 | UNSTEADY STAGNATION POINT FLOW AND HEAT TRANSFER OVER A STRETCHING/SHRINKING SHEET | 27 |
| 3.1 | Introduction | 27 |
| 3.2 | Prescribed Surface Temperature | 27 |
| 3.2.1 | Mathematical Formulation | 27 |
| 3.2.2 | Results and Discussion | 31 |
| 3.2.3 | Conclusion | 35 |
| 3.3 | Prescribed Surface Heat Flux | 35 |
| 3.3.1 | Mathematical Formulation | 35 |
| 3.3.2 | Results and Disussion | 37 |
| 3.3.3 | Conclusion | 39 |
| 4 | UNSTEADY STAGNATION POINT FLOW AND HEAT TRANSFER OVER A STRETCHING/SHRINKING SHEET WITH SUCTION OR INJECTION | 44 |
| 4.1 | Introduction | 44 |
| 4.2 | Mathematical Formulation | 45 |
| 4.3 | Result and Discussion | 46 |
| 4.4 | Conclusion | 48 |
| 5 | THERMAL RADIATION EFFECTS ON THE UNSTEADY STAGNATION POINT FLOW AND HEAT TRANSFER OVER A STRETCHING/SHRINKING SHEET | 54 |
| 5.1 | Introduction | 54 |
| 5.2 | Mathematical Formulation | 55 |
| 5.3 | Result and Discussion | 57 |
| 5.4 | Conclusion | 60 |
| 6 | CONCLUSIONS | 64 |
| 6.1 | Summary of Research | 64 |
| 6.2 | Further Researches | 65 |
| | BIBLIOGRAPHY | 67 |
| | APPENDICES | 72 |
| | BIODATA OF STUDENT | 84 |
| | LIST OF PUBLICATIONS | 85 |