SOME ASPECTS OF SHEAR AND NATURAL CONVECTIVE FLOWS OBEYING ARRHENIUS LAW OF VISCOSITY

by

ROBERT JOHN D'SOUZA

THESIS SUBMITTED TO THE
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY

Department of Mathematics

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

NEW DELHI-110016

March, 1987

DEDICATED

TO

MY PARENTS

CERTIFIÇATE

This is to certify that the thesis entitled 'Some Aspects of Shear and Natural Convective Flows Obeying Arrhenius Law of Viscosity being submitted by Mr.Robert John D'Souza to the Indian Institute of Technology,Delhi, for the award of the degree of Doctor of Philosophy in Mathematics, is a record of bona fide research work carried out by him under my supervision for the last three years and to the best of my knowledge it has reached the standard fulfilling the requirements of the regulations relating to the degree.

I further certify that the results contained in this thesis have not been submitted, either in part or in full, to any other University or Institute for the award of any Degree or Diploma.

K.N. MEHTA
Professor
Department of Mathematics,
Indian Institute of Technology,
New Delhi, 110 016, INDIA

ACKNOWLEDGEMENTS

It gives me a great pleasure to express my deep sense of gratitude to Dr. K.N. Mehta, Professor, Department of Mathematics, Indian Institute of Technology, Delhi, for his invaluable help, guidance and supervision throughout the preparation of this thesis. I express my sincere thanks to the Head of the Department of Mathematics for the constant help in my work, and the authorities of IIT Delhi for providing me necessary research facilities. I thank the Ministry of Education, Government of India for the financial assistance provided to me.

My profound thanks are due to the Principal, Karnataka Regional Engineering College, Surathkal for sponsoring me under the Quality Improvement Programme for a Ph.D. studies and to Professor M.N. Channabasappa for encouraging me to do research and showing great interest in my work.

I owe my sincere thanks to my colleagues Dr. S.S. Prabhu, Dr. R.K. Yaji and Mr.P. Mohanan for their constant help and support throughout the preparation of this work. I am grateful to Mr. D. D. Rao and Mr.P.M. Padmanabhan Nambiar for their help during my stay at Delhi. The job of typing the manuscript of my thesis was excellently handled by Ms. Neelam Dhody. I deeply appreciate her efforts.

I gratefully acknowledge the contributions of several of my family members who took great interest in my studies. I owe the greatest debt to my brother Bernard, whose constant help and guidance have been instrumental in shaping my career.

Next in the list comes my wife whose understanding and sacrifice have been exemplary. The tolerance and patience of my children, I value and appreciate greatly.

ROBERT JOHN D'SOUZA

ABSTRACT

The thesis entitled "Some Aspects of Shear and Natural Convective Flows Obeying Arrhenius Law of Viscosity" deals basically with shear flows in channels of different geometries, whose boundaries are maintained at a constant temperature and when heat generation due to viscous dissipation is taken into account. The relation between the viscosity μ and temperature T is taken as

$$\mu = \mu_o \exp(\beta (\frac{T_o}{T} - 1))$$

where μ_o is the viscosity at reference temperature T_o and β is a nondimensional activation energy parameter which measures the sensitivity of viscosity to variations in temperature.

In all the shear flow problems considered in this thesis, it is found that the shear rate-shear stress diagram is S-shaped or monotonic depending on whether the activation energy parameter is large or small. The parameter of each problem is identified and its effect on shear rate-stress diagram and heat transfer is considered.

In Chapter II the effect of radius ratio, angular velocity ratio on flow in an annulus due to the axial, circular motion of the boundaries and the effect of aspect

ratio on flow in a rectangular duct due to the motion of a moving wall is considered.

In Chapter III, the effect of permeability on flow in a porous medium between plane and cylindrical surfaces in relative motion is studied.

Chapter IV is concerned with the effect of velocity slip at the boundaries on plane and annular Couette flows. Further, the effect of the thickness of the porous lining on flow of constant viscosity fluid through a pipe and a rectangular duct whose boundaries are provided with a porous lining is considered. It is shown that for small values of the thickness of the porous lining, the effect is to increase the mass flow rate and to decrease the friction factor.

Chapter V deals with plane, annular and circular Couette flows with surface mass transfer. The effect of Cross flow Reynolds number is studied.

In Chapter VI, we have studied the effect of activation energy on buoyancy induced convection due to differential heating in fluid saturated porous enclosures of rectangular and annular geometries. It is shown that an increase in the activation energy parameter causes an increase in circulation and heat transfer rate.

CONTENTS

Page

Page

Page

Page