

ABSTRACT

The unsteady mixed convection boundary layer flow of a Newtonian fluid near the region of the stagnation point over an elliptic cross section of a cylinder in both horizontal (blunt elliptic cylinder) and vertical (slender elliptic cylinder) is considered in this project. The governing system of higher order partial differential equations is reduced into a system of first order differential equations. Then, the transformed equations are solved numerically by Keller-box scheme. The numerical results are obtained for various values of the Prandtl numbers and parameter λ (parameter for major and minor axes of the cylinder). Meanwhile, the features of assisting and opposing flow are investigated.

Keywords: Mixed Convection, Unsteady Boundary Layer, Newtonian Fluids, Keller-box scheme

ABSTRAK

Masalah aliran lapisan sempadan tidak mantap berserta olakan campuran di sekitar titik genangan melepasi silinder berbentuk elips bagi kedua-dua paksi menegak dan melintang dalam bendalir Newtonian dipertimbangkan dalam projek ini. Sistem persamaan pembezaan separa berperingkat tinggi diturunkan kepada persamaan pembezaan separa berperingkat satu. Kemudian, persamaan tersebut diselesaikan secara berangka dengan skim Keller-box. Keputusan berangka diperolehi bagi pelbagai nilai nombor Prandtl dan parameter λ (parameter untuk paksi major dan minor dari silinder). Sementara itu, ciri-ciri aliran membantu dan menentang juga diselidiki.

Kata kunci: Campuran Konveksi, Cecair Newtonian, Keller-box skim

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CHAPTER 1

INTRODUCTION

1.1 Brief Introduction

In this chapter, we will expose some background information about unsteady mixed convection boundary layer from an elliptic cylinder. In fact, we also will explain the aim of this study together with the application of the topic in engineering field. In the last section of this chapter, we will introduce the Navier Stokes equation. Navier Stokes equation is essential to our study since we are going to derive our model from it.

1.2 Background of the Problem

Convection is defined as the transfer of heat through a fluid (liquid or gas) caused by molecular motion. However in fluid mechanics, convection is refers to movement of fluid regardless of the cause .There are two major types of heat convection namely forced convection and natural convection. Forced convection occurs when a fluid flow is induced by an external force, such as a pump, fan or a mixer. On the other hand, Natural convection is caused by buoyancy forces due to density differences caused by temperature variations in the fluid. At heating the density change in the boundary layer will cause the fluid to rise and be replaced by cooler fluid that also will heat and rise. This continues phenomenon is called free or natural convection. Therefore, many problems about free convection always arise in engineering service. An example of free convection is the cooling process in heat exchanger components. By understanding the properties of the convection occurring in the process, we can monitor and even predict the lifespan of the heat exchanger components.

In this study, we only consider incompressible viscous fluid. Therefore, we need to assume that the density of the fluid will not change. Arise from that, only liquids full fill the condition as incompressible viscous fluid. Besides that, concept of dynamic pressure mentions that the stagnation pressure at the stagnation point is equal to total pressure throughout the flow field.

Lastly, our study is about the unsteady mixed convection boundary layer from an elliptic cylinder. We will look into the difference caused by blunt orientation and slender orientation. This boundary layer problem is solved by Keller's Box schemed. The reason for applying this numerical schemed is due to its efficiency and flexibility in dealing with problems of free convection. In fact, it is easily adaptable for solving equation of any order (Cebeci and Bradshaw, 1977).

1.3 Problem Statement

How does Prandtl number affect the result of local skin coefficient, Nusselt number, velocity profile and temperature profile in unsteady mixed convection over a cylinder of elliptic cross section? How does mixed convection coefficient affect the result of local skin coefficient, Nusselt number, velocity profile and temperature profile in unsteady mixed convection over a cylinder of elliptic cross section? What is the effect of blunt orientation and slender orientation to the local skin coefficient, Nusselt number, velocity profile and temperature profile in unsteady mixed convection over a cylinder of elliptic cross section?

1.4 Objectives of the Study

The objective of the study is to analyze the model of unsteady mixed convection boundary layer flow over cylinders of elliptic cross section. The analog is including:

1. The effect of Prandtl number on local skin coefficient, Nusselt number, velocity profile and temperature profile.
2. The effect of mixed convection parameter on local skin coefficient, Nusselt number, velocity profile and temperature profile.
3. The effect of blunt orientation and slender orientation on local skin coefficient, Nusselt number, velocity profile and temperature profile.

1.5 Scope of the Study

The unsteady mixed convection boundary layer flow over horizontal cylinders of elliptic cross section in an incompressible viscous fluid is considered in this project. The analysis is only based on the stagnation point. The numerical scheme used is Keller box method and numerical results are obtained from various

values for blunt and slender orientations. The results are discussed based on the velocity profile, temperature profile, Nusselt number and skin friction coefficient.

1.6 Significances of Study

In environment and engineering services, mixed convection over a cylinder is an essential problem. Mixed convection occur during the motion of fluid that result from vary in density and heat change. In manufacture industry, most of the manufacturing machine has its own heat exchanger components which are made from tubes of elliptic cross section. The benefit of this design is it creates less resistance for cooling the fluid pass by. As a result, the study of heat transfer for an elliptic cross section cylinder is useful to create an effective and efficient heat exchanger component and design.

1.7 Governing Equations

The governing equations for unsteady incompressible viscous fluid flow consist of continuity, momentum and thermal energy equations. The continuity equation expresses the principle of mass convection. Meanwhile, the momentum equation is derived using the Newton's second law of motion. Lastly, the thermal energy equation is formulated from the first law of thermodynamics. In vector form, these equations are expressed as (Guaram and Smith, 1980; Lukaszewich, 1990):

$$\bar{\nabla} \cdot \bar{\mathbf{u}} = 0, \quad (1.1)$$

$$\rho \frac{D\bar{\mathbf{u}}}{D\bar{t}} = -\bar{\nabla}\bar{p} + \mu\bar{\nabla}^2\bar{\mathbf{u}} + \mathbf{F}, \quad (1.2)$$

$$\rho C_p \frac{D\bar{T}}{D\bar{t}} = c\bar{\nabla}^2\bar{T}. \quad (1.3)$$

In the above equations, $\bar{\mathbf{u}}$ is the velocity vector, \bar{T} is the temperature of the fluid, \bar{p} is the pressure, \bar{t} is the time, ρ is the density of the fluid, μ is the dynamic viscosity, \mathbf{F} is the body force, C_p is the specific heat at constant pressure and c is the thermal conductivity. The symbol $\bar{\nabla}^2$ is the Laplacian operator where the gradient is defines as $\bar{\nabla} = \frac{\partial}{\partial \bar{x}} \mathbf{i} + \frac{\partial}{\partial \bar{y}} \mathbf{j}$. Here \mathbf{i} and \mathbf{j} are the unit vectors, \bar{x} is the coordinate measured along surface of the cylinder and \bar{y} is the coordinate measured in the normal direction to the wall. Equations 1.1 to 1.3 are applied for both steady and unsteady case.