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## Steady Flow and Heat Transfer between Two Rotating Discs of Different Transpiration at Constant Heat Flux

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*The flow and heat transfer of a viscous incompressible fluid between two coaxial infinite porous rotating discs have been considered for small cross flow Reynolds number. The discs are rotating with different angular velocities and one of them is kept at constant heat flux. The governing equations have been solved using cross flow Reynolds number as perturbation parameter. The effects of the heat flux in the velocity components and temperature fields are obtained and shown graphically.*

### 1. Introduction

The flow of an incompressible fluid over a single infinite rotating disc was first studied by Von Karman (1)and Bodewadt (2) Batchelor (3) applied the solution of Von Karman and Bodewadth for the case of two infinite rotating discs. Stewartson (4) obtained the approximate solutions for large and small values of Reynolds numbers. Stuart (5) investigated the flow of a single rotating disc of infinite radius with uniform suction at the disc and obtained numerical solution for both large and small values of suction parameter. Pearson (6), Lance and Rogers (7) and Mellor (8) et.al. obtained the numerical solution of the problem of Stewartson. Rao and Gupta (9) extended the Stuarts's problem by considering the effect of transverse magnetic field for large suction Reynolds number. Loper and Benton (10) studied the spin up of electrically conducting fluid. Gaur (11) discussed the problem of Stewartson by considering the effect of porosity. Narayan and Rudraih (12) studied the flow of a viscous incompressible fluid between two co-axial circular discs with uniform suction at the stationary disc and they obtained the solutions for large and small suction Reynolds number. Wilson (13) studied the Narayan and Rudraih's problem only by changing the application of suction in either one of the discs. Chawla (14,15) studied hydro magnetic spin up and flow induced by torsion ally oscillating disc. Khare (16) studied the Narayan and Rudraih's problem for electrically conducting viscous fluid in presence of transverse magnetic field. Hossain and Rahman (17) studied the problem of Gaur by considering transverse magnetic field.

In all these above investigations heat transfer aspect has not been considered. Purohit and Patidar (18) studied the steady flow and heat transfer of viscous incompressible fluid between two infinite rotating discs for small Reynolds number. They have considered the rate of suction to be different from the rate of injection Dhanak (19) studied the effects of uniform suction on the stability of flow on a rotating disc. Recently Das and Aziz (20) extended the problem studied by Purohit and Patider by introducing a transverse magnetic field.

The aim of the present paper is to investigate the effect of constant heat flux at the lower disc on the flow of a viscous incompressible fluid between the two parallel porous rotating disc of infinite extent. The governing equations have been solved with perturbation technique taking cross flow Reynolds number as the perturbation parameter.

### 2. Mathematical Analysis

Consider the flow of a viscous incompressible fluid between two co – axial parallel porous discs of infinite



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## THREE DIMENSIONAL OSCILLATORY FREE CONVECTIVE MHD FLOW AND HEAT TRANSFER ALONG AN INFINITE VERTICAL POROUS PLATE

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*(Received November 12, 2003)*

**Abstract.** The free convection MHD flow and heat along a vertical porous plate are investigated when a transverse sinusoidal suction velocity distribution fluctuating with time is applied. Due to this type of suction velocity at the plate the flow becomes three dimensional one. For asymptotic flow condition, the wall shear stress in the direction of main flow and the rate of heat transfer from plate to the fluid are obtained. The effects of various parameters entering into the problem are discussed and show graphically.

### 1. Introduction

The problem of laminar flow control is gaining considerable importance in the fields of Aeronautical Engineering, in view of its applications to reduce drag and hence the vehicle power requirement by a substantial amount. The development on this subject has been compiled by Lachmann [4]. Theoretical and experimental investigations have shown that the transition from laminar to the turbulent flow which causes the drag coefficient to increase, may be prevented by suction of the fluid and heat transfer from boundary layer to the wall. The effect of different arrangements and configurations of the suction holes and slits on the drag have been studied extensively. To obtain any desired reduction in the drag by increasing suction alone is uneconomical as the energy consumption of the suction pump will be more. Therefore the method of "cooling of the wall" in controlling the laminar flow together with the application of suction has become more useful and has received the attention of more workers. The free convection flow past and infinite porous plate was analyses by Messiha [5] in case of constant suction velocity. Pop[7] studied the effects of a suction velocity which varies periodically with time on the unsteady free convection flow past a vertical porous plate. Pande et. al.[6] investigated the effects of unsteady free convection on the flow near a porous infinite vertical limiting surface with constant suction. Most of the investigators have however, confined themselves to two dimensional flows. There may arise situations where the flow fields may be essentially three dimensional, for example, when variation in the suction velocity distribution is transverse to the potential flow.

Recently Gersten and Gross [2] have studied the effects of transverse sinusoidal suction velocity on the flow and heat transfer over a porous plane wall. There after Singh et. al.[9] analysed the

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**AMS Subject Classification :** 76W.

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**Abstract**

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2000 Mathematics Subject Classification: 76D.

Key words and phrases: free convection, fluctuating flow, heat transfer.

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## Oscillatory free convective MHD flow past an infinite plate through a porous medium with constant heat flux

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**Abstract.** A theoretical analysis of unsteady free convective flow is presented when a viscous, incompressible and electrically conducting fluid flows through a porous medium occupying a semi-infinite region of the space bounded by an infinite vertical porous plate. A magnetic field of uniform strength is applied perpendicular to the plate and the fluid is subjected to a normal suction velocity. The free stream velocity of the fluid vibrates about a mean constant value while the heat flux at at the plate is constant. Analytic expressions for the velocity of the fluid are given. The effects of porous medium, magnetic parameter and Grashof number upon the velocity field are also shown in a graphic representation.

**Keywords.** Free convective MHD flow, porous medium.

1991 Mathematics subject classification: 76 W.

### 1. Introduction

Many researchers have worked on fluctuating flows of viscous incompressible fluids past an infinite plate. Stuart [1], Suryaprakash Rao [2,3], Reddy [4], Messiha [5], Siddappa and Chetty [6], Prakash and Rajvanshi [7] are some of them. Lighthill [8] initiated the work on fluctuating flows. He studied an important class of two dimensional time dependent flow problems dealing with the response of the boundary layer to unsteady fluctuations about a mean value.

Flows through porous medium are very much prevalent in nature and therefore, the study of flows through porous media has become of principal

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## THREE DIMENSIONAL FLUCTUATING FREE CONVECTIVE FLOW AND HEAT TRANSFER THROUGH A POROUS MEDIUM BOUNDED BY AN INFINITE VERTICAL POROUS PLATE

U.N. DAS[1], A. AZIZ[2] AND M. RAHMAN[3]

(*Received 5 August 2000*)

**Abstract.** The free convective flow and heat transfer through a porous medium bounded by an infinite vertical porous plate are investigated when a transverse sinusoidal suction velocity distribution fluctuating with time is applied. Due to this transverse velocity the flow of fluid is three dimensional. A series expansion method is used to get the solution of the governing equations and the expressions for velocity and temperature fields are obtained. The skin friction and the rate of heat transfer at the surface, are discussed in details.

**Introduction.** The flow through a porous medium, under the influence of temperature differences, is one of the most considerable and contemporary subject, because it finds great applications in geothermy, geophysics and technology (Yamamoto and Iwamura 1976), (Cheng 1978).

Studies associated with flows through a porous medium have been based on the Darcy's empirical equation :

$$\vec{q}' = -\frac{(\text{const})}{\mu}\nabla p \qquad (1)$$

where $\vec{q}'$ is mean filter velocity, $\mu$ is the viscosity of the fluid and $\nabla p$ is the pressure gradient. Later Muskat (1937) has shown that the constant in equation (1) must depend on the permeability of the porous medium and showed that

$$\vec{q}' = \frac{K'}{\mu}(\nabla p) \qquad (2)$$

where $K'$ is the permeability of the porous medium. But this law fails to explain the phenomenon occuring in highly porous medium. Taking into account the effects of the viscous stress Brinkman (1917) generalized the Darcy's law to study the flow through highly porous media :

$$0 = -(\nabla p) - \frac{\mu}{K'}\vec{q}' + \mu\nabla^2\bar{q} \qquad (3)$$

Following the method of local averages given by Eringen and Suhubi (1964), a general equation of motion has been derived analytically by Ahmadi and Manvi (1971) for the flow of a viscous fluid through rigid porous medium and applied the results obtained to some basic flow problems. These equations were later used by Gulab Ram and Mishra (1977) to study the MHD

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## The Fractional Calculus, Fractional Differential Equations, and Laplace Transform

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**Abstract** - This research review study paper explores the possibility of applying the Laplace transform for solving linear fractional differential equations from several sources, academic articles and journals. The Laplace transform is a very powerful component in engineering, science, and applied mathematics. It permits to transform the fractional differential equation into the algebraic equation, so as to solve the algebraic equations to obtain the unknown value as its function, and that further can be processed by applying the Inverse Laplace Transform.

The subject applications of fractional calculus, which means, calculus of integrals as well as derivatives of some arbitrary real and complex order, have possessed seemingly high reputation in the past 30 years, specifically because of their established applications in innumerable diverse fields of engineering and science. Certain areas of contemporary fractional model applications involve Fluid Flow, Dynamical Processes, Diffusive Transport close to Diffusion, Solute Transport in Similar to Porous Structures, Electromagnetic Theory, Viscoelastic Material Theory, Earthquake Dynamics, Dynamical Control Theory Systems, Bioscience, Signal and Optical Processing, Geology, Economics, Astrophysics, Chemical Physics, Statistics, Probability and so on.

### I. INTRODUCTION

Even though fractional derivatives carry a lengthy history in mathematics, their multiple definitions of nonequivalent fractional derivatives are responsible of their non usage (Podlubny, 1999). Another problem is that the fractional derivatives do not carry clear geometrical interpretation due to the nonlocal characteristics (Podlubny, 2002). But, the physics and mathematics have proved its need, especially due to its interdisciplinary application that can be conveniently formatted by using fractional derivatives. To give an example, the earthquake, nonlinear oscillation can be assessed only with fractional derivatives (He, 1998). Again, it has been used the traffic model of fluid-dynamics using fractional derivatives ((He, 1999). This has completely eliminated the shortage arose out of various assumptions made so far in the continuous traffic flow circumstances. Based on experimental data available, the equations of fractional partial differential for the porous media seepage flow are also suggested, and the fractional order differential equations proved to be the most vital tool model several other physical phenomena. Further the fractional derivative review and applications in statistical and continuum were produced, while the analytical results on the uniqueness and subsistence of relevant fractional differential solutions to the equations were investigated by several authors (Grigorenko & Grigorenko, 2003). Many fractional differential methods were used to solve equations, along with fractional differential and partial equations, fractional integral and differential equations, moreover, the dynamic systems involving fractional derivatives, like Adomian's method of decomposition; Variation method of iteration; Homotopy method of perturbation; Homotopy method of analysis; and certain spectral methods (Momani & Noor, 2006).

### II. DIFFERENTIAL EQUATIONS

In the branch of fractional calculus, mathematical analysis finds several ways to define the powers of real or complex numbers of $D$ – the differentiation operator.
D f (x) = d / dx f (x), and of the integration operator $J$ (J symbol, 2014).
J f (x) = ∫ 0 x, f(s) ds, and
Calculus development of such equations is generalized as classical one.
The *powers* term indicates linear operator iterative application of a function, in different analogy called functional composition acts like a variable,
i.e. $f^{-2}(x) = f \circ f(x) = f(f(x))$.
To give an example, it can be meaningfully interpreted as
D = D 1 2
Acting as the square root of a function analogue for the differentiation operator, which develops the elements in the similar space, that means, a certain linear operator expression applied *twice* for any different function and that produces the similar effect like differentiation. Otherwise, the D - linear functional and be specified for each $a$ – the real-number in a way, when $a$ acts like a value $n \in \mathbb{Z}$ of the integers that coincides normal $n$-fold $D$ differentiation when $n > 0$, and when $n < 0$, the $-n$ th power of $J$. The basic motivation for introducing these types of differentiation $D$ operator is because of the operator power sets $\{D^a \mid a \in \mathbb{R}\}$ which is

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## Three dimensional fluctuating free convective MHD flow and heat transfer through a porous medium bounded by an infinite vertical porous plate

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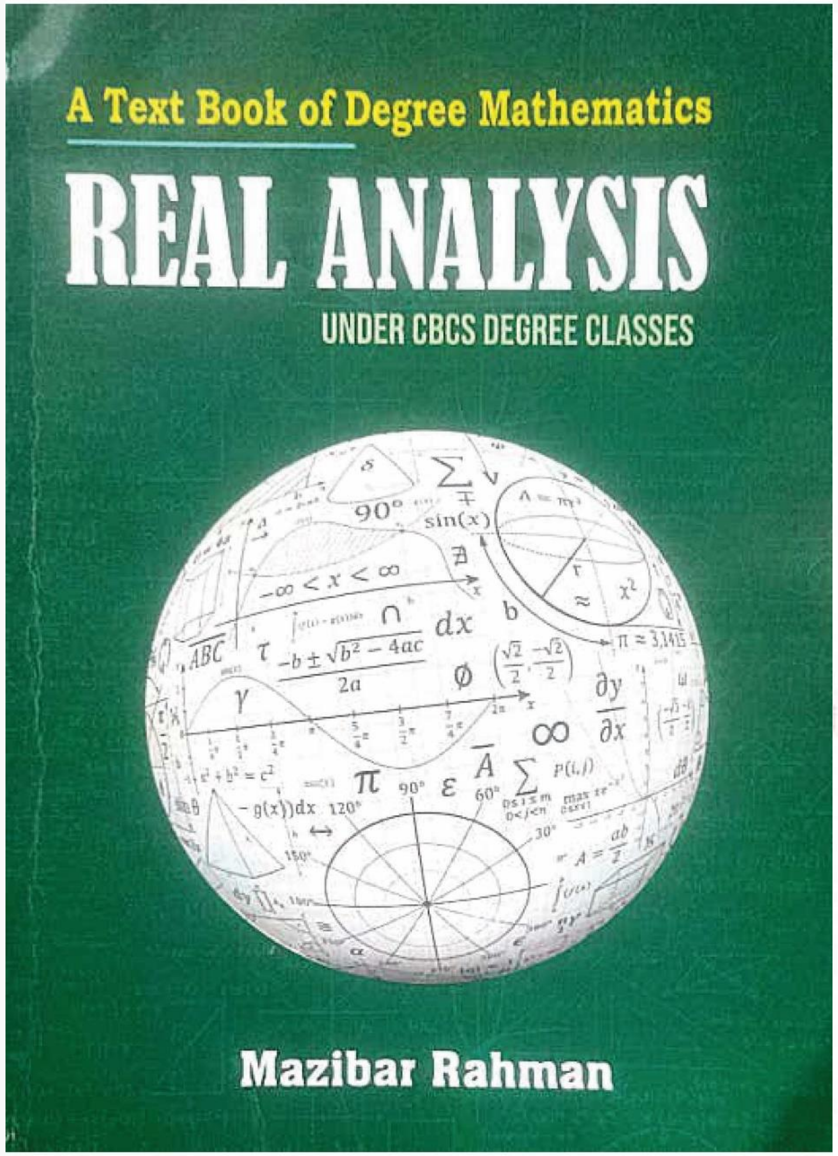


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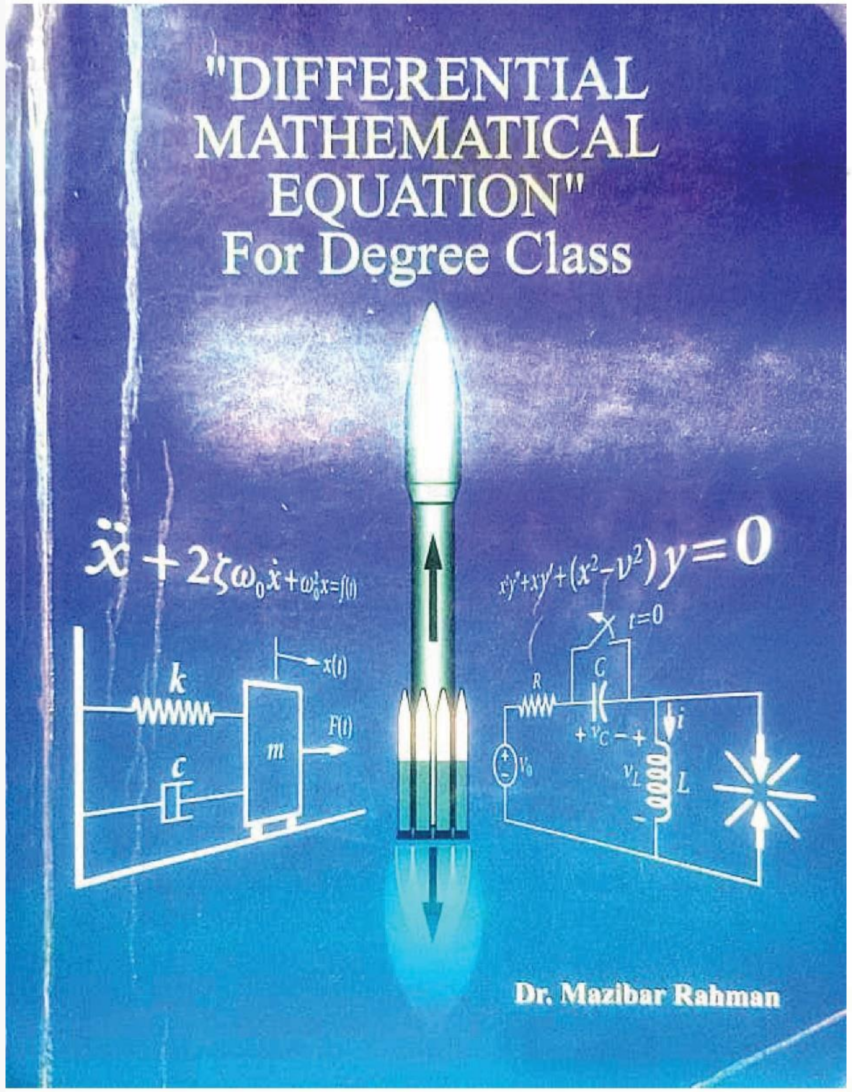


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