CHAPTER-2

REVIEW OF THE LITERATURE

2.1 INTRODUCTION

Complex engine systems are becoming more commonly implemented to meet the increasing demands on fuel efficiency. Future engine systems may also include both the exhaust gas treatment and fuel processing devices.

Engine developers have successfully utilized engine system models to evaluate the performance of their system. The engine is defined as a collection of interacting elements that functions together to produce desired power out put for a particular purpose. Therefore it is important to realise that the complexity and details of the models to be selected and the basics should be studied by theoretical investigation in complexity and the results of the studies are to be compared with the published results of other researchers.

Thus in the present study an attempt is made to categorise the flow where there will be a possibility for mathematical formulation which can yield solutions to know the characteristics of the fluid flow clear.

Boundary layer behaviour over a moving continuous solid surface is an important type of flow occurring in several engineering processes. For example, materials travelling between a feed roll and a wind-up roll or on conveyor belts, the piston inside the engine cylinder posses the characteristics of a moving continuous surface. Two-dimensional boundary layer flow caused by a linearly stretching sheet in an otherwise quiescent incompressible Newtonian and non-Newtonian fluid has a
very simple closed form exponential solution. Study of laminar boundary layer flow over a stretching sheet has gained considerable relevance in, for example, in fuel industries, in an aerodynamic extrusion of plastic sheets and boundary layer along liquid film in condensation processes. Drag, heat and mass transfer are governed by the structure of the layer. Flow due to a continuously moving surface involve continuous pulling of a sheet through a reaction zone as in metallurgy, in textile and in paper industries, in the manufacture of polymer sheets, sheet glass and crystalline materials.

2.2 VISCOUS FLOWS

In view of these applications, in a series of three articles entitled “Boundary layer behaviour on continuous solid surfaces” Sakiadis [1] initiated the study of boundary layer flow over a continuous solid surface moving with constant speed and also pointed out the differences in boundary conditions between a moving flat plate of finite length and a continuous surface. The governing equations for both two-dimensional and axisymmetric flows were determined.

Erickson et al [2] extended this problem to the case in which the transverse velocity at the moving surface is non-zero, with heat and mass transfer in the boundary layer. These investigations have a definite bearing on the problem of polymer sheet extruded continuously from a die. This work was followed by Crane [3], Gupta and Gupta [4]. Crane [5] investigated the boundary layer flow on an accelerating surface in which the local velocity is proportional to the distance from the slit. This situation is of considerable practical relevance as this type of motion occurs in the drawing of polymer films or fibres.
Denberg and Fansler [6] investigated the non-similar solution for the flow past a stretching wall. Chen and Char [7] investigated the heat transfer characteristics over a continuous stretching surface with variable temperature. As there is an appreciable temperature difference between the surface and the ambient fluid, one needs to consider the temperature dependent heat sources or sinks which may exert strong influence on the heat transfer characteristics.

The problem of laminar flow control (LFC) has become very important in recent years particularly in the field of aeronautical engineering owing to its application to reduce the drag and enhance the vehicle power by a substantial amount. In the case of constant suction velocity. Several methods have been developed for the purpose of artificially controlling the boundary layer. Hence free convection flow past an infinite porous plate was analysed by Messiha [8].

The boundary layer suction is one of the effective methods of reducing the drag co-efficient which entails large energy losses. By this method decelerated fluid particles in the boundary layer are removed through the holes and slits in the wall into the interior of the body and, thus the transition from laminar to turbulent flow may be delayed or prevented which causes an increase of drag co-efficient. In order 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 “cooling of the wall by convection” in controlling laminar flow together with the application of suction has become more useful and has received the attention of many researchers.
A theoretical and experimental treatment for the moving flat plate was made by Tsou, Sparrow and Goldstein [9]. They determined heat transfer rates for certain values of Prandtl numbers.

The transport of heat in porous media is a process that finds application in a broad spectrum of disciplines ranging from chemical engineering to geophysics. Many metallurgical processes involve the cooling of continuous strips by drawing them through a quiescent fluid and that in the process of drawing these strips are some times stretched. The examples are drawing, annealing and tinning of copper wires. In all the above cases the properties of the final product depend to a great extent on the rate of cooling. By drawing such strips in a porous medium, the rate of cooling can be controlled and a final product of desired characteristics can be achieved. In view of these considerations, Vajravelu [10] studied the flow and heat transfer characteristics in a saturated porous medium over a stretching surface considering both PST and PHF cases. Ganapathy [11] have studied the physical phenomena in the context of unsteady boundary layer flow in a porous medium where the fluid is viscous. Analytical solutions for the velocity field in the boundary layer and for the temperature distribution in the stretching sheet have recently been investigated by Dutta and Gupta [12]. Dutta [13] has solved the conjugate heat transfer problem from an accelerating surface in the presence of uniform suction and blowing in a viscous fluid. They observed that the cooling of the sheet increases with stretching speed, Prandtl number and the suction or blowing parameter.

The analysis of the temperature field as modified by the generation or absorption of heat in moving fluids is important in view of several physical problems such as
i) Problems dealing with chemical reactions

ii) Problems concerned with dissociating fluids.

Foraboschi and Federico [14] have assumed that the volumetric rate of heat generation as

\[ Q = \begin{cases} 
Q_0 (T - T_0) & , \quad T \geq 0 \\
0 & , \quad T < 0 
\end{cases} \]

in their study of the steady state temperature profiles for linear parabolic and piston flow in circular tubes. The above reaction as explained by [14] is valid as an approximation of the state of some exothermic process and having \( T_0 \) as the onset temperature. When the inlet temperatures are not less than \( T_0 \), they used \( Q = Q_0 (T-T_0) \) and studied its effects on the heat transfer in laminar flow of non-Newtonian heat generating fluids.

In 1976 Moalem [15] have studied the effect of temperature dependent heat sources \( Q \propto \frac{1}{a + bT} \) occurring in electrical heating on the steady state heat transfer within a porous medium.

Topper [16] have analysed the piston flow in pipes with circular cross-section when the rate of heat generation depends linearly on the local temperature.

Grubka and Bobba [17] have studied about the heat transfer characteristics of a continuous stretching sheet with variable temperature.

Free convective flow past an infinite vertical porous plate was studied by Soundalgekar[18,19] and the MHD case of Ref. [18] was also studied by Soundalgekar [20] in case of an isothermal vertical porous plate. Kays [21] studied
the convective heat and mass transfer past a stretching sheet. Cheng [22] examined free and forced convection flow about an inclined surface in porous media. Thakkar, Soundalgekar and Gupta [23] have analysed about the mixed convection of an incompressible viscous fluid in a porous medium past a hot vertical plate.

The transport of heat, mass and momentum in laminar boundary layers on moving stretching surface has considerable practical relevance in, for example, in electrochemistry [24, 25], polymer processing [26] and in fibre industries etc. Firstly the study of mass transfer carried special importance in energy transfer. The flow in the boundary layer in the presence of heat and mass transfer has been studied by Somers (1956), Wilox (1961) and Gill et al (1965).

Radwan and Elbashbeshy [27] considered the study of a steady two-dimensional laminar flow and mass transfer over a stretching surface with variable concentration in a transverse magnetic field. They observed that the local mass transfer and concentration profiles are very sensitive to the change in the values of the magnetic parameter Mn and the concentration parameter λ. However the hydromagnetic flow and heat transfer problems have much importance industrially i.e., in metallurgical processes. Another interesting application of hydromagnetics to metallurgy lies in the purification of molten metals from non-metallic inclusions by the application of magnetic field. Thus Chakraborti and Gupta [28] studied the hydromagnetic flow and heat transfer in a viscous fluid initially at rest and at a uniform temperature over a stretching sheet.

Pavlov [29] studied the MHD boundary layer flow of an electrically conducting fluid due to the stretching of an elastic plane surface in the presence of
uniform magnetic field and obtained an exact solution of the problem. Lighthill [30] had initiated the important class of time dependent viscous flow problems which deal with the effects of unsteady fluctuations of the main stream velocity on the flow of an incompressible fluid past two-dimensional bodies. Staut [31] studied about the oscillatory flow over an infinite flat porous plate with constant suction and obtained interesting results. Messiba [32] obtained the effect of varying part of suction velocity on skin friction co-efficient at the plate. He also studied the velocity and temperature distributions past an infinite flat porous plate when the suction and free stream velocities vary periodically with time.

Nickerson [33] also obtained the useful results while studying the effect of free stream oscillations on the laminar boundary layers past a flat plate. Recently Abdelhafez [34] have made a very interesting analysis by including the effects of an accompanying parallel free stream. Another physical phenomenon occurs when the free stream oscillates in time about a constant mean. This type of physical phenomena will have definite bearing to the fibric, aeronautic, plastic and polymer industries.

Non-linear streaming due to the oscillatory stretching of a sheet was discussed by Wang [35]. The similarity solutions for the unsteady boundary layer equations for the case of a moving surface was studied by Surmadevi and Nath [36]. The heat transfer problem associated with the Newtonian boundary layer flow past a stretching sheet has been studied by several authors [37, 38, 39]. By taking the advantage of the mathematical equivalence of the thermal boundary layer problem with the concentration analogue, results obtained for heat transfer characteristics can be carried
directly over to the case of mass transfer by replacing the Prandtl number by Schmidt number. However the presence of a chemical reaction term in the mass diffusion equation generally destroys the formal equivalence with the thermal energy problem and moreover, generally prohibits the construction of an otherwise attractive similarity solutions. Thus Chambre and Young [41] considered the diffusion of a reactive species into the fluid flow past a wedge shaped body and concluded that a similarity solution exists only in the case of stagnation point flow treated earlier by Chambre [40]. It may be remarked that the natural convection flows over inclined plates, in the absence of mass diffusion, have been studied by several investigators [42, 43,44]. The literature seems to fail to reveal any analytical or experimental study on combined diffusion of heat and chemical species over an inclined plate with variable surface temperature. There is an important class of flows in which the driving force for the flow is provided by a combination of thermal and chemical species diffusion effects. Such circumstances arise, for example, during cleaning operations, as the residual fluid diffuses into the surrounding fluid at a different temperature, in the curing of plastics and in the manufacture of pulp-insulated cables.

All the above studies are restricted to two-dimensional, viscous flows with or without heat and mass transfer, and with or without magnetic field and porous media with steady or unsteady behaviours.

None of the above researchers have studied about the variable heat transfer or variable mass transfer. Hence in view of this, Arunachalam and Rajappa [45] have studied the thermal boundary layer in liquid metals with variable thermal conductivity for a class of flows where the potential velocity is a power of the distance along a
stationary wall. They have approximated the velocity components in the energy equation by those of the inviscid outer flow. In order to simplify the equation, they derived further a non-linear differential equation and then employed regular perturbation technique and obtained closed form analytical solution.

Vajravelu and Hadjinicolau [46] studied about the heat transfer characteristics in a viscous fluid over a stretching sheet with viscous dissipation and internal heat generation. The linearly stretching sheet was generalised to one that stretches with a power law velocity by Afzal and Varshney [47], Kuiken [48] and Banks [49]. This has been further extended by Chaim [50] to that of a sheet stretching with a power law velocity and having a variable magnetic field of the special form.

Vajravelu and Nayefh [51] analysed the flow and heat transfer by introducing the temperature dependent heat source or sink. The similar problems were carried out by Heruska, Watson and Sankara [52]. On the other hand the thermal aspects of the problem have also been extended in various ways. Afzal [53] presented the solution for the heat transfer from a stretching sheet with a power law velocity. Heat transfer analysis in stagnation point fluid flow over a flat sheet stretched with linear velocity is carried out by Chaim [54]. In his study the thermal conductivity is assumed to vary with temperature. The work of Arunachalam et al [45] was further extended by Govindarajulu and Thangraj [55] who showed that similarity solutions exist for arbitrary outer flow and non-isothermal walls. A similar problem for a flow impinging normally on a stretching sheet was further studied by Chaim [56]. The flow which he has considered was a combination of two well known exact solutions of the Navier Stoke's equations. Chaim [57] have further studied the similarity
solutions for a micropolar fluid. Motivated by these above analyses and in contrast with the work of Chaim [58], the present work consists of the heat and mass transfer flow in a viscous fluid with variable thermal conductivity and variable mass diffusivity in one of the chapters, as these properties and results are true in polymer solutions.

In this regard here it is considered two more general cases of boundary conditions namely;

i) Surface with prescribed power law temperature and power law mass concentration (PST).

ii) Surface with prescribed power law heat flux and power law mass flux, (PILF) varying quadratically with the distance.

In addition to this it is contemplate to study the problem having linearly stretched continuous sheet with suction or blowing and the stretching sheet where the transverse velocity is zero at the surface. Later Wang [59] considered the three-dimensional flow caused by a stretching flat surface in two lateral directions in an otherwise ambient fluid. Thakkar [60] have studied the unsteady three dimensional MHD flow due to the impulsive motion of a stretching surface. The author [60] has not considered the mass transfer flow in his study, hence in one of the present chapters this problem has been extended in order to study the unsteady laminar boundary layer flow of an electrically conducting viscous fluid induced by the impulsive stretching of the flat surface in two lateral directions in an otherwise quiescent fluid embedded in a porous medium with both heat and mass transfer.
2.3 VISCO-ELASTIC FLOWS

All the above studies are restricted to Newtonian and viscous flows. It is well known that a number of industrial fluids such as molten plastics, polymers etc., exhibit non-Newtonian behaviour. Therefore, heat and mass transfer in non-Newtonian fluids is also of practical importance. Hence Kim et al [61] developed universal functions independent of the geometry of two-dimensional or axisymmetric bodies to calculate the heat transfer characteristic parameters for non-Newtonian fluids. Boundary layer flow on continuous solid surfaces is an important type of flow occurring in a number of technical processes. Drag, heat and mass transfer are governed by the structure of the layer. A detailed knowledge of this structure is of utmost importance for understanding the phenomena associated with this type of flow.

In the spinning of filaments without blowing, laminar boundary layer flow occurs over a relatively small length of the spinning zone 0.0 - 0.5m from a dye. In the spinning process, the initial velocity is low 0.3m/s. Boundary layer flow with imposed time scales is not uncommon in nature, the boundary layer in the atmosphere is exposed to the rotation of the earth. In a rotating frame of reference, flows are accelerated by the Corolis force. If the angular velocity is $\omega/z$, it can be shown that atmospheric flows have an imposed time scale of $\omega^1$. In this respect, Crane [62] investigated about the motion of stellar atmospheres set up which is controlled by the interaction of temperature and magnetic fields.

According to Wang [63] who did investigation on an elastic sheet stretched with back and forth in a fluid. His problem was governed by a non-dimensional parameter S which represents the relative magnitude of frequency to stretching rate.
water and 5.4% polyisobutylene in cetane which have an approximate value of Prandtl number of 440 and 3 respectively so the asymptotic cases of large and small Prandtl numbers.

Sam Lawrence and Nageshwar Rao [67] have studied about the flow and heat transfer on a moving solid boundary (viz., a polymer sheet or filament extruded continuously from a dye) in a fluid which has many industrial applications. The heat transfer for the visco–elastic fluid is found to be less as compared to that for the viscous fluid. The power required in stretching the sheet in a visco–elastic (non–Newtonian) fluid is less than when it is placed in a viscous (Newtonian) fluid. Therefore in the present years non–Newtonian fluids have gained considerable importance due to their extensive use in the industry.

In the boundary layer theory, similarity solutions are found to be very useful in the interpretation of certain fluid motions at large Reynold’s numbers and thus was analysed by Surmadevi and Nath [68]. Besides the problems of heat and mass transfer in the boundary layers on continuous stretching surfaces with a given temperature and mass concentration distribution or heat flux and mass flux distribution moving in an otherwise quiescent fluid medium has attracted many researchers during the last few decades. Examples of such technological processes are hot rolling, wire drawing, glass fibre and paper production, drawing of plastic films, metal and polymer extrusion and metal spinning. Both kinematics of stretching and the simultaneous heating or cooling during such processes have descisive influence on the quality of the final products and was studied by Magyari and Keller [69]. According to Hausler [70] who constituted the constitutive equation to describe
the mechanical properties of rubber elements, which has (visco-elastic property) and used in certain technical applications like shock and vibration isolation in mechanical and civil engineering. A unidirectional fibre reinforced composite essentially consists of an elastic matrix which is reinforced by a random or regular network of closely spaced aligned fibres. The elastic stress analysis of such composites can be performed by idealising the material as a transversely isotropic elastic medium. The overall elasticity parameters associated with the transversely isotropic elastic idealisation can be estimated by recourse to a theory of composite materials applicable to fibre strengthened solids.

According to Carvalho and Souza Mendes [71], the flow pattern at low Reynolds's number in the neighbourhood of the contraction is very sensitive to the mechanical behaviour of the flowing fluid of an extensional viscosity leads to vertex enhancement in the corner region of a non-Newtonian fluid in such geometry. On the corresponding flow of a non-Newtonian fluid these vertices are much weaker and smaller. Moreover the thickening behaviour of most of the polymeric liquids leads to higher viscous effects in the predominantly extensional flow.

The main reason for the dearth of heat transfer studies on the flow resides the fact that velocity field is greatly affected by the non-Newtonian behaviour of the polymeric liquid. For more general three-dimensional representation, the method of continuum mechanics is needed. One of the most popular models for non-Newtonian fluids is the model that is called the second order fluid or fluid of second grade. It is reasonable to use the second order fluid model to do numerical calculations.
The problem of laminar flow control (LFC) is gaining considerable importance in recent years particularly in the field of aeronautics engineering in view of its applications to reduce the drag and enhance the vehicle power requirement by the application of visco-elastic fluids.

With the above views, a critical review on the situation of the no slip boundary condition, the existance and uniqueness of the solution has been given by Rajagopal [72]. In order to clarify these results, Rajagopal and Gupta [73] have considered the study of the flow of a second order fluid past an infinite porous plate with velocity component along the x-axis tending to U as y→∞. In 1990, Rollin's and Vajravelu [74] analysed the characteristics of a second order fluid over a continuous stretching surface with internal heat generation or (absorption) in both the PST and PHF cases.

Chang et al [75] have worked on the concept of explicit solutions for the similarity solutions of the flow of a non–Newtonian fluid over a stretching sheet. Sankara [76] analysed the micro–polar fluid (visco–elastic) flow past a stretching sheet. Troy et al [77] showed that for a certain stage of values of the parameters, the equations governing the flow of a second grade fluid past a stretching sheet could be shown to have an exact solution. Weng–Dong Chang [78] derived another closed form solution of the non–Newtonian flow problem of Rajagopal et al [79]. Bhatnagar et al [80] obtained the solutions for Walters’ liquid ‘B’ fluid over a stretching sheet in the presence of constant free–stream velocity. This study was further channelised to investigate the flow of short memory fluids of the type Walters’ liquid B’ by several researchers Sam Lawrence [81], Siddappa and Abel [82], Fosdick et al [83], Erdogan et al [84] and Erdogan et al [85].
In 1993 Maneschy and Massoudi et al [86] have studied about the heat transfer analysis of a non-Newtonian fluid past a porous plate not considering MHD flow.

Hence MHD flow of non-Newtonian fluids was probably first studied by Sarpakaya [87]. He predicted in his work that the study of non-Newtonian fluids in the presence of a magnetic field has applications in many areas. A few examples are the flow of nuclear fuel slurries, flow of fluid metals and alloys. He studied the non-Newtonian fluids, Bingham plastic and Ostwald fluids and concluded his results with the remark that, as the intensity of the magnetic field increases, the distribution of velocity is increasingly more uniform.

Since MHD flow of visco-elastic fluids also have applications in the field of electromagnetic propulsion and some fluids with thixotropic behaviour will help in the flow of blood, coating of paper, plastic extension and lubrication with heavy oils and greases.

In view of all these applications, Anderson et al [88] studied the MHD flow of a non-Newtonian Power law fluid over a stretching sheet in an ambient fluid. Surmadevi and Nath [89] have also studied the MHD boundary layer flow of a non-Newtonian fluid over a continuously moving surface with a parallel free stream.

Abel and Veena [90] have studied about the Visco-elastic fluid flow and heat transfer characteristics in a saturated porous medium over an impermeable stretching surface with frictional heating and internal heat generation or absorption with PST and PHF cases.
Prasad et al [91] investigated the momentum and heat transfer in a visco-elastic fluid flow in a saturated porous medium over a non-isothermal stretching sheet. Their important finding is that, the effect of visco-elasticity and porosity is to increase the wall temperature in case of blowing and to decrease in both the cases of suction and when the stretching sheet is impermeable.

The magnetohydrodynamic flow of non-Newtonian fluids through porous media have applications in many fields and this type of studies are of great interest in the interaction of the geometric field and fluids in the geothermal region. An analysis has been carried out by Gupta and Sridhar [92] for visco-elastic effects in non-Newtonian flow through porous medium. It has been shown that under certain circumstances the fluid undergoing an external deformation may not exhibit any shear thickening.

Recently, flow of non-Newtonian polymer solutions was investigated by Savvas et al [93] and it is shown that computer simulation is a powerful and accurate technique to predict flow behaviour of such solutions.

In 2001, an analysis was carried out by Abel and Joshi [94] to study the effect of heat transfer in MHD visco-elastic fluid over a non-isothermal stretching sheet with internal heat generation.

In 2001, Sonth et al [95] have analysed the heat and mass transfer in a visco-elastic fluid flow over an accelerating surface with heat source/sink and viscous dissipation considering both PST and PHF cases.
Firstly, unsteady flows of a second order fluid in a bounded region have been studied by Ting [96]. Some unsteady unidirectional flows of second order fluids have been considered by Rajagopal [97]. These works showed the no-slip condition at the boundary for this type of flow suffices. A recent work of Rajagopal [98] showed that the solutions for unsteady flows of a second order fluid occupying the space above the plate are bounded if the co-efficient of higher derivative is positive. However, this is not necessary for steady flows of a second order fluid.

Erdogan [99] have studied about the unsteady motions of a second order fluid over a plane wall and has shown that a Newtonian fluid induced by a flat plate that applies a constant stress to the fluid flows faster than a second order fluid. Besides, these excellent reviews of the literature dealing with non-steady flows are presented and consequently the behaviour of visco-elastic fluids in laminar flow through porous media has been the subject of numerous investigators, including Pilitsis and Beirs [100], Pascal and Pascal [101], Jones and Walters’ [102], Rudraiah and Kaloni [103]. Tcipel [104] and Sounalgekar [105].

Veena et al [106] investigated about the oscillatory motion of a visco-elastic fluid past a stretching sheet and found that the effects of unsteadiness and skin friction on the wall velocity are appreciable.

Hence motivated by all the above researchers and because of the utmost importance of Newtonian and non-Newtonian fluids in industry, engineering, in the investigation on in-cylinder flows, and in chemical engineering, the present thesis has been extended some of the above research problems in different aspects.
The present study considers the constitutive equation for motion as suggested by Crane [2] for viscous fluid and the constitutive equation as suggested by Walters' [112, 113] for visco-elastic fluid.

The review of the literature is the presentation of the past many and present investigations analysed and studied by several researchers in sequel. The literature presents the studies about the viscous flows, steady and unsteady flows and visco-elastic flows.

Since boundary layer behaviour over a moving continuous solid surface is an important type of flow occurring in several engineering processes. Study of laminar boundary layer flow over a stretching sheet in viscous fluid has gained considerable relevance in, for example in fuel industries, in an aerodynamic extrusion of plastic sheets etc. Drag, heat and mass transfer are governed by the structure of the layer. In view of all these applications, the first researcher to study about boundary layer behaviour on continuous solid surfaces was Sakiadis [1]. He initiated the study of boundary layer flow over a continuous solid surface moving with constant speed and also pointed out the differences in boundary conditions between a moving flat plate of finite length and a continuous surface. Then several investigators viz., Erickson et al [2], Crane [3], Gupta and Gupta [4], Denberg and Fansler [6] have extended the initial problems of Sakiadis [1] and Crane [3] to the different physical situations.

It is well known that a number of industrial fluids such as molten plastics, polymers etc., exhibit non-Newtonian behaviour. Heat and mass transfer in non-Newtonian fluids is also of practical importance. Thus many researchers diverted their study towards the visco-elastic (non-Newtonian) fluids which have elastic
property in addition to viscosity. Besides magnetohydrodynamic flow of visco-elastic fluids have applications in the field of electromagnetic propulsion and some fluids with thixotropic behaviour will help in the flow of blood, coating of paper and lubrication with heavy oils and greases.

Hence in view of these applications of non-Newtonian magnetohydrodynamic (MHD) fluid flows, the study of MHD non-Newtonian fluids was probably first studied by Sarpakaya [87]. He studied about the Bingham plastics and Ostwald fluids which are visco-elastic in nature and concluded his results by the remark that as the intensity of the magnetic field increases, the distribution of velocity is increasingly more uniform. In this regard further many scientists viz., Anderson et al [88], Surmadedi and Nath [89], Abel and Veena [90], Prasad et al [91] and still many researchers have investigated about the above studies considering with different physical aspects.

Some unsteady unidirectional flows of second order fluids (non-Newtonian) was studied by Ting [96] for the first time. Like wise afterwards Rajagopal [97], Erdogan [99], Pilitisis and Beirs [100], Pascal and Pascal [101], Rudraiah and Kaloni [103] have done the excellent reviews of the literature dealing with unsteady flows.

Besides the above a brief introduction about the next chapters of the thesis is also given in the review of literature.

The scope of the present work is to study the heat transfer characteristics in a viscous fluid caused by a porous and linearly stretching the sheet with internal heat generation with suction or blowing. The thermal conductivity is assumed to vary
linearly with temperature. The study considers two more general type of boundary conditions namely PST – prescribed surface temperature and PHF – prescribed wall heat flux. Several closed form analytical solutions for non–dimensional temperature, heat flux are obtained in the form of confluent hypergeometric [Kummer’s] functions. The effect of various physical parameters like suction and blowing parameter, heat source or sink parameter, Prandtl number on temperature profiles are discussed. The effect of all these parameters on the temperature gradient is also being analysed and are demonstrated through graphs.

Further, it is studied about the heat and mass transfer flow in a two–dimensional Newtonian fluid with variable thermal conductivity and variable mass diffusivity over a stretching sheet with internal heat generation. Temperature and concentration variables are assumed to vary linearly as this type of flow behaviour is found in liquid metals. Several analytical closed form solutions for non–dimensional temperature, concentration, heat flux and mass flux profiles are obtained and the results are justified by drawing the graphs. It is also considered the PST and PHF type of boundary conditions for both heat and mass transfer flow.

The study is further consisting of the analytic analysis of non–Newtonian magnetohydrodynamic flow over a stretching surface with heat and mass transfer. In heat transfer analysis, PST and PHF cases are considered. The solutions of equations of momentum, mass and heat transfer are obtained analytically. Emphasis has been laid to study the effects of various parameters like magnetic parameter Mn, visco–elastic parameter k1, Schimdt number Sc, and Prandtl number Pr on the flow, heat and mass transfer characteristics.
Inspite of the above analyses, the present study considers about the heat transfer characteristics in a visco–elastic Walters’ liquid B’ fluid past a stretching sheet with viscous dissipation and internal heat generation. An analysis has been carried out for two different cases of heating processes namely PST and PHF to get the effect of visco–elastic parameter \( k_1 \) for various situations. The solutions for the temperature and dimensionless temperature gradient are obtained in terms of Kummer’s functions.

Further an investigation on the non–similar solutions for heat and mass transfer flow in an electrically conducting visco–elastic fluid over a stretching sheet saturated in a porous medium with suction/blowing is considered. Many graphs are presented to demonstrate the physical situations of wall temperature, wall concentration, temperature gradient and concentration gradient with the impact of various physical parameters like \( k_1 \)-visco–elastic parameter, \( \text{Ec} \)-Eckert number, \( \text{Pr} \)-Prandtl number, \( \text{Sc} \)-Schmidt number and suction/blowing parameter \( \nu_w \).

Next investigation is on the presentation of the study of diffusion of chemically reactive species of an electrically conducting visco–elastic fluid (Walters liquid B’ model) immersed in a porous medium over a stretching sheet with prescribed surface concentration (PST) and prescribed wall mass flux (PHF). The influence of reaction rate parameter on the transfer of chemically reactive species is also considered. Here the flow is caused solely by the linearly stretching sheet and the reactive species is emitted from this sheet and undergoes an isothermal and homogeneous one stage reaction as it diffuses into the surrounding fluid. Several non–dimensional similarity transformations are to be used to reduce the non-linear
concentration conservation equation to an ordinary differential equation in both the cases of PST and PHF. An exact analytical solution due to Siddappa and Abel [ZAMP 36, 1985] is adopted for velocity, where as the concentration equation is solved analytically for zeroth and first order reactions in both the PST and PHF cases. The computational results presented through graphs showed that the effect of destructive chemical reaction is to reduce the thickness of the concentration boundary layer and to increase the mass transfer rate from the sheet to the surrounding fluid in the presence of transverse magnetic field.

Further, an analysis about an oscillatory motion of an electrically conducting visco-elastic fluid over a stretching sheet in a saturated porous medium with suction/blowing is investigated. The physical aspect of this problem is that the surface absorbs the fluid in a porous medium in the presence of magnetic field and the velocity oscillates depending on the stretching rate (b). Analytical expressions for the velocity and the co-efficient of skin friction have been studied, first by the perturbation technique and then by power series method. It is noted that the effect of unsteadiness in the wall velocity and skin friction are found to be appreciable in the presence of suction or blowing parameter.

Further it is being studied on the development of velocity, temperature and concentration fields of an incompressible electrically conducting viscous fluid caused by the impulsive stretching of the surface in two lateral directions and by suddenly increasing the surface temperature from that of the surrounding fluid in a saturated porous medium. The differential equations governing the unsteady three-dimensional laminar boundary layer flow are solved analytically and asymptotically. The
important finding of the present work is that the surface shear stress in x and y
directions, the surface heat transfer and the surface mass transfer increase with the
magnetic parameter Mn and with permeability parameter k₂, the stretching ratio, and
there is a smooth transition from the short-time solution to the long-time solution.

Finally the thesis presents the important conclusions and findings of the
present study.