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Modelling of heat and mass transfer during fluid flow

Dr. Prerana Pathak

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Dr. Prerana Pathak
Assistant Professor, Department of Mathematics, Dr. Bhim Rao Ambedkar Government Degree College Maharajganj, Uttar Pradesh, India

Abstract

Mathematical modelling is an artistic endeavour in certain ways. A review of the state of the art in the mathematical modelling of the entire spectrum of anatomical, physiological, biophysical, and biomechanical characteristics is valuable for research on many facets of physiological systems. A mathematical model of a system is a collection of mathematical relationships between various component properties and quantitative measures of the behaviour of the system. For the purposes of developing the model, the relationships between the quantities in the model adequately reflect the behaviour of the real system. Models are created using what is known about the system. Theoretical models are constructed using verified prior knowledge about the system, including its composition and operations, the fundamental chemical and physical principles that apply, and quantitative information about its dimensions, composition, rates of processing, and other characteristics. They can be used to forecast the behaviour of the system under situations that haven't been directly tested or cannot be tested, in addition to giving a description. They use rules developed for a broad range of phenomena and systems to describe the relationships between the numerous components of a system, its structure, and its behaviour.

The application of fluid dynamics principles to physiological fluids is commonly recognised as the field of study known as physiological fluid dynamics. Research in this field requires a solid grasp of the mechanical relationships between the structure, function, and properties of tissues as well as theoretical knowledge of the anatomy and physiology of the system under study. The main objective of the subject is to gain improved understanding of the mechanics of living systems, including tissues, organs, and fluxes. The ultimate goal is to restore these systems' function, which may be impacted by mechanical forces caused by diseases.

Keywords: Fluid dynamics, biomechanical aspects, physiological fluids, tissues, organs

Introduction

A special kind of fluid movement known as peristaltic transport uses progressive waves to expand and shrink an area. The mechanism of peristalsis aids in the performance of many physiological processes, including blood flow in small vessels of the human circulatory system, transport of ovum and cilia, movement of spermatozoa in the ductus differences of the male reproductive organ, semen transport in the vas deferens, bile transport from the gall bladder to the duodenum, urine transport from the kidney to the bladder through ureters, and food transport in the digestive tract. The flow of lymphatic fluids within lymphatic vessels is also made possible by this technique. Research findings on peristaltic flows have found extensive applications in several industries due to their numerous advantages. They are employed in the transportation of corrosive and hygienic fluids when it is preferable to prevent the fluid from coming into touch with various machine components. Additionally, they play a significant role in numerous biomedical engineering devices, such as heart-lung machines and blood pumps.

Heat and mass transfer in asymmetric channels

It should be emphasised that the related issues of heat and mass transfer that arise during peristaltic transport were not given enough attention in the aforementioned investigations of peristaltic flow of various types of fluids under varied conditions. Furthermore, no prior research has taken into account the temperature dependency of the fluid characteristics in such circumstances. It should be noted that the exchange of thermal energy between the various parts of a physical system is the basic definition of heat transfer. The temperature of the various parts or components as well as the physical characteristics of the medium through which heat transfer occurs determine how quickly heat is transferred. Furthermore, any external agency or buoyant forces are likely to have an impact on a fluid's flow when it passes through a medium.

Corresponding Author:
Dr. Prerana Pathak
Assistant Professor, Department of Mathematics, Dr. Bhim Rao Ambedkar Government Degree College Maharajganj, Uttar Pradesh, India

Convective heat transfer is the movement of fluids that transfers heat from one particle to another and from one area to another. Mass transfer is a necessary part of this process. Convection is the mechanism via which heat transmission occurs in the case of fluids (Including liquids and gases). A partial differential equation is the heat equation that controls the temperature change and thermal distribution in a particular system. Even though the equation's closed form solution can be obtained in some circumstances, numerical techniques are frequently required in order to solve the problem.

The movement or transfer of mass from one place or component to another is referred to as mass transfer. Mass transfer occurs frequently in many different engineering processes. The study of mass transfer is especially important in the field of chemical engineering, particularly in relation to various heat transfer, separation process, and reaction engineering issues. The flow pattern and diffusivity have an impact on the mass transfer rate.

Eyring-Powell nanofluid model

The coordinate system of a typical particle of the fluid mass is represented by (x 0, y0), where O is the origin, the x 0 -axis being along the centre line, and the y 0 -axis being along the transverse direction. The peristaltic flow of a viscous, electrically conducting Eyring-Powell nanofluid in a non-uniform channel of height d1+d2 is examined here, taking into account a long wavelength approximation and low Reynolds number. The geometry of the flow is illustrated. It is anticipated that the sinusoidal waves will spread out along the channel walls as wave trains that move at a constant speed of c, or y 0 = h 0 1 and y 0 = h 0 2.

While it is anticipated that two-phase nanofluid models will produce more accurate findings, found that, in terms of the hydrodynamical fields, two-phase and single-phase models are nearly comparable. Furthermore, the single-phase model-based governing equations for the study of nanofluid flows are simple to comprehend, and the analysis is less complex. In their study of the state-of-the-art in heat transfer and single-phase and two-phase nanofluid flows, proposed that certain terms in the single-phase governing equations might be appropriately changed to increase the accuracy of the results. In light of these observations, the current formulation, which is based on the consideration of a single-phase model, is given below.

Blood flow in arteries subject to a vibrating environment

Most people think of vibration as a system's oscillating motion. Whole-body vibration can occur as a result of the vibration environments that the human body is exposed to throughout daily activities. An individual's whole body may vibrate, for instance, when operating heavy vibrating machinery or travelling over uneven terrain. Because of the nature of their employment, many professionals—including jackhammer operators, astronauts aboard boosters, and helicopter crews—are forced to work in environments that vibrate. Again, there are situations where localised vibration is exclusively applied to specific bodily areas. When a person operates various vibrating instruments or devices, such as a drilling machine, chain saw, or punch press, only his hand and arm are vibrated, not his entire body. Once more, the only thing vibrating while we stand on a vibrating platform is our feet. On the other hand, the effect steadily diminishes when the vibration waves approach the upper body. Vibration has both positive and negative effects. Clinicians have noticed that the human body vibrates, which restricts blood flow to various organs. It has been established that vibrating settings are the source of numerous health issues. It often has the potential to have detrimental effects on one's health. If vibration exposure is prolonged, the effects of the vibrations become more severe.

Stagnation point flow and heat transfer

A stagnation point is, as far as we are aware, the point in a particular flow field where the local velocity disappears noted that objects in the flow field have extremely visible stagnation sites on their surfaces, where the object is responsible for bringing the fluid velocity down to zero. The fluid's greatest static pressure, or stagnation pressure, is commonly referred to as the stagnation pressure, while the temperature at a stagnation point is known as the stagnation temperature. As the fluid velocity is zero at the stagnation point, it may be further said that all of the kinetic energy is transformed to internal energy at that point. The stagnation temperature is equal to the total temperature at all points along the streamline that lead to the stagnation point, as noted by Van Wylen and Sonntag (1965). Many studies focused on the dynamics of stagnation flow/heat transfer under different conditions because of their significance in engineering, industry, and the study of physiological fluid dynamics.

The current work, which is driven by the aforementioned talks, attempts to investigate certain details about heat transfer and MHD stagnation point flow during blood flow in the microcirculatory system. A computational method that is appropriate for determining the numerical estimates of various physical variables related to the current inquiry has been developed in order to formulate and analyse a theoretical model mathematically. The heat transfer of an electrically conducting fluid over a sheet in stretching motion and MHD stagnation point flow comprise the physical model. The appropriate consideration has been given to the effects of injection/suction and the induced magnetic field.

Transport of third-order fluids in a magnetic environment

As previously stated, electrokinetic phenomena comprise a group of distinct effects that can be seen in a range of circumstances, such as fluid flowing through porous media, fluid moving through a fluid containing solid or liquid particles, or gaseous bubbles with sizes ranging from micrometres (1×10^{-6} m) to nanometers (1×10^{-9} m). Among the various instances of electrokinetic phenomena are electrophoresis and electroosmosis. As explained in Chapter 3, electroosmosis, also known as electroosmotic flow, is the movement of a liquid in a porous media when an external electric field is acting on it; electrophoresis is the movement of particles when an external electric field is acting on them. The theory behind electroosmotic flow (EOF) states that it is caused by the Coulomb force generated by an electric field in a solution. Along with other electrokinetic phenomena, an electrical double layer (EDL), sometimes known as a double layer (DL), is linked to the electroosmosis phenomenon. The term "electrical double layer" describes the formation of two parallel layers of charge at an object's surface when it emerges from a liquid. In actuality, the electroosmotic movement of liquids is fundamentally influenced by the creation of electrical double layers.

Effects of Hall current and Joule heating

It is evident that the analyses in question have applied Ohm's law without accounting for the influence of Hall current. In the electrically conductive flow area, however, a number of intricate phenomena, including Hall current and Joule heating, take place when the system is exposed to a notably strong magnetic field. The ionised liquid's flow shape is likely to undergo significant alteration as a result of these causes. It should be noted that an additional potential fluctuation between the conductor's opposite sides is a major cause of Hall current. By using electrons to move across the liquid mass, the Hall effect modifies the Lorentz force and the current density.

This study concerns a scenario in which an externally applied magnetic field that is strong enough to operate on electrokinetic forces and an external pressure gradient drives the flow. The modified version of the generalised Ohm's law that accounts for the Hall effect has been taken into consideration in order to include the effect of Hall current in the theoretical analysis.

Temperature distribution and entropy generation during Darcy

Many research study flow and heat transfer in fluid-saturated porous media have employed the Darcy model, which is predicated on the idea that the seepage velocity is proportionate to the pressure gradient. However, keep in mind that the model only works in scenarios in which the fluid moves slowly and the porous medium's permeability is minimal. This crucial finding was reported by Bear (2013), who noted that when the Reynolds number exceeds unity, the flow stops being Darcian. The flow separation that occurs in the porous matrix could be the cause of this. This is explained theoretically by adding a nonlinear element to the equation relating velocity to pressure gradient. When the fluid velocity is high enough, a modification to the momentum equation is required to describe complex flow problems in porous media. As a result, Forchheimer added a quadratic drag factor to the momentum equation for flow through porous medium, changing Darcy's equation.

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