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Chemical reaction in peristaltic motion of MHD couple stress fluid in channel with Soret and Dufour effects

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ABSTRACT

This paper looks at the peristaltic motion of MHD couple stress fluid in an inclined asymmetric channel. Simultaneous effects of heat and mass transfer are considered. Soret and Dufour features lead to the coupled differential systems. Channel walls satisfy the convective conditions of heat and mass transfer. Exact solutions for the stream function and pressure gradient are derived. Temperature and concentration are obtained numerically. Graphical illustrations for axial velocity, temperature, concentration and streamline patterns are developed. Physical interpretation of obtained results has been presented. It can be seen that both Soret and Dufour numbers reduce the concentration field while reverse effect is seen towards temperature for both numbers. It is also observed that concentration reduces towards destructive chemical reaction and enhances for constructive chemical reaction. The heat transfer Biot number gives rise to fluid temperature. Further more the mass transfer Biot number decreases the concentration.

Introduction

Mechanism of peristalsis is a series of wave-like muscle contractions and relaxations that moves bio-fluid in different processes. Various phenomenon involving peristalsis include urine movement from kidney to gallbladder, bile transport in duct, chyme transport in small intestine, food processing in digestive tract, flow of blood in small vessels, locomotion of worms and many others. Peristalsis finds its numerous applications in medical and industrial systems which include various devices like rollers, hose and tube pumps, dialysis, open-heart by pass and heart-lung machines etc. There is abundant literature on peristalsis subject to different aspects. It is due to its widespread occurrence in biomechanical engineering and technology. Latham [1] initially observed the peristaltic motion for flow of viscous fluid. Later Shapiro et al. [2] studied the peristaltic activity for flow of viscous fluid in the tube and channel. They employed long wavelength and low Reynolds number approximations. Extensive information now exists for peristalsis. Few investigations [3–11] and several interesting Refs. therein can be consulted for useful research on this topic.

It is also recognized that peristalsis in presence of magnetic field is significant in engineering and medical processes. MHD concept is employed in formation of various medical, engineering and industrial devices. Few of these include heat exchangers, pump meters, radar systems, magnetic devices for cell separation, magnetic drug targeting and magnetic tracers. Thus impact of inclined MHD on peristalsis of Williamson fluid in channel with convective conditions has been considered by Hayat et al. [12]. Muhammad et al. [13] explained the effects of viscous dissipation and Joule heating in MHD 3D flow with heat and mass fluxes. Some more work related to MHD peristaltic transport can be seen in the Refs. [14–17].

Stokes [18] developed the couple stress fluid model. When additives are mixed in the fluid then cohesive forces of fluid resists additive factors. This resistance creates a combined force and then a couple stress is generated in the fluid. Such fluid is known as couple stress fluid. This model is regarded as generalization of Newtonian fluid model dealing with body couples and couple stresses in fluid medium. Note that couple stress fluid has an asymmetric stress tensor. Devakar and Iyengar [19] examined the Stoke's problem for couple stress fluid with isothermal conditions. Also Stokes second problem of viscoelastic fluids with constitutive equation has been discussed by Duan and Qiu [20]. Ramesh [21] analyzed the heat and mass transfer in peristalsis of couple stress fluid. He discussed the influence of inclined magnetic field. Relevant studies in this direction are given in the investigations [22–24].

In many studies the influences of diffusion-thermo (Dufour) and thermal-diffusion (Soret) are neglected. Now it is known that Soret and

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Nomenclature

Parameters with units

u, v	velocity components (m/s)
t	time (s)
x, y	coordinates (m)
p	pressure (kg/ms^2)
$d_1 + d_2$	channel width (m)
c	speed of wave (m/s)
λ	wavelength (m)
$\mathbf{B}$	magnetic field
$\mathbf{J}$	current density
μ	dynamic viscosity (kg/ms)
η	couple stress viscosity (kg/ms)
ρ	fluid density (kg m^{-3})
c_p	specific heat (m^2 s^{-2})
k^*	thermal conductivity (WK^{-1} m^{-1})
Q_0	heat source/sink parameter (Wm^{-3})
D	mass diffusivity coefficient (m^2/s)
K_T	thermal diffusion ratio
c_s	concentration susceptibility
g	gravitational acceleration (ms^{-2})
h_1,h_2	position of walls in wave frame (m)
α	angle of inclination (∘)
a_1,a_2	amplitudes of waves (m)
T,C	temperature (K) & concentration
σ^*	electrical conductivity (S/m) or $(\Omega m)^{-1}$
T_0, T_1	temperatures at the walls
C_0, C_1	concentrations at the walls
T_m	mean fluid temperature (K)
k_1	chemical reaction rate (s^{-1})
ϕ	phase difference

Dimensionless parameters

β	heat generation parameter
Sr	Soret number
Du	Dufour number
θ, σ	dimensionless temperature & concentration
γ_1	couple stress fluid parameter
δ	wave number
M	Hartman number
Re	Reynold number
Br	Brinkman number
Ec	Eckert number
γ	chemical reaction parameter
Sc	Schmidt number
Fr	Froude number
Pr	Prandtl number
B_h, B_m	heat and mass transfer Biot numbers

Dufour impacts appreciably influence the fluid motion. Heat and mass transfer phenomenon in a slip flow of a viscoelasticity-based micropolar fluid has been examined by Sui et al. [25]. Hayat et al. [26–28] analyzed the impacts of heat and mass transfer in peristalsis with convective conditions at the channel boundaries. Here the authors considered the Soret and Dufour effects, thermal radiation and curved channel. Further the analysis of heat and mass transfer in presence of chemical reaction has vast practical significance in diverse fields of science and industry. Thus Muthuraj et al. [29] explored the chemical reaction effect on MHD peristaltic flow of Dusty fluid in channel with heat and mass transfer. Hayat et al. [30–32] analyzed the effects of peristalsis with chemical reaction. It is also found that geometrical configurations are of inclined characteristics in the physiological and engineering processes. Thus the above mentioned aspects have vast applications in various fields of life. Now-a-days thermophoresis (Soret effect) is applied in industry for separation of large and small molecules from their solvent in thermal field flow fractioning (TFFF). This is beneficial in case of biological samples (cells, proteins and DNA) where large variations in temperature can disintegrate the samples. Furthermore various industrial processes included Haber process (chemically binding of nitrogen from air to make ammonia), disinfection (chemical treatment to kill bacteria and viruses) and pyroprocessing (chemically

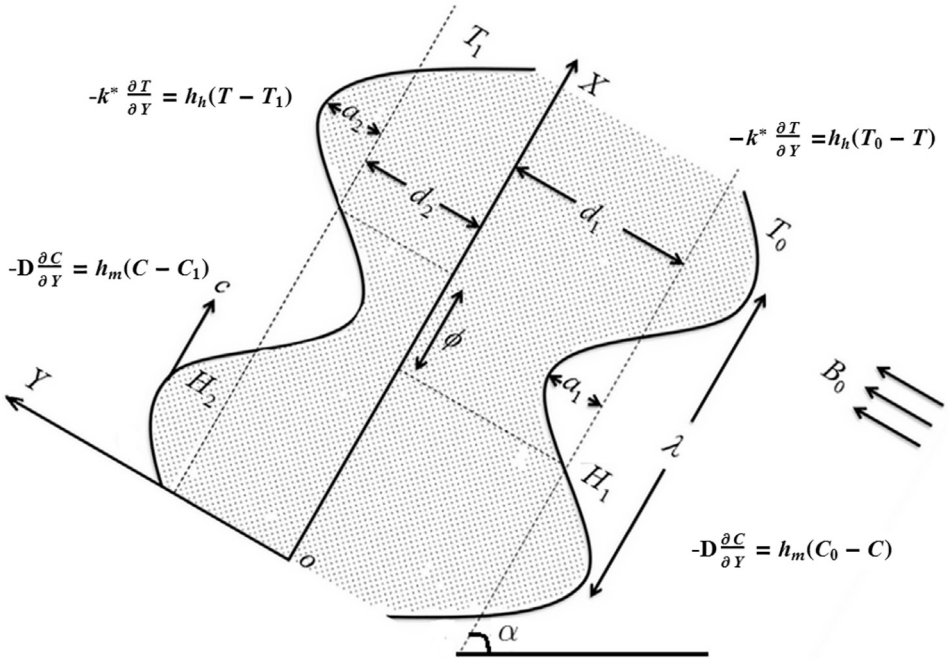

Fig. 1. Geomerty of problem.