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Heat and mass transfer in a vertical double passage channel filled with electrically conducting fluid

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HIGHLIGHTS

- MHD heat transfer in a double passage channel with first order chemical reaction is analyzed.
- Equations are solved by regular perturbation technique and differential transform method.
- Grashof, Brinkman and Hartmann numbers essentially affect heat transfer.
- Rise of Grashof and Brinkman numbers enhances the fluid flow at different baffle positions.

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ABSTRACT

This paper investigates the influence of first order chemical reaction in a vertical double passage channel in the presence of applied electric field. The wall and ambient medium are maintained at constant but different temperatures and concentrations and the heat and mass transfer occur from the wall to the medium. The channel is divided into two passages by means of a thin perfectly conducting baffle. The coupled non-linear ordinary differential equations are solved analytically by using regular perturbation method (PM) valid for small values of Brinkman number. To understand the flow structure for large values of Brinkman number the governing equations are also solved by differential transform method (DTM) which is a semi-analytical method. The effects of thermal Grashof number ($Gr_T = 1, 5, 10, 15$), mass Grashof number ($Gr_C = 1, 5, 10, 15$), Brinkman number ($Br = 0, 0.1, 0.5, 1$), first order chemical reaction parameter ($\alpha = 0.1, 0.5, 1, 1.5$), Hartmann number ($M = 4, 6, 8, 10$) and electrical field load parameter ($E = -2, -1, 0, 1, 2$) on the velocity, temperature and concentration profiles, volumetric flow rate, total heat rate, skin friction and Nusselt number are analyzed. It was found that the thermal Grashof number, mass Grashof number and Brinkman number enhances the flow whereas the Hartmann number and chemical reaction parameter suppresses the flow field. Also the obtained results have revealed that the heat transfer enhancement depends on the baffle position.

1. Introduction

Free convection flow in a vertical channel has been the subject of many previous investigations due to its possible applications in many industrial and engineering processes such as cooling of electronic equipment, heat exchangers, chemical

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Nomenclature

B_0	Uniform magnetic field
Br	Brinkman number
C_p	Specific heat at constant pressure
$C_1,\ C_2$	Concentrations in stream-I and stream-II
$C_{01},\ C_{02}$	Reference concentrations
c_s	Dimensionless total species rate
D	Diffusion coefficient
E	Electrical field load parameter
E_0	Uniform electric field
$\tilde{E}$	Dimensionless total heat transfer rate
Gc	Mass Grashof number
Gr	Thermal Grashof number
Gr_C	Modified mass Grashof number
Gr_T	Modified thermal Grashof number
g	Acceleration due to gravity
k	Thermal conductivity of the fluid
M	Hartmann number
$n_1,\ n_2$	Wall concentration ratios
$Nu_1,\ Nu_2$	Nusselt numbers
P	Pressure
p	Dimensionless pressure gradient
Q_v	Dimensionless total volume flow rate
Re	Reynolds number
T_0	Reference temperature
$T_1,\ T_2$	Temperatures in stream-I and stream-II
$T_{w_1},\ T_{w_2}$	Wall temperatures
$U_1,\ U_2$	Velocities in stream-I and stream-II
$u_1,\ u_2$	Dimensionless velocities in stream-I and stream-II
$\bar{U}_1$	Reference velocity
X, Y	Dimensional coordinate axis
y	Dimensionless coordinate axis

Greek letters

α	First order chemical reaction parameter
β_T	Coefficient of thermal expansion
β_C	Concentration expansion coefficient
$\triangle C$	Concentration difference
$\triangle T$	Temperature difference
θ	Dimensionless temperature
μ	Dynamic viscosity
ν	Kinematic viscosity
ρ	Density of the fluid
ρ_0	Static density
σ_ε	Electrical conductivity of the fluid
τ_1, τ_2	Skin friction
ϕ	Rescaled species concentration

processing equipments, gas-cooled nuclear reactors and others. Tao [1] analyzed the laminar fully developed mixed convection flow in a vertical parallel-plate channel with uniform wall temperatures. Aung and Worku [2] discussed the theory of combined free and forced convection in a vertical channel with flow reversal conditions for both developing and fully developed flows. Combined free and forced convection flow of an electrically conducting fluid in a channel in the presence of a transverse magnetic field is of special technical significance because of its frequent occurrence in many industrial applications such as geothermal reservoirs, cooling of nuclear reactor, thermal insulation and petroleum reservoir.

For the first time Hartmann [3] investigated the MHD flow of a viscous, incompressible, electrically conducting fluid between two parallel plates in the presence of a transverse magnetic field. Since then, a number of researchers have investigated the flow of an electrically conducting fluid through channels (ducts) because of its important applications