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Scaling group transformation on fluid flow with variable stream conditions

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ABSTRACT

Thermophoresis particle deposition with chemical reaction on Magnetohydrodynamic flow of an electrically conducting fluid over a porous stretching sheet in the presence of a uniform transverse magnetic field with variable stream conditions is investigated using scaling group transformation. Starting from Navier–Stokes equations and using scaling group transformations, the governing equations are obtained in the form of differential equations. The fluid viscosity is assumed to vary as a linear function of temperature. It is found that the decrease in the temperature-dependent fluid viscosity makes the velocity to decrease with the increasing distance of the stretching sheet. At a particular point of the sheet the fluid velocity decreases with the decreasing viscosity but the temperature increases in this case. Impact of thermophoresis particle deposition in the presence of chemical reaction plays an important role on the concentration boundary layer. The results thus obtained are presented graphically and discussed.

1. Introduction

Scaling group transformation analysis, also called symmetry analysis, was developed by Sophius Lie to find point transformations that map a given differential equation to itself. This method unifies almost all known exact integration techniques for both ordinary and partial differential equations [1]. Group analysis is the only rigorous mathematical method to find all symmetries of a given differential equation and no ad hoc assumptions or a prior knowledge of the equation under investigation is needed. The boundary layer equations are especially interesting from a physical point of view because they have the capacity to admit a large number of invariant solutions, i.e., basically analytic solutions. In the present context, invariant solutions are meant to be a reduction to a simpler equation such as an ordinary differential equation. Prandtl's boundary layer equations admit more and different symmetry groups. Symmetry groups or simply symmetries are invariant transformations, which do not alter the structural form of the equation under investigation [2]. Newton's law of viscosity states that shear stress is proportional to velocity gradient. Fluids that obey this law are known as Newtonian fluids. Amongst Newtonian fluids we can cite water, benzene, ethyl alcohol, hexane and most solutions of simple molecules. There are numerous fluids that violate Newton's law of viscosity. The non-linear character of the partial differential equations governing the motion of a fluid produces difficulties in solving the equations. In the field of fluid mechanics, most of the researchers try to obtain the similarity solutions in such cases. In case of scaling group of transformations, the group-invariant solutions are nothing but the well known similarity solutions [3]. A special form of Lie-group of transformations, known as scaling group transformation, is used in this paper to find out the full set of symmetries of the problem and then to study which of them are appropriate to provide group-invariant or more specifically similarity solutions.

Thermophoresis is the term describing the fact that small micron sized particles suspended in a non-isothermal gas will acquire a velocity in the direction of decreasing temperature. The gas molecules coming from the hot side of the particles have a greater velocity than those coming from the cold side. The faster moving molecules collide with the particles more forcefully. This difference in momentum leads to the particle developing a velocity in the direction of the cooler temperature. The velocity acquired by the particles is called the thermophoretic velocity and the force experienced by the suspended particles due to the temperature gradient is known as the thermophoretic force. The magnitudes of the thermophoretic force and velocity are proportional to the temperature gradient and depend on many factors like thermal conductivity of aerosol particles and carrier gas. They also depend on the thermophoretic coefficient, the heat capacity of the gas and the Knudsen number. Corrosion of heat exchanger, which reduces heat transfer coefficient, and fouling of gas turbine blades are the examples of this phenomenon. Thermophoresis principle is utilized to manufacture graded index silicon dioxide and germanium dioxide optical fiber preforms used in the field of

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