Journal of Magnetism and Magnetic Materials 389 (2015) 48–55

Contents lists available at ScienceDirect

Journal of Magnetism and Magnetic Materials

journal homepage: www.elsevier.com/locate/jmmm

Interaction of magnetic field in flow of Maxwell nanofluid with convective effect

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ARTICLE INFO

Article history:
Received 27 February 2015
Received in revised form
21 March 2015
Accepted 5 April 2015
Available online 8 April 2015

Keywords:
Three-dimensional flow
Maxwell fluid
MHD
Nanoparticles
Convective boundary condition

ABSTRACT

Magnetohydrodynamic (MHD) three-dimensional flow of Maxwell nanofluid subject to the convective boundary condition is investigated. The flow is generated by a bidirectional stretching surface. Thermophoresis and Brownian motion effects are present. Fluid is electrically conducted in the presence of a constant applied magnetic field. Unlike the previous cases even in the absence of nanoparticles, the correct formulation for the flow of Maxwell fluid in the presence of a magnetic field is established. Newly proposed boundary condition with the zero nanoparticles mass flux at the boundary is employed. The governing nonlinear boundary layer equations through appropriate transformations are reduced in the nonlinear ordinary differential system. The resulting nonlinear system has been solved for the velocities, temperature and nanoparticles concentration distributions. Convergence of the constructed solutions is verified. Effects of emerging parameters on the temperature and nanoparticles concentration are plotted and discussed. Numerical values of local Nusselt number are computed and analyzed. It is observed that the effects of magnetic parameter and the Biot number on the temperature and nanoparticles concentration are quite similar. Both the temperature and nanoparticles concentration are enhanced for the increasing value of magnetic parameter and Biot number.

1. Introduction

The investigations on non-Newtonian fluids are remarkably enhanced during the past few decades because of their practical implications in technology and industrial processes. Many of the materials in our daily life include apple sauce, sugar solution, muds, chyme, soaps, emulsion, shampoos, blood at low shear rate etc. exhibits the characteristics of non-Newtonian fluids. In the literature, there is no single relation that characterizes all the properties of non-Newtonian fluids which characterize all the properties of such materials. Many models of non-Newtonian fluids are developed by the researchers in the past. Among these models, Maxwell fluid is a simplest subclass of rate type non-Newtonian fluids. This model is widely used to explore the effects of stress relaxation. The involvement of stress relaxation in the stress tensor of Maxwell fluid makes it highly nonlinear and complicated in comparison to Newtonian fluid. Maxwell fluid model reduced into the simple Navier–Stokes relation when extra stress time is zero. The boundary layer flows of viscoelastic non-Newtonian fluids have been widely used in engineering technology and industrial applications. Such flows commonly involved in power engineering and food engineering, petroleum production, polymer solutions and in polymer melt, the cooling of a metallic plate in a cooling bath, drawing on plastic films and many others. Abundant studies on this topic exist in the literature, but few interesting and recent studies can be seen in the Refs. [1–8].

Nowadays, the cooling of electronic devices is the major industrial requirements due to the fast technology, but the low thermal conductivity rate of ordinary base fluids includes water, ethylene glycol and oil is the basic limitation. To overcome on such limitation, the nanoscale solid particles are submerged into host fluids which change the thermophysical characteristics of these fluids and enhanced the heat transfer rate dramatically. Choi [9] was the first who identified this colloidal suspension. The recent developments in nanofluids and their mathematical modeling, play vital role in industrial and nanotechnology. The nanofluids are used in the applications such as cooling of electronics, heat exchanger, nuclear reactor safety, hyperthermia, biomedicine, engine cooling, vehicle thermal management and many others. Further the magneto nanofluids are useful in the manufacturing processes

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http://dx.doi.org/10.1016/j.jmmm.2015.04.019
0304-8853/