ARTICLE IN PRESS

+ MODEL

Available online at www.sciencedirect.com

ScienceDirect

Karbala International Journal of Modern Science xx (2017) 1—12
http://www.journals.elsevier.com/karbala-international-journal-of-modern-science/

Magnetohydrodynamic squeezing flow analysis of nanofluid under the effect of slip boundary conditions using variation of parameter method

M.G. Sobamowo [a,*], L.O. Jayesimi [b], M.A. Waheed [c]

[a] Department of Mechanical Engineering, University of Lagos, Akoka, Lagos, Nigeria
[b] Works and Physical Planning Department, University of Lagos, Akoka, Lagos, Nigeria
[c] Department of Mechanical Engineering, Federal University of Agriculture, Abeokuta, Nigeria

Received 3 October 2017; revised 2 December 2017; accepted 3 December 2017

Abstract

In this paper, two-dimensional squeezing flow of nanofluid under the effects of a uniform transverse magnetic field and slip boundary conditions is analyzed using variation of parameter method. The approximate analytical solutions of the variation of parameter method show excellent agreement and accuracy with the solutions of numerical method using shooting method coupled with Runge–Kutta coupled. Therefore, the developed analytical solutions are used to investigate the effects of fluid properties, magnetic field and slip parameters on the squeezing flow of nanofluid. From the results, it is observed that the velocity of the fluid increases with increase in the magnetic field parameter under the influence of slip condition while under no-slip condition, the velocity of the fluid decreases with increase in the magnetic field parameter. Also, the fluid velocity increases as the slip parameter increases but it decreases with increase in the magnetic field parameter and Reynolds number under the no-slip condition. It is hoped that this study will enhance the understanding of squeezing flow process such as found in various biological and industrial applications.

Keywords: Nanofluid; Squeezing flow; Slip boundary; Magnetic field; Variation of parameter method

1. Introduction

The study of flow of fluid between two parallel plates has attracted a lot of research interests in the past few decades. This is due to its various industrial and biological applications such as in moving pistons, chocolate fillers, hydraulic lifts, electric motors, flow inside syringes and nasogastric tubes, compression, and injection, power transmission squeezed film and polymers processing. Following the pioneer work of Stefan [1] on the flow of fluid between two parallel plates called squeezing flow, there have been improved studies on the flow process. However, the earlier studies [1—3] on squeezing flow were based on Reynolds equation which its insufficiencies for some cases of flow situations have been pointed out by Jackson [4] and Usha and Sridharan

* Corresponding author.
E-mail address: mikegbeminiyiprof@yahoo.com (M.G. Sobamowo).
Peer review under responsibility of University of Kerbala.

https://doi.org/10.1016/j.kijoms.2017.12.001

[5]. Consequently, there have been several attempts and renewed research interests by different researchers to properly analyze and understand the squeezing flow of fluid using different analytical and numerical methods [5−26]. Also, the effects of magnetic field, flow characteristics and fluid properties on the flow process have been widely investigated under no slip conditions [27−42]. However, in many cases of fluid and flow problems such as polymeric liquids, thin film problems, nanofluids, rarefied fluid problems, fluids containing concentrated suspensions, and flow on multiple interfaces, slip condition prevails at the boundary of the flow. Therefore, Navier [43] proposed the general boundary condition which demonstrates that the fluid slips at the solid−fluid boundary or surface. Such consideration of slip condition in the flow analysis of fluids is of great importance especially when fluids with elastic characteristics are under consideration [44]. Consequently, Ebaid [45] investigated the effects of magnetic field and wall slip conditions on the peristaltic transport in an asymmetric channel. Also, the influence of slip on the peristaltic motion of third-order fluid in asymmetric channel was analyzed by Hayat et al. [46]. In another work, Hayat and Abelman [47] presented a study on the effects of slip condition on rotating flow of a third grade fluid in a nonporous medium. Two year later, Abelman et al. [48] extended their work to a porous medium and obtained the numerical solutions for the steady magnetohydrodynamics flow of a third grade fluid in a rotating frame. Most of the past efforts in analyzing the squeezing flow problems have been largely based on the studies of viscous fluids. Additionally, the analyses of flow and heat transfer of nanofluid under the influences of various flow and eternal parameters have been carried out with different semi-analytical or approximate analytical methods [49−72]. However, due to the limitations in the past analytical methods, the quest for comparatively simple, flexible, generic and highly accurate analytical solutions continues. In the search of new and relatively simple method, the variation of parameters method has shown to be one of the most effective, accurate, convenient approximate analytical methods for large class of weakly and strongly nonlinear equations. It is a user friendly method with reduced size of calculation. It is a direct and straightforward iteration method and it generates solution with a rapid rate of convergent and without any restrictive assumptions or transformations, without linearization or any perturbation, without discretization or approximation of the derivatives. The procedures and requirements show that variation of parameter method (VPM) is different from variational iteration method (VIM). Unlike VIM, VPM gives solution to the linear or nonlinear problems without taking highest order term into consideration and it is free from the determination or the use of Lagrange multiplier. In VPM, there is no concept of exact and approximate multiplier as against the VIM where exact, semi-exact and approximation multipliers are used for the solution purposes. It also possesses the advantages of VIM such as with few numbers of iterations, VPM can also converge to correct solutions or results. It is a very efficient and reliable method [73−76]. To the best of the authors' knowledge, a study on squeezing flow of nanofluid under the influences of magnetic field and slip boundary conditions using variation of parameter method has not been carried out in literature. Therefore, in the present work, analysis of axisymmetric magnetohydrodynamic squeezing flow of nanofluid in a porous medium under the influence of slip boundary condition using variation parameter method is presented. Also, the effects of the various flow and eternal parameters on the squeezing flow are investigated.

2. Problem formulation

Consider the flow of an incompressible nanofluid squeezed between two parallel plates which are at distance $2h$ apart as shown in Fig. 1. The plates approach each other slowly with a constant velocity under in the presence of a magnetic field as shown in the figure. Assuming that the fluid is incompressible, the flow is laminar and isothermal, the governing equations of motion for the flow of the nanofluid are given as:

$$\nabla \cdot \tilde{v} = 0, \quad (1)$$

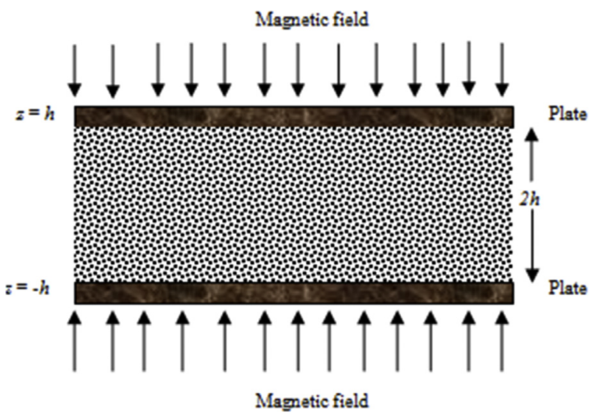

Fig. 1. Model of the squeezing flow of nanofluid under transverse uniform magnetic field.

Please cite this article in press as: M.G. Sobamowo et al., Magnetohydrodynamic squeezing flow analysis of nanofluid under the effect of slip boundary conditions using variation of parameter method, Karbala International Journal of Modern Science (2017), https://doi.org/10.1016/j.kijoms.2017.12.001