Mixed convection flow and heat transfer of Biomagnetic fluid with magnetic/non-magnetic particles due to a stretched cylinder in the presence of a magnetic dipole

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Abstract: *In this paper, a steady two dimensional mixed convection boundary layer flow of biomagnetic fluid with magnetic ($CoFe_2O_4$) and non-magnetic (Al_2O_3) particles suspension within base fluid blood over a stretched cylinder in the presence of a magnetic dipole is studied. Where, thermal conductivity is considered temperature dependent. The governing PDEs are converted into a system of ODEs by applying some acceptable non-dimensional similarity variables and numerically solved them by utilizing an efficient numerical technique that consists with common finite difference along with central differencing, a tridiagonal matrix manipulation and on an iterative procedure. The impacts of ferromagnetic interaction parameter, particles volume fraction, mixed convection and Prandtl number is discussed for $CoFe_2O_4$-blood and Al_2O_3-blood by graphical demonstrations of velocity, temperature distributions as well as skin friction coefficient and the rate of heat transfer. It is found that the performance of magnetic particles ($CoFe_2O_4$) in blood flow and heat transfer is better than non-magnetic (Al_2O_3) particles. A comparison was made with previous existing literature to validate the current results.*

Keywords: Biomagnetic fluid dynamics; Blood; FerroHydrodynamics; magnetic/non-magnetic particles; Cylinder.

1. INTRODUCTION

Due to the numerous applications of biomagnetic fluid dynamics (BFD) in medical and bio-engineering such as drug delivery, cancer treatment, eye treatment, magnetic resonance imaging (MRI) etc. [1-3], it has gained serious attention from the researchers in last few decades. With a spreading world race, medical and engineering sectors are required more effective advancement and its implementation. Based on this purpose, researchers were engaged themselves to evolve progression of fluid heat transfer with higher thermal conductivities. Such idea was first introduced by Choi [4] with the term "nanofluid" and found that by applying this concept the barrier of thermal conductivity of base fluid is greater than regular fluid. Basically, nanofluid is a fluid where regular fluid such as blood, water, oil etc. are mixed with different types of nanoparticles.

In view of medical applications, BFD model was enchanted by many researchers because in BFD, all biological fluids are influenced by a strong applied magnetic field. One of the characteristics of biomagnetic fluid is blood. Blood is treated as a magnetic fluid due to the presence of iron oxides which are present with highly concentration in the mature red blood cells. In bio-medical applications progression magnetic particles play a vital role than non-magnetic particles due to its unique property. Because magnetic particles can easily manipulated by magnetic force, which can further enable fleet and simple detachment of target molecules bound to the particles from reaction mixtures than non-magnetic particles.

Hakim et al. [5] investigated the flow and heat transfer of Newtonian/Non-Newtonian fluid with Fe_3O_4 magnetic and Al_2O_3 non-magnetic particles over a flat plate. They found that the skin friction coefficient and rate of heat transfer becomes higher for non-Newtonian fluid than Newtonian fluid. Shah et al. [6] was the first who introduced the concept of fractional derivatives to analyze the flow of blood along with magnetic particles through a circular cylinder. Sharma et al. [7] investigated the flow of artificial blood with Iron oxide magnetic particles under the influence of external magnetic field. A comprehensive study of non-Newtonian Casson and Carreau model were discussed by Dey et al. [8]. Where spiral component of blood circulation assumed pulsatile and parabolic characteristics of human blood flow. Using finite element method, Marwan et al. [9] analyzed the behavior of human heart to transport blood in the active vascular system. Hemmat Esfe et al. [10] performed a numerical analysis of mixed convection flow and heat transfer water-Al_2O_3 nanofluid in an inclined two-sided lid driven cavity. Recently, Ferdows et al. [11] examined the flow of blood with $CoFe_2O_4$ magnetic particles through an unsteady stretched/shrinking cylinder. In that study, they found that temperature of blood- $CoFe_2O_4$ is enhanced significantly in case of BFD compare than MHD and FHD. The impact of temperature dependent fluid viscosity and thermal conductivity on blood-Fe_3O_4 flow and heat transfer in the presence of magnetic dipole was examined by Alam et al. [12] and observed that the blood flow could be controlled by applying a strong magnetic field.

A pioneering research has been already exists related to this model but still needed to improve the thermal enhancement of blood heat transfer. According to the best information of authors no study has been done yet about the impacts of variable fluid properties on mixed convection flow over a stretched cylinder where blood is considered as base fluid and two different types of particles namely magnetic ($CoFe_2O_4$) and non-magnetic particles (Al_2O_3) are considered. The hope is that the results that obtained from this research can be useful in medical applications especially in drug delivery and cancer treatment.