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EFFECTS OF MAGNETIC PARTICLES DIAMETER AND PARTICLE SPACING ON BIOMAGNETIC FLOW AND HEAT TRANSFER OVER A LINEAR/NONLINEAR STRETCHED CYLINDER IN THE PRESENCE OF MAGNETIC DIPOLE

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Magnetic particles are essential in materials science, biomedical, bioengineering, heat exchangers due to their exceptional thermal conductivity and unique properties. This work aims to model and analyze the biomagnetic fluid flow and heat transfer, namely the flow of blood with magnetic particles (Fe_3O_4) induced by stretching cylinder with linear and nonlinear stretching velocities. Additionally, this study investigates the impact of particles diameter and their spacing under the influence of ferrohydrodynamics (FHD) principle. The collection of partial differential equations is transformed using similarity transformations to produce the theoretically stated ordinary differential system. An efficient numerical technique, which is further based on common finite difference method with central differencing, a tridiagonal matrix manipulation and an iterative procedure are used to solve the problem numerically. The major goal of this extensive study is to enhance heat transformation under the influence of numerous parameters. There have been numerous displays of the velocity profile, temperature distribution, local skin friction factor and rate of heat transfer in terms of the appearing physical parameters. It is observed that variation in velocity and temperature distributions is the cause of increasing the ferromagnetic interaction parameter and the size of magnetic particles. The enhancement of particle diameter causes an increment in the skin friction while the rate of heat

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transfer declines. For verifying purposes, a comparison is also shown with previously published scientific work and found to possess suitable accuracy.

Keywords: Biomagnetic fluid dynamics (BFD); blood; magnetic particles; particles spacing; stretched cylinder; finite difference method.

1. Introduction

Based on the applied research and wide range of applications in biomedical engineering, the study of magnetic fluid has become a hot issue in the 21st century. Magnetic fluid offers numerous ways to ameliorate the performance of heat transmission in regular fluid as blood, water, oil, etc. According to Choi,[1] the thermal conductivity of base fluid boost up when nanoparticles were mixed, and more importantly fluid heat transfer rate as well as increased and such characteristics are useful to apply in industrial sectors. Among all class of nanoparticles, magnetic particles have advantages to get suspended with biological fluids easily and providing the best solutions for biomedical applications especially in drug delivery.[2] Compared to other fields in fluid dynamics, biomagnetic fluid dynamics (BFD) is a relatively recent field. The study of BFD has recently attracted the interest of scientists since it directly relates to diseases and disorders of the human body, where the influence of magnetic field is vigorously explored. Due to the hemoglobin molecule, a type of iron oxide carried by the red blood cells, blood is one of the prominent examples in BFD that can behave as a magnetic fluid. As a result in BFD mathematical model both the principles namely- magnetohydrodynamics (MHD) and ferrohydrodynamics (FHD) are employed. Fundamentally, the BFD model is composed of the FHD and MHD concepts with the fluids being electrically nonconducting and the body force being due to magnetizationpolarization force.[3–5]

Following the discovery in Ref. 1, the study of nanofluid, or fluid that has been mixed with nanoparticles, has recently become more fascinating. The study of boundary layer flow and heat transfer due to stretching cylinder was initially investigated by Crane[6] and Wang[7] extended Crane's initial investigation and discovered that for higher Reynolds number values, fluid velocity and temperature dropped. Using water as the base fluid and Cu as nanoparticles, Pandey *et al.*[8] suggested a two-dimensional flow model over a stretching cylinder under the impact of thermal radiation. They found that the velocity boundary layer declined with increasing nanoparticle volume fraction, and the authors of this model used nanoparticle volume fraction up to 6%. Later on, Singh *et al.*[9] examined the Cu–H_2O flow and heat transfer through a porous stretchable cylinder in the presence of nonuniform heat source, where the volume fraction of solid particles was taken 0–25%. They reveal that with improvement of Reynolds number, temperature-dependent internal heat, the rate of heat elevated. Ashorynejad *et al.*[10] investigated the steady MHD flow of water-based nanofluid flow and heat transfer over a stretchable cylinder where three different types of nanoparticles, Cu, Al_2O_3, Ag and TiO_2, are considered. Their results show that for nanoparticles volume fraction, drag force factor increased