Chapter 1

Introductory Chapter: Fluid Flow Problems

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Additional information is available at the end of the chapter

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1. Introduction

This chapter will cover various flow regimes and their solutions, including, Newtonian, non-Newtonian, and nanofluids via integral transforms and numerical schemes.

1.1. Background

In many real life problems, heat transfer is an important issue and becomes a challenge for the engineers and industrialists. In order to overcome this challenge, one of the methods, which is commonly in use, is to increase the available surface area of heat exchange [1–4]. Hussanan et al. [5] studied the use of oxide nanoparticles for the energy enhancement in water, kerosene, and engine oil-based nanofluids. Tesfai [6] experimentally investigated graphene and graphene oxide suspension for thermal management application. Shafie et al. [7] are considered the first who reported a theoretical study on molybdenum disulfide (MoS_2) nanoparticle suspended in water-based nanofluid in a channel. Khan et al. [8] and Khan [9] also analyzed Molybdenum Disulfide nanofluids in a vertical channel with various effects. Few other interesting investigations in this direction are those made by Wu and Zhao [10], Khan [11], Ali et al. [12] Sheikholeslami and Bhatti [13], Rashidi et al. [14], Mahian et al. [15], and Kasaeian [16].

About 300 years ago, the idea of fractional derivatives was presented [17–21]. This was considered an abstract area of mathematics by many researchers at the initial stages, which will be of no use and will contain only mathematical manipulations. For the last few decades, a new era started in the field of mathematics that changed the interest of scientists from pure mathematics to various applied fields of mathematical sciences, for instance, bioengineering, viscoelasticity, mechatronics and biophysics. Applications of fractional calculus have also been found to be used widely in various fields of science despite mathematics and physics. In fluid dynamics, the noninteger order calculus has been widely used to describe the viscoelastic behavior of the materials. The viscoelasticity of a material is defined as being deformed and exhibiting a viscous and elastic behavior through the mechanical energy of storage and simultaneous behavior. The commonly used fractional derivative operators are that of the Riemann-Liouville and the Caputo fractional derivatives. However, there have been some shortcomings in use of these operators. When the Riemann-Liouville fractional derivatives are used, the derivative of a constant is not zero, and some terms are contained without physical significance while applying the Laplace transform, whereas in the case of Caputo fractional derivatives, the kernel is a singular function. To overcome this problem, in 2015, Caputo and Fabrizio have developed a new approach without singularities [18]. The time fractional derivative operator of Caputo-Fabrizio is suitable for the use of the Laplace transform. Frequently, the classical models of equations governing the fluid flow are changed to fractional models, just by replacing derivatives w.r.t time with fractional order derivatives of order $\alpha \in (0, 1)$ see for example [18]. Many scientists and researchers have used the Caputo-Fabrizio fractional derivatives in their studies for physical models [22–28]. Atangana et al. [29] have studied the ground water flowing in aquifer using the applications of the Caputo-Fabrizio derivatives. Very recently, Atangana and Baleanu have presented a new fractional derivative with nonlocal and nonsingular kernel [30–34]. Keeping in mind the above important features, the fractional model for non-Newtonian fluid is considered in the present project.

MHD is the study of magnetic properties of electrically conducting fluids. Liquid metals, plasma, salt water, and electrolytes are the examples of MHD fluid. The pioneering work on MHD has been done by Alfven [35]. In 1970, for his great work, he also received a Nobel Prize. In engineering and technology, MHD has many applications such as hydromagnetic generators (it includes disk system) and MHD flow meters, plasma studies, bearings, pumps, solar energy collection, geothermal energy extractions and nuclear reactors, boundary layer control, extraction of petroleum products, and cooling of the metallic plate. There are many applications of hydromagnetic flow of non-Newtonian fluids in a rotating body in metrology, geographic, turbo machinery, astrophysical, and several other areas. In addition, it has a lot of applications in the biomedical field for instance blood flow in capillaries and flows in blood oxygenation, etc. Also, it has many applications in engineering such as in transpiration cooling, porous pipe design, and design of filters [36]. The role of Hall effect on MHD flow in a rotating frame is remarkable.

In many industrial and natural conditions, the flow through porous media occurs. As rainwater penetrates through the permeable aquifer, hydrological engineering forced flow of oil into sandstone deposits, membrane separation process, drying process and powder technology. Recently, there have been numerous reports dealing with the transport phenomena in porous media, especially due to their importance in various applications, involving the manufacturing and processing industries. It is assumed that the fluid is incompressible, and the fluid flow in the saturated porous medium is treated in most studies where the mass density is constant and the velocity of the fluid is independent of the mass density. The researchers can get help from a better knowledge of free convection through a porous medium in several fields such as heat exchanger, geothermal systems, insulation design, grain storage, catalytic reactors, filtering devices, and metal processing. Recently, attention has been focused on the uses of porous media in high-temperature applications. Porous media are used for the improvement of heat transfer in thermal insulation systems and coolant passages. It is the immeasurable need to ponder on convection flows of Newtonian and non-Newtonian fluids over a vertical oscillating plate passing through a porous medium. In the applied science and engineering, porous media play an important role such as:

- Soil Science: the porous media (soil) contains and transports nutrients and water to plants.
- Hydrology: the porous media are a water bearing and sealing layer.
- Chemical Engineering: porous media are used as a filter or catalyst bed.
- Petroleum Engineering: porous media in the form of reservoir rock, stores, crude oil, and natural gas.

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