NON-NEWTONIAN FLUIDS FOR INDUSTRIAL APPLICATIONS

Modeling and Simulations

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Non-Newtonian Casson Fluid through a Porous Rotating Channel with Seepage Flow

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Abstract
Rotating channels represent complex geometries that play a crucial role in various engineering applications, including the optimization of blood flow simulators, filtration systems, and chemical reactors. In these systems, non-Newtonian fluids, such as Casson fluid, exhibit unique flow characteristics, especially when subjected to rotational and porous conditions. This study focuses on the steady, laminar flow of incompressible Casson fluid through a rotating channel filled with porous material, where a uniform angular velocity is applied and seepage occurs at the upper wall of the channel. The governing equations for this flow are derived from the Darcy–Brinkman model, and through the use of similarity transformations, these equations are converted into a sixth-order ordinary differential equation (ODE). The analytical solution to this ODE is obtained, providing insights into the behavior of the fluid under the given conditions. The impact of the Casson parameter on the primary, secondary, and seepage velocities is thoroughly analyzed, with particular attention

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paid to the influence of rotational effects in a porous medium. Graphical representations are employed to illustrate the flow behavior and highlight the significant changes in velocity profiles due to variations in the Casson parameter. This comprehensive analysis contributes to a deeper understanding of non-Newtonian fluid dynamics in rotating porous channels, with potential applications in engineering fields such as biomedicine, environmental engineering, and industrial fluid systems.

***Keywords*:** Casson fluid, Non-Newtonian fluid, rotating channel, porous medium, seepage flow, Darcy–Brinkman model, similarity transformation

9.1 Introduction

This paper holds significant applications in various engineering and scientific fields where fluid mechanics plays a crucial role. The study's insights into the behavior of Casson fluids—common in biological systems, industrial processes, and food technology—when influenced by rotation, porous media, and seepage effects, can enhance the design and optimization of filtration systems, chemical reactors, and biomedical devices like blood flow simulators. Additionally, the research is valuable for environmental engineering, particularly in groundwater flow analysis and pollution control in porous media, where such non-Newtonian fluids are encountered.

The Casson fluid model was introduced in 1959 by British rheologist N.W. Casson [1] in his study of colloidal suspension flows. Casson proposed a mathematical framework to characterize materials with yield stress and shear-thinning properties, serving as a bridge between Newtonian and non-Newtonian fluid mechanics. His contributions were particularly impactful in industries such as printing and ink manufacturing, where understanding the flow behavior of complex fluids like printing inks is crucial. Casson fluids are characterized by two key flow parameters: yield stress, arising from attractive forces between fluid particles, and plastic viscosity, linked to particle asymmetry [10]. Micropolar fluids [14], which incorporate microstructure and couple stress effects, exhibit nonsymmetric stress components [15]. Rott [16] presented an analytical solution for viscous flow at a stagnation point on a vertical plane. Bluman and Cole's seminal work, *Similarity Methods for Differential Equations*, highlights the relationship between dimensional analysis and similarity solutions [17]. Chakraborti and Gupta [18] proposed a similarity solution for flow with constant suction velocity along a smooth surface, while Vajravelu and Rollins [19] explored heat transfer in a conducting fluid over a fat plane. Studies have also examined the influence of chemical reactions [20] on convective heat and mass transfer over a porous stretching surface. Arthur *et al.* [21] investigated Casson fluid flow over a porous surface under