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Analysis of Irreversibility in the Flow of Jeffrey Fluid Through an Inclined Channel Considering Navier-Slip

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Abstract. In this paper, we investigate the phenomenon of entropy generation of natural convection Jeffrey fluid flow through a sloping channel under Navier-Slip conditions. The study considers the influences of the Soret effect, inclined magnetic field, and Hall current. Employing appropriate transformations, we express the main equations in dimensionless form. Numerical solutions are implemented using the spectral quasi-linearization method (SQLM). Graphical representations are utilized to assess the impacts of diverse thermophysical parameters. Empirical findings indicate that augmenting the channel inclination angle, inclination angle, Soret number, and magnetic parameter induces a proportional rise in entropy generation. Conversely, a surge in Hall current yields a reduction in entropy generation. When the Soret parameter, magnetic parameter, channel inclination angle, and Jeffrey fluid parameter increase, it increases flow and cross-flow velocity. A contrary trend is observed for the Hall parameter.

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Key words: Natural convection, inclined magnetic field, sloping channel, Entropy, SQLM.

1. Introduction

Natural convection in enclosures draws attention with its many applications in various fields, encompassing lead-acid batteries, thermal storage, solar collectors, food, and drying technologies. This process is synonymous with natural heat convection and is driven by buoyancy disparities induced by temperature gradients. Engineers harness natural convection flows occurring between vertically oriented parallel walls for diverse purposes, such as cooling electronic equipment, devising heat exchangers, operating nuclear reactors, exploiting solar energy, and implementing geothermal systems, among other industrial endeavors [8,10,12,19,40,43]. Researchers in fluid mechanics and heat transfer have extensively probed these flows due to their paramount significance in the relevant sector.

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The exploration of natural convection phenomena provides valuable insights for optimizing technology and advancing engineering applications in an energy-efficient and sustainable manner. Hajizadeh *et al.* [14] studied the unforced convective flow of a nanofluid between vertically aligned parallel plates. Tanveer *et al.* [39] investigated the free convection flows of nanofluids by taking the generalized fractional thermal flux into account. Recently, Ali *et al.* [2] investigated the synergistic influence of heat transfer and a magnetic field on the phenomenon of free convection in magneto-hydrodynamic (MHD) Casson fluid flow occurring between parallel plates. Most recently, Bako and Ajibade [3] explored the impacts of g-jitter on natural convection Couette flow within a vertical channel.

The Soret effect, a phenomenon where a mass flux is induced by a temperature difference, plays a crucial role in various physical processes and finds applications in fields such as geosciences and chemical engineering [33, 38]. Mandal *et al.* [24] conducted a study utilizing an inclined stretching plate with different surface conditions to investigate the characteristics of the Soret effect and its interaction with magnetohydrodynamics. Mishra *et al.* [25] focused on the impact of Soret diffusion in hydromagnetically mixed convective flow passing through the center of infinite vertical plates. Recently, Agrawal *et al.* [1] conducted research into the influence of Soret number in conjunction with Hall parameter and induced magnetic field effects on combined convection flow through vertical channels. The objective of this study was to elucidate how the interplay between the Soret effect and magnetic forces affects flow characteristics and heat transfer phenomena. Most recently, Hamza *et al.* [15] investigated the heat transfer flow in natural convection controlled by the Arrhenius equation, influenced by an induced magnetic field within a micro-channel.

Fluid flows with slip at boundaries indeed have significant implications for various micro and macroscopic devices, including applications such as surface polishing. In 1823, Navier [29] introduced a slip boundary condition, stating that the velocity at the interface between a solid and a fluid is linearly affected by shear stress. Building upon Navier's work, Das *et al.* [9] presented the findings of their research, which focused on slip flow through sloping porous channel. In their study, the authors considered the influences of viscous dissipation and joule heating within the fluid flow. Filahi *et al.* [11] investigated the thermosolutal convection within a horizontal porous layer containing a binary fluid influenced by the Soret effect. Gjerde and Scott [13] conducted a study to examine the instability in kinetic energy within fluid flows subject to slip boundary conditions. Recently, Bernatchou *et al.* [6] analyzed the impact of a magnetic field on double diffusive free convection occurring within an inclined enclosure that contains a nanofluid. The study also encompassed consideration of the Soret number's influence. Most recently, Raghunath [36] conducted an investigation into the heat and mass transfer characteristics of nanofluid flow based on water over a stretching sheet. The study also considered the impact of thermal radiation, magnetic field, and Soret number.

Non-Newtonian fluids find diverse applications spanning industries such as food, pharmaceutics, paints, coatings, and polymer processing. In recent decades, there has been extensive discourse concerning the rheological attributes of non-Newtonian fluids, which captivates researchers. The Jeffrey fluid, as expounded in references [17, 18, 28, 42], stands among various models utilized for elucidating the conduct and properties of these fluids.