Entropy Generation of MHD Poiseuille Flow with Hall and Joule Heating Effects

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***Abstract*—**In this article investigation has been conducted on the effects of Hall parameter, rotation parameter and Joule heating on the entropy generation of fully developed electrically conducting Poiseuille flow. The coupled system of ordinary differential equations for the flow are obtained, non-dimensionalised and solutions are constructed by Adomian decomposition technique. The effects of Hall current, Ion-slip, Joule heating and magnetic parameters on the velocity, temperature, entropy generation and Bejan number are explained and shown graphically. The results indicate that fluid entropy generation is induced by increase in Hall current, rotation and Joule heating parameters. Furthermore Bejan number is accelerated by Hall current, rotation, Magnetic and Joule heating parameters which signifies that heat transfer irreversibility dominates entropy generation.

***Keywords*—** Poiseuille flow, Hall current, Ion-slip, Entropy generation, Adomian decomposition method (ADM).

I. INTRODUCTION

Investigation regarding Magnetohydrodynamic flows was pioneered by the discoveries of Alfven and others in the 1940s [1]. Magnetohydrodynamics (MHD) has been described as the study of the interplay between magnetic fields and conducting fluids. Such fluids must be electrically conducting; these include liquid metals (such as mercury, gallium, molten magnesium, molten antimony, liquid sodium etc.), plasmas (ionized gases or electrically conducting gases) such as solar atmosphere and salt water or electrolyte. Since its introduction in the past half century several engineering and industrial problems have been addressed: lubrication control of high-speed spinning machine components with magnetic fields, improved MHD generators [2], crystal growth control [3], magnetoastronautical flows [4], fusion reaction [5], electrolysis (reduction of aluminium oxide to aluminium) [6]. Due to the significance of MHD flows appreciable studies have been reported in literature, MHD Couette flow [7-9], MHD Poiseuille flow [10-11], MHD couple stress fluid [12-14], MHD nanofluid [15-17], MHD second grade fluid [18-20], MHD third grade fluid [21-23], MHD micropolar fluid [24-25], other interesting investigations are in refs.[26-33]. In addition, several investigations have been conducted to incorporate Hall-magnetohydrodynamics, rotating magnetohydrodynamic flows in the study of magnetohydrodynamic.

In all the previously mentioned investigations on magnetohydrodynamics, an assumption of small and moderate magnetic field was taken in the application of Ohm's law resulting in unnoticeable impact in the flows. However current trend in the application of MHD is towards strong magnetic field owing to its numerous applications in magnetic fusion systems, electrically-conducting aerodynamics, energy generators, Hall accelerators and flight magnetohydrodynamics. Lighthill [34] was the first to suggest the inclusion of Hall effect in MHD flows, notwithstanding Sato [35] conducted the first significant research of Hall current effects on magnetohydrodynamic boundary layers, it was reported that such flow becomes secondary in nature. Furthermore, investigations have revealed that the interaction of the Coriolis and electromagnetic forces cannot be ignored in MHD flows. It is noteworthy that Coriolis and MHD forces are comparable in magnitude and Coriolis force stimulates secondary flow in the fluid. Rotating magnetohydrodynamic flows have practical applications in the turbo machinery, the solidification process in metallurgy, and some astrophysical problems. In view of the foregoing several investigators have studied the significance of Hall and rotating magnetohydrodynamcs in various fluid flows under different configurations. Mohanty [36] investigated MHD flow in a rotating channel. Jana et al. [37] studied the hydromagnetic Couette flow and heat transfer with Ion-slip effect. Hall current effect on hydromagnetic Couette flow in a rotating system was considered by Jana and Datta [38]. Seth et al. [39] studied an unsteady MHD Couette flow in a rotating system. Rao and Rao [40] studied the MHD flow of Rivlin–Ericksen fluid of rotating second grade contained between two infinite, parallel plates. Kasiviswanathan and Gandhi [41] reported on MHD flow of rotating micropolar fluid between two infinite parallel, rotating disks.

In this article detailed analysis of the effects of Hall current and Ion-slip on electrically conducting Poiseuille flow in a rotating frame of reference is considered. To the best of authors' knowledge the irreversibility associated with the Hall current and Ion-slip effects of this important flow has not been adequately addressed. First law of thermodynamics approach has been applied in several investigations reported in literature, however in several engineering processes, factors responsible for exergy loss in various fluid flows are of interest

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