Entropy generation analysis of 3D tangent hyperbolic fluid flow over a rotating disk of variable thickness

Priya Bartwal[a,*], Himanshu Upreti[b] and Alok Kumar Pandey[a]

[a]Department of Mathematics, Graphic Era (Deemed to be University), Dehradun, Uttarakhand, India
[b]SoET, BML Munjal University, Gurugram, Haryana, India

Email address: pbartwal25@gmail.com (Corresponding author)

Abstract: The theme of this work is to examine the impact of entropy generation on the three-dimensional flow of tangent hyperbolic fluid over a rotating disk of variable thickness. The momentum and energy equations are based on temperature-dependent dynamic viscosity and temperature-dependent thermal conductivity. The combined impact of entropy generation and magnetic field, Soret-Dufour numbers and slip parameters are analyzed for the cases of suction and injection. The dimensionless governing equations are solved numerically by applying the Legendre wavelet collocation method. The results of entropy generation and Bejan number are displayed through graphs. From the outcomes, the profiles of Bejan number continuously decrease with increasing thickness coefficient of the disk.

1. INTRODUCTION

The flow over rotating disk has a significant role in industrial engineering and medical science such as rotating machinery, computer storage systems, medical equipment, etc. Von-Kármán [1] was the first to study the fluid flow over a rotating disk.

Entropy generation is the measurement of entropy produced in irreversible processes such as heat exchangers, material blending or stretching, refrigerators, and air conditioners. According to the second law of thermodynamics i.e., the net entropy of the system remains constant for reversible process. The concept of entropy generation initially addressed by Bejan [2].

After reviewing the above literature, the current study aims to investigate the impact of the MHD flow of tangent hyperbolic fluid with entropy generation over a rotating disk of variable thickness. The viscosity and thermal conductivity models are dependent on temperature. The surface roughness is determined at the disk surface using the MW (Miklavčič and Wang) model. The numerical solutions of the non-linear ordinary differential equations are achieved using the Legendre wavelet collocation method [3].

2. FORMULATION OF THE PROBLEM

$$U_r + \frac{U}{r} + W_z = 0, \tag{1}$$

$$\rho\left(UU_r - \frac{V^2}{r} + WU_z\right) = -p_r + (1-n)\left[\mu(T)U_z\right]_z + \mu(T)\sqrt{2}n\Gamma U_z U_{zz} - \sigma B_0^2 U, \tag{2}$$

$$\rho\left(UV_r + \frac{UV}{r} + WV_z\right) = (1-n)\left[\mu(T)V_z\right]_z + \mu(T)\sqrt{2}n\Gamma V_z V_{zz} - \sigma B_0^2 V, \tag{3}$$

$$\rho(UW_r + WW_z) = -p_z + (1-n)\left[\mu(T)W_z\right]_z + \mu(T)\sqrt{2}n\Gamma W_z W_{zz}, \tag{4}$$

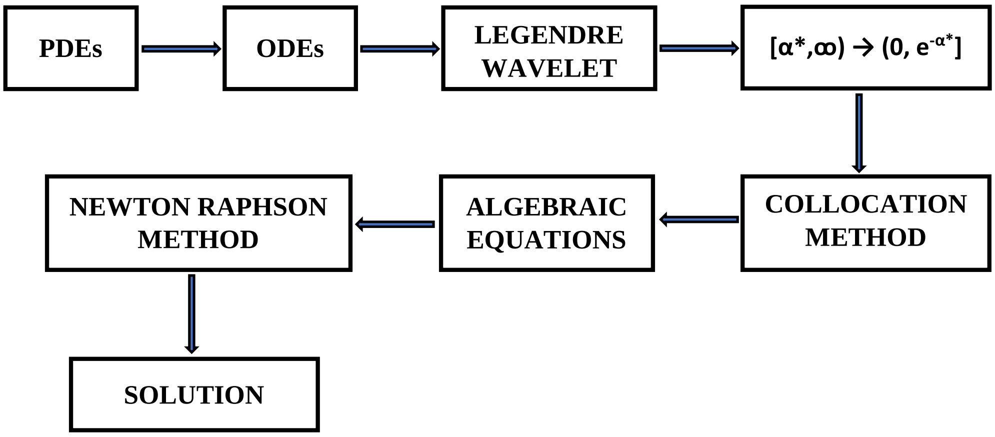
$$(\rho C_p)(UT_r + WT_z) = \left[k(T)T_z\right]_z + (\rho C_p)\frac{D_m K_T}{C_s C_p} C_{zz} + \sigma B_0^2\left[U^2 + V^2\right], \tag{5}$$

$$UC_r + WC_z = D_m C_{zz} + \frac{D_m K_T}{T_m} T_{zz}. \tag{6}$$

Boundary conditions:
$$\left.\begin{aligned} &U = N_1 \rho \upsilon_\infty U_z, V = \Omega r + N_2 \rho \upsilon_\infty V_z, W = w_0, T = T_w, C = C_w \;\; at \;\; z = d\left(\frac{r}{R_0}+1\right)^{-m_1}, \\ &U \to 0, V(\infty) \to 0, \; p \to p_\infty, T \to T_\infty, C \to C_\infty \;\; at \;\; z \to \infty. \end{aligned}\right\} \tag{7}$$

Here, $\mu(T) = \mu_\infty \{1 + \xi_1 (T - T_\infty)\}^{-1}$ and $k(T) = k_\infty \{1 + \xi_2 (T - T_\infty)\}$. (8)

3. SOLUTION METHODOLOGY



4. FINDINGS AND CONCLUSIONS

- Entropy generation rate enhances with the thickness coefficient of the disk for both cases i.e., suction and injection.
- The outlines of the Bejan number reduce for the increasing values of the thickness coefficient of the disk.

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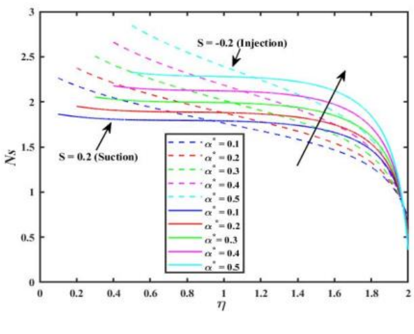

Fig 1. Variation in entropy generation profiles due to the thickness coefficient of the disk.

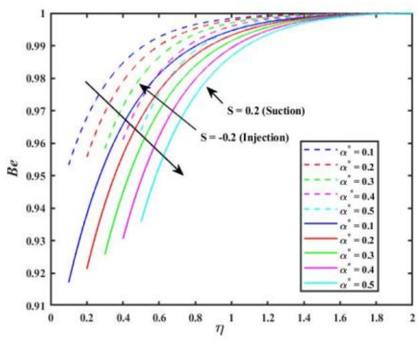

Fig 2. Variation in Bejan number profiles due to the thickness coefficient of the disk.