Inspection of Couette and Pressure-Driven Poiseuille Entropy Optimized Dissipated Flow in a Suction/Injection Horizontal Channel: Analytical Solutions

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Article

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Consider the constant flow of a viscous, electrically conducting, and compressible fluid in pathways made by two infinitely equivalent permeable surfaces divided by a length $h$. The $x$-axis extends in the flow path along the bottom stationary plate, whereas the $y$-axis is orthogonal to the surfaces. The channel plates are subjected to a consistent transverse magnetic field that is implemented perpendicularly. In this subject, two scenarios are investigated. The first is the Couette flow, In the second scenario, both porous surfaces are parallel and fixed at a range of $2h$, and the motion is Poiseuille flow controlled by pressure. The flow across the $x$-axis is supposed to be totally generated and dependent on $y$ - exclusively. The governed system is solved using help of analytical solutions. It is found that the entropy generation is higher near the cloud porous plate in comparison to the hot porous plate and the rising values of suction/injection parameter boost up the fluid temperature. The enhancement of magnetic field parameter causes to reduce the momentum boundary layer thickness. The Brinkman number improves the thermal boundary thickness. The magnetic field
parameter, suction/injection and Brinkmann number accelerates the entropy generation in both cases.

**Keywords:** Analytical solution; viscous dissipation; suction/injection; MHD; Horizontal Channels; Entropy Generation;

1 INTRODUCTION

One of the fundamental processes in computational fluid dynamics is the flow of Couette and Poiseuille, in which flow pattern is caused by the motion of the boundary surface. The generalised circulation of a viscous incompressible flow created by a plate traveling similar to a stationary plate and facilitated by a favourable pressure gradient condition. Couette flow is valuable in a plethora of engineering purposes and is thoroughly investigated from both mechanics and heat transmission viewpoints. Muhuri [1] investigated the Couette interaction between two porosity surfaces where one of the surfaces travels at an uniform speed with suction/injection. Because of their plethora of engineering and commercial uses, hydro magnetic link tends to flow have enticed the interest of many scientists. These streams can be discovered in MHD generators, geothermal underground aquifers, petroleum storage tanks, business incubators, and micro liquid instruments. Multiple scholars [2-4] had examined MHD fluid flow in a variety of physical settings.

Due to the generation of entropy, the majority of commercial and scientific flow processes and thermodynamic frameworks cannot function at ideal levels. Consequently, it is essential to identify the causes of entropy creation in order to mitigate their consequences and maximise the flow's performance. Numerous academics have theorised the formation of entropy in heat flow regimes beneath various physical conditions [5-7]. Makinde and Eegunjohi [8] published a numerical results for the impacts of convective heating on entropy formation in a permeable-walled channel. Eegunjohi and Makinde [9], Eegunjohi and Makinde [10] analysed the MHD stream flow having porous walls and convective heating.

Pressure-driven Poiseuille flow refers to the flow of a viscous, incompressible fluid that is produced by two parallel porosity plates that are 2h apart and fixed. None of the previous discussions on radioactive Magnetohydrodynamic in porous channels conducted a study to examine the irreversibility in light of entropy production. a number of scientists [11-13] Discussed the MHD flow and thermal performance across porous

**ENTROPY GENERATION**

Every thermodynamic system experience entropy production. Formation of entropy is directly linked to thermal irreversibility. It is crucial to figure out the rate of entropy production in a framework to maximise energy for the system's proper performance. Consider the motion of a Newtonian, incompressible fluid subject to the Fourier law of thermal conduction. The volumetric rate of entropy formation is expressed in Cartesian pattern by Bejan [19] as

$$E_g = \frac{\kappa}{T_0^2} \left( \left( \frac{\partial T}{\partial x} \right)^2 + \left( \frac{\partial T}{\partial y} \right)^2 \right) + \frac{\mu}{T_0} \left( 2 \left( \frac{\partial u}{\partial x} \right)^2 + \left( \frac{\partial v}{\partial y} \right)^2 \right) + \left( \frac{\partial u}{\partial x} \right)^2 \right)$$  \hspace{1cm} (1)

So much as either a thermal or velocity differential is maintained in a system, the preceding version of entropy generation demonstrates that irreversibility is caused by two impacts: conductivity (κ) and viscosity.

In numerous significant convective thermal transport scenarios, velocity and temperature patterns are rationalized under the assumption that the flow is hydrodynamically evolving \( \frac{\partial v}{\partial x} =0 \) and thermally advancing \( \frac{\partial T}{\partial x} \neq 0 \) or thermally growing \( \frac{\partial T}{\partial x} =0 \) [20-21].

The equation (1) is simplified as:

$$E_g = \frac{\kappa}{T_0^2} \left( \left( \frac{\partial T}{\partial x} \right)^2 + \left( \frac{\partial T}{\partial y} \right)^2 \right) + \frac{\mu}{T_0} \left( \left( \frac{\partial u}{\partial x} \right)^2 \right) \hspace{1cm} (2)$$
By utilizing dimensionless quantities the prior equation can be written as

\[
N_s = \frac{1}{Pe^2} \left( \frac{\partial \Theta}{\partial x} \right)^2 + \left( \frac{\partial \Theta}{\partial y} \right)^2 + \frac{Br}{\Omega} \left( \frac{\partial u}{\partial y} \right)^2 = N_c + N_y + N_f
\]  

(3)

**BEJAN NUMBER**

The Bejan number Be is an alternate dispersion criterion for irreversibility; it signifies the ratio between liquid friction \(N_f\) and thermal transport \(N_c + N_y\).

\[
\phi = \frac{N_f}{N_y}
\]  

(4)

Where \(\phi\) = Irreversibility ratio

Therefore, the Bejan number can be determined using the computational model:

\[
Be = \frac{N_c + N_y}{N_f} = \frac{1}{1 + \phi}
\]  

(5)

The Bejan number ranges from zero and one. Be = 1 indicates that entropy is produced exclusively by the irreversibility of thermal transmission. If Be=0, the total entropy is formed exclusively by the irreversibility of fluid friction, whereas if Be=0.5, thermal transmission and friction

In this investigation, the second rule of thermodynamics is applied along two simultaneous porous surfaces. In addition, two distinct scenarios are identified and analysed: Couette flow with porous walls and Poiseuille flow (pressure-driven) in a channel having viscous dissipation.

2. Mathematical Derivation:

Consider the constant flow of a viscous, electrically conducting, and compressible fluid in pathways made by two infinitely equivalent permeable surfaces divided by a length \(h\). The x-axis extends in the flow path along the bottom stationary plate, whereas the y-axis is orthogonal to the surfaces. The channel plates are subjected to a consistent transverse magnetic field \(B_0\) that is implemented perpendicularly. In this subject, two scenarios are investigated. The first is the Couette flow, In the second scenario, both porous surfaces are parallel and fixed at a range of \(2h\), and the motion is Poiseuille
flow controlled by pressure. The flow across the $x$-axis is supposed to be totally generated and dependent on $y$ - exclusively. We have the velocity component as $v = -v_0$, which corresponds to the suction/injection velocity. The Couette flow involving suction/injection is displayed in figure 1.

The equations regulating the independent flow of a viscous, incompressible fluid are as follows

**Case1: COUETTE FLOW**

\[ \frac{d^2 u^*}{dy'^*} + v_0 \frac{du^*}{dy'^*} - \frac{\sigma B_0^2}{\rho} u^* = 0 \]  

(6)

\[ \frac{k^*}{\rho C_p} \frac{d^2 T^*}{dy'^*} + v_0 \frac{dT^*}{dy'^*} + \frac{\mu}{\rho C_p} \left( \frac{du^*}{dy'^*} \right)^2 = 0 \]  

(7)

the constraints include

\[ \begin{cases} u^* = 0, T^* = T_0 \text{ at } y'^* = 0 \\ u^* = U, T^* = T_w \text{ at } y'^* = h \end{cases} \]  

(8)

**3 SOLUTION OF THE PROBLEM (CASE-1)**

The following are the dimensionless components in the preceding computations:
Equations (6) and (7) are shown in dimensionless form as

\[
d\frac{d^2 u}{dy^2} + S \frac{du}{dy} - Mu = 0
\]  
(9)

\[
d\frac{d^2 \theta}{dy^2} + S Pr \frac{d\theta}{dy} + Ec Pr \left(\frac{du}{dy}\right)^2 = 0
\]  
(10)

With boundary conditions:

\[
\begin{align*}
    u &= 0, \theta = 0 \text{ at } y = 0 \\
    u &= 1, \theta = 1 \text{ at } y = 1
\end{align*}
\]  
(11)

Solving the equations (9) and (10) subject to the boundary conditions (11) are obtained

\[
u = C_1 e^{\alpha y} + C_2 e^{\beta y}
\]  
(12)

where \( \alpha, \beta = \frac{1}{2} \left[ -s \pm \left( s^2 + 4M \right)^{\frac{1}{2}} \right] \)

\[
\theta = D_1 + D_2 e^{-sPr y} - Br \left[ C_3 e^{2\alpha y} + C_4 e^{2\beta y} + C_5 e^{(\alpha + \beta)y} \right]
\]  
(13)

**Case 2: POISEUILLE FLOW (PRESSURE DRIVEN)**
The Poiseuille flow configuration with suction/injection is depicted in figure 2.

The governing momentum and energy equation as follows

\[ \begin{align*}
\nu \frac{d^2 u^*}{dy^2} + \nu_0 \frac{du^*}{dy} - \frac{1}{\rho} \frac{dp}{dx} - \frac{\sigma B_0^2}{\rho} u^* &= 0 \\
\frac{k^*}{\rho C_p} \frac{d^2 T^*}{dy^2} + \nu_0 \frac{dT^*}{dy} + \frac{\mu}{\rho C_p} \left( \frac{du^*}{dy} \right)^2 &= 0
\end{align*} \]  
(14)  
(15)

The boundary conditions are

\[ \begin{align*}
u^* = 0, T^* = T_w \text{ at } y^* = h \\
u^* = 0, T^* = T_0 \text{ at } y^* = -h
\end{align*} \]  
(16)

3 SOLUTION OF THE PROBLEM (CASE- 2)

Equations (14) and (15) can be written as

\[ \begin{align*}
\frac{d^2 u}{dy^2} + s \frac{du}{dy} - Mu &= 0 \\
\frac{d^2 \theta}{dy^2} + s Pr \frac{d\theta}{dy} + Ec Pr \left( \frac{du}{dy} \right)^2 &= 0
\end{align*} \]  
(17)  
(18)

With boundary conditions:

\[ \begin{align*}
u = 0, \theta = 1 \text{ at } y = 1 \\
u = 0, \theta = 0 \text{ at } y = -1
\end{align*} \]  
(19)

Solving equations (17) and (18) subject to (19) gives

\[ u = K_1 e^{\alpha y} + K_2 e^{\beta y} + \frac{1}{M} \]  
(20)

Where

\[ \alpha, \beta = \frac{1}{2} \left[ -S \pm \left( S^2 + 4M \right)^{1/2} \right] \]
\[ \theta = L_1 + L_2 e^{-Pr_y} - Br \left[ K_3 e^{2\alpha y} + K_4 e^{2\beta y} + K_4 e^{(\alpha+\beta)y} \right] \]  

(21)

4 RESULTS AND DISCUSSION

Entropy generation on Magneto hydrodynamic in a channel with suction/suction is examined in this section. In both instances, figures illustrate the impact of a non-dimensional governing attribute on velocity, temperature, Bejan number, and Entropy generation. Various flow characteristics are depicted in Figures 3 through 18 for the first case, in which the flow is situated among a migrating and a fixed porous plate, and in Figures 19 through 34 for the second scenario, in which the flow is among two parallel stable porous plates attributable to a pressure gradient.

Figure 3: Case 1: Velocity versus Magnetic parameter \( M \) when \( S = 0.5 \)
Figure 4: Case 1: Velocity versus suction/injection Parameter $S$ when $M=$1

Figure 5: Case 1: Temperature versus Magnetic parameter $M$ when $S=0.5$, $Br=2$ and $Pr=0.71$
Figure 6: Case 1: Temperature versus suction/injection Parameter \( S \) when \( M = 1, \ Br = 2 \) and \( \Pr = 0.71 \)

Figure 7: Case 1: Temperature versus Prandtl number \( \Pr \) when \( M = 1, \ Br = 2 \) and \( S = 0.5 \).
Figure 8: Case 1: Temperature versus Brinkman number $Br$ when $M = 1$, $S = 0.5$ and $Pr = 0.71$

Figure 9: Case 1: Entropy generation number $Ns$ versus $M$ when $S = 0.5$, $Br = 2$, $Pr = 0.71$ and $Br\Omega^{-1} = 1$. 
Figure 10: Case 1: Entropy generation number $N_s$ versus $S$ when $M=1$, $Br=2$, $Pr=0.71$ and $Br\Omega^{-1}=1$.

Figure 11: Case 1: Entropy generation number $N_s$ versus $Pr$ when $M=1$, $Br=2$, $S=-2,-1.5,-1,-0.5,0.5,1,1.5,2$ and $Br\Omega^{-1}=1$.
Figure 12: Case 1: Entropy generation number $N_s$ versus $Br$ when $M=1$, $Pr=0.71$, $S=0.5$ and $Br\Omega^{-1}=1$.

Figure 13: Case 1: Entropy generation number $N_s$ versus $Br\Omega^{-1}$ when $M=1$, $Pr=0.71$, $S=0.5$ and $Br = 2$.
Figure 14: Case 1: Bejan number versus $M$ when, $S = 0.5$, $Pr = 0.71$, $Br = 2$ and $Br \Omega^{-1} = 1$.

Figure 15: Case 1: Bejan number versus $S$ when, $M = 1$, $Pr = 0.71$, $Br = 2$ and $Br \Omega^{-1} = 1$. 
Figure 16: Case 1: Bejan number versus Pr when, $M = 1$, $S = 0.5$, $Br = 2$ and $Br \Omega^{-1} = 1$.

Figure 17: Case 1: Bejan number versus $Br$ when, $M = 1$, $S = 0.5$, $Pr = 0.71$ and $Br \Omega^{-1} = 1$. 
Figure 18: Case 1: Bejan number versus $Br\Omega^{-1}$ when, $M = 1$, $S = 0.5$, $Pr = 0.71$ and $Br = 2$.

Figure 19: Case 2: Velocity versus Magnetic parameter $M$ when $S = 0.5$.
Figure 20: Case 2: Velocity versus suction/injection Parameter $S$ when $M=1$

Figure 21: Case 2: Temperature versus Magnetic parameter $M$ when $S=0.5$, $Br=2$ and $Pr=0.71$
Figure 22: Case 2: Temperature versus suction/injection parameter $S$ when $M=1$, $Br=2$ and $Pr=0.71$

Figure 23: Case 2: Temperature versus Prandtl number $Pr$ when $M=1$, $Br=2$ and $S$ =0.5
Figure 24: Case 2: Temperature versus Brinkman number $Br$ when $M=1$, $S=0.5$ and $Pr=0.71$

Figure 25: Case 2: Entropy generation number $Ns$ versus $M$ when $S=0.5$, $Br=2$, $Pr=0.71$ and $Br\Omega^{-1}=1$. 
Figure 26: Entropy generation number $N_s$ versus $S$ when $M=1$, $Br=2$, $Pr=0.71$ and $Br\Omega^{-1}=1$.

Figure 27: Entropy generation number $N_s$ versus $Pr$ when $M=1$, $Br=2$, $S=-0.5, 0, 0.5, 1, 1.5, 2$ and $Br\Omega^{-1}=1$. 
Figure 28: Case 2: Entropy generation number $N_s$ versus $B_r$ when $M = 1$, $Pr = 0.71$, $S = 0.5$ and $Br\Omega^{-1} = 1$.

Figure 29: Case 2: Entropy generation number $N_s$ versus $Br\Omega^{-1}$ when $M = 1$, $Pr = 0.71$, $S = 0.5$ and $B_r = 2$.
Figure 30: Case 2: Bejan number versus $M$ when, $S = 0.5, Pr = 0.71, Br = 2$ and $Br\Omega^{-1} = 1$.

Figure 31: Case 2: Bejan number versus $S$ when, $M = 1, Pr = 0.71, Br = 2$ and $Br\Omega^{-1} = 1$. 
Figure 32: Case 2: Bejan number versus Pr when, $M = 1, S = 0.5, Br = 2$ and $Br\Omega^{-1} = 1$.

Figure 33: Case 2: Bejan number versus Br when, $M = 1, S = 0.5, Pr = 0.71$ and $Br\Omega^{-1} = 1$. 
Figure 34: Case 2: Bejan number versus $Br\Omega^{-1}$ when, $M = 1, S = 0.5, Pr = 0.71$ and $Br = 2$.

**Case 1: COUETTE FLOW**

As illustrated in Fig. 3 and 5, the consequence of magnetic field strength $M$ on velocity & temperature is that velocity drops as $M$ increases. This reduction is caused by the effect of Lorentz force acting as a resistance to the flow as expected. From Fig. 5 demonstrate the temperature $\theta$ decrease with increase $M$. The decline is traceable to Lorentz force exerted as a friction to the intended motion. As shown in Figure 5 that the temperature $\theta$ declines as $M$ increases.

The impact of suction/Injection feature $S$ on velocity $u$ and temperature $\theta$ are depicted in Fig. 4 and 6. We discovered that both the velocity and the temperature escalate as $S$ rises. This is valid on a physical level, as fluid suction improves with fluid velocity, hence boosting shearing heating inside the channel. The graphic depicts the temperature fluctuation for various choices of the Prandtl number. It is evident that the temperature of a fluid rises as its volume increases. As a result of this improvement in the Prandtl number, the thermal diffusivity of the conducting fluid drops, resulting in a reduction in the heat created by viscous dissipation inside the channel. While Figs. 7 and 8 illustrate the changes of temperature for distinct Prandtl and Brinkmann numbers. This is due to the fact that as the Brinkmann number rises, the viscous dissipation within the channel becomes more pronounced, causing the temperature to rise as well.
Figures 9-13 show the effects of the various regulating factors on entropy generation Ns inside the channel. The magnetic field characteristic M on the entropy generation quantity Ns diminishes with increasing M attributes at the wall y = 1 and has the reverse pattern at y = 0. According to Fig. 10, the influence of suction/injection component S on the entropy generating quantity Ns is within the channel. It is shown that entropy generation improves with suction (+S) but decreases with injection (+I) near a cooled, static porous plate (-S). Near the advancing hot porous plate, the opposite trend can be noticed. The significance of the Prandtl number Pr on entropy production inside the channel is depicted in Fig. 11. It indicates that Ns rise as Pr increases. As Pr grows, the temperature gradient widens with improvement. Figs. 12 and 13 illustrate the impact of the Brinkman number on entropy production.

We noticed that Ns grows as Br improves. Around the channel surfaces, the impact of Br on entropy production is more significant, but it decreases toward the midline from both permeable plates. It has been found that there is a fluid portion inside the channel wherein Br has no effect on entropy. According to Fig. 14, the effect of increasing magnetic field parameter M attributes on Bejan number Be grows, while the effect of increasing suction/injection component S values on Bejan number Be drops, as shown in Fig. 15. Figs. 16-18 depict the proportion of heat transport irreversibility to total entropy generation. Around the cold, static porous plate, thermal performance irreversibility drives entropy generation, whereas around the hot, circulating porous plate, fluid friction irreversibility is the primary contributor. As Pr rises, it is noticed that the supremacy of heat transport irreversibility grows near the cold static porous plate, while the supremacy of fluid friction irreversibility reduces near the hot conveying porous plate. Near the centerline of the channel, the strength of fluid friction irreversibility on entropy generation is seen to increase as the Prandtl number rises. For all settings of the group characteristic, fluid friction irreversibility leads the entropy generation close to the heated, moving porous surface. In Fig. 17, the Bejan number corresponds to various values of the Brinkman number. For comparatively small quantities of Br, thermal performance irreversibility drives entropy generation around the cold static porous plate, but fluid friction irreversibility leads from the centerline to the hot flowing porous plate. For significant Br numbers, irreversible thermal expansion controls entropy generation close to both channel permeable plates. In furthermore, this figure demonstrates that when the Brinkman number grows, the majority of heat
transport irreversibility near the porous plates of the increasing efficiency, while the supremacy of fluid friction irreversibility around the centerline also rises. In this graphic, there is a fluid area inside the channel wherein Br has no influence. Both heat transport and fluid friction directly contribute to the overall entropy generation (Be = 0.5) at the specified portion.

Fig. 18 depicts the spatial patterns of the Bejan number inside the channel for varying values of the group characteristic (BrΩ⁻¹). This figure illustrates that for comparatively small ranges of (BrΩ⁻¹), heat transport irreversibility leads entropy generation close to the cold, static porous surface (y = 1), but as (BrΩ⁻¹) improves, thermal performance irreversibility eventually yields to fluid friction irreversibility.

Case 2: PRESSURE-DRIVEN POISEUILLE FLOW

Figs. 19 and 21 illustrate the consequence of magnetic field component M on velocity u and temperature T patterns. With increasing magnetic field configuration M, a behaviour equivalent to that of Couette flow (Case-1) is observed, while the reverse behaviour is observed for temperature variation T.

Figs. 20 and 22 illustrate the effect of suction/injection component on velocity and temperature. Observed similarities with the Couette flow (Case-1). That is, velocity and temperature improve as suction/injection component S accelerates. Figs. 23, 27, and 32 depict the influence of the Prandtl number Pr on temperature, entropy generation proportion Ns, and Bejan number Be. With an increment in Prandtl number Pr, the temperature, entropy generation number Ns, and Bejan number Be are shown to boost. The consequence of the Prandtl number on temperature is identical to the Couette flow (Case-1). We have observed that thermal performance irreversibility outperforms entropy generation near a cold porous plate, whereas fluid friction irreversibility prevails near a warm porous plate. As Pr grows, it is observed that the superiority of heat transport irreversibility around the cold porous plate intensifies, whereas the influence of fluid friction irreversibility around the hot porous plate is not affected by changes in Pr. As Pr grows close to the centreline, the input of thermal performance irreversibility to the generation of total entropy declines.
Figs. 24, 28, and 33 illustrate the effect of the Brinkmann number $Br$ on temperature, entropy generation value $Ns$, and Bejan number $Be$. Temperature, entropy generation number ($Ns$), and Bejan number ($Be$) have all been noticed to rise when $Br$ climb. The fact that the temperature rises as $Br$ surges is analogous to the Couette flow (Case-1). We noticed that as $Br$ grows, entropy formation due to the irreversibility of fluid friction improves. Therefore, as $Br$ grows, the temperature gradient around the cold porous surface develops.

Figs. 25 and 26 depict the consequences of magnetic field component $M$ and suction/injection quantity $S$ on the entropy generating number $Ns$. The entropy regime reduces with increase $M$ and the reverse behaviour in $Ns$ ith rise $S$. From Fig. 25, we can see that the flow is slowed by the magnetic field's transverse application, and Ohmic dissipation causes a significant temperature increase in the porous channel as $M$ increases. Fig. 26 demonstrates that it increases the impacts of $S$. On the cold porous plate, we noticed that the $Ns$ increases with increasing suction (+$S$) but decreases with increasing injection (-$S$). We contrast the fact that the $Ns$ is greater in the Couette flow (Figure 10) to pressure-driven flow (Fig. 25).

Figs. 29, 30 and 31 are sketched to check the behaviour of $Br\Omega^{-1}$, magnetic parameter (M) and suction/injection parameter (S) on entropy generation and Bejan number respectively. Here, we have noticed from these figures that entropy rate and Bejan number curves are increased against rising estimations of magnetic parameter and $Br\Omega^{-1}$. But inverse behaviour is noticed for suction/injection parameter on Bejan number.

The calculated values of the coefficient for skin friction $C_f$ with velocity for Couette mobility and pressure-driven Poiseuille are provided in Tables 1 and 2 for a variety of suction parameter $S$ and Hartmann number $M$ variables.

According to Table 1, the coefficient for skin friction $C_f$ increases as the suction parameter $S$ rises and falls as the Hartmann number $M$ increases for couette mobility. The coefficient of skin friction $C_f$ drops as the suction parameter $S$ and Hartmann number $M$ increase in Tables 2 for pressure-driven Poiseuille.
In Tables 3 and 4, the calculated values of the thermal transfer rates $\theta'(0)$ and $-\theta'(1)$ for various values of the suction parameter $S$ and the Hartmann number $M$ are listed. It is noticed from Table 3 that the heat transport rate $\theta'(0)$ and $-\theta'(1)$ reduces as the suction parameter $S = -1, -2$ Hartmann number $M$ rises, while the converse occurs as the rotation parameter $K^2$ grows. This is reasonable from a scientific standpoint. With rising values of the rotational factor, the viscous fluid is heated quicker, and as a result, the rate of heat transfer between the surfaces increases.

In tables 3-6, the rate of heat transmission coefficients $\theta'(0)$ and $-\theta'(1)$ for varying values of suction/injection component, magnetic field component, Brinkmann number, and Peclet number are given. According to Table-3, the suction/injection component boosts the heat transfer rate at plate $y=0$ but drops at plate $y=1$.

However, we have detected a complete reversal in the upward trend of magnetic field input variables. Table-4 demonstrates that the suction/injection clearly indicates the heat transmission rate at both surfaces, but the magnetic field component minimizes. The Brinkmann number and Peclet number boost the heat transmission rate at both surfaces in Couette circulation, as seen in Table 5. In moreover, table 6 reveals that both the Brinkmann number and the Peclet number diminish the heat transmission rate at the surface $y=0$, whereas the opposite is true at the surface $y=1$.

Convey the Be matching to various Br values in Figure 34. We noticed that transmission irreversibility outperforms entropy generation close to the cold porous plate, with outright ascendancy occurring around the centre of the channel. From the centreline toward the hot porous plate, fluid friction irreversibility controls, and as the porous plate is reached, thermal performance irreversibility becomes dominant only at massive Br attributes.

**Table 1**

Couette motion: Numerical values of skin friction coefficient for different values of Magnetic parameter $M$ and $S$ with $y = 0$

<table>
<thead>
<tr>
<th>$S \setminus M$</th>
<th>Skin friction $C_f$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
Table 2
Pressure-driven Poiseuille flow: Numerical values of skin friction coefficient for different values of Magnetic parameter $M$ and $S$ with $y = 0$

<table>
<thead>
<tr>
<th>$S \setminus M$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>0.2689</td>
<td>0.1779</td>
<td>0.0987</td>
<td>0.0491</td>
</tr>
<tr>
<td>-1</td>
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<td>0.3235</td>
<td>0.1766</td>
<td>0.0868</td>
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<tr>
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<td>0.5514</td>
<td>0.2995</td>
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<td>0.2361</td>
</tr>
<tr>
<td>2</td>
<td>1.9866</td>
<td>1.3143</td>
<td>0.7290</td>
<td>0.3631</td>
</tr>
</tbody>
</table>

Table 3
Couette motion: Numerical values of Nusselt number for different values of Magnetic parameter $M$ and $S$ with $Br = 0.5$, $Pr = 0.71$ and $y = 0.1$

<table>
<thead>
<tr>
<th>$S \setminus M$</th>
<th>$\theta'(0)$</th>
<th>$-\theta'(1)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>-2</td>
<td>0.8097</td>
<td>0.7628</td>
</tr>
<tr>
<td>-1</td>
<td>1.2482</td>
<td>1.1450</td>
</tr>
<tr>
<td>1</td>
<td>2.6786</td>
<td>2.2933</td>
</tr>
<tr>
<td>2</td>
<td>3.7027</td>
<td>3.0702</td>
</tr>
</tbody>
</table>
Table 4

Pressure-driven Poiseuille flow: Numerical values of Nusselt number for different values of Magnetic parameter $M$ and $S$ with $Br=0.5$, $Pr=0.71$ and $y=0.1$.

<table>
<thead>
<tr>
<th>$S \setminus M$</th>
<th>$\theta'(0)$</th>
<th>$-\theta'(1)$</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>-2</td>
<td>0.3766</td>
<td>0.3676</td>
</tr>
<tr>
<td>-1</td>
<td>0.4670</td>
<td>0.4621</td>
</tr>
<tr>
<td>1</td>
<td>0.4537</td>
<td>0.4585</td>
</tr>
<tr>
<td>2</td>
<td>0.3525</td>
<td>0.3615</td>
</tr>
</tbody>
</table>

Table 5

Couette motion: Numerical values of Nusselt number for different values of brinkman number $Br$ and Prandtl number $Pe$ with $S=0.5$, $M=1$ and $y=0.1$.

<table>
<thead>
<tr>
<th>$Br \setminus Pe$</th>
<th>$\theta'(0)$</th>
<th>$-\theta'(1)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>2.1609</td>
<td>2.5471</td>
</tr>
<tr>
<td>2</td>
<td>2.7397</td>
<td>3.1634</td>
</tr>
<tr>
<td>3</td>
<td>3.3186</td>
<td>3.7798</td>
</tr>
<tr>
<td>4</td>
<td>3.8975</td>
<td>4.3961</td>
</tr>
</tbody>
</table>

Table 6

Pressure-driven Poiseuille flow: Numerical values of Nusselt number for different values of brinkman number $Br$ and Prandtl number $Pe$ with $S=0.5$, $M=1$ and $y=0.1$.

<table>
<thead>
<tr>
<th>$Br \setminus Pe$</th>
<th>$\theta'(0)$</th>
<th>$-\theta'(1)$</th>
</tr>
</thead>
</table>


<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.4199</td>
<td>0.3449</td>
<td>0.2677</td>
<td>0.1988</td>
<td>-0.0376</td>
<td>0.0277</td>
<td>0.0583</td>
<td>0.0697</td>
</tr>
<tr>
<td>2</td>
<td>0.4143</td>
<td>0.3376</td>
<td>0.2597</td>
<td>0.1909</td>
<td>0.0814</td>
<td>0.1341</td>
<td>0.1539</td>
<td>0.1563</td>
</tr>
<tr>
<td>3</td>
<td>0.4087</td>
<td>0.3302</td>
<td>0.2517</td>
<td>0.1831</td>
<td>0.2004</td>
<td>0.2404</td>
<td>0.2496</td>
<td>0.2430</td>
</tr>
<tr>
<td>4</td>
<td>0.4032</td>
<td>0.3229</td>
<td>0.2438</td>
<td>0.1753</td>
<td>0.3193</td>
<td>0.3468</td>
<td>0.3452</td>
<td>0.3296</td>
</tr>
</tbody>
</table>

5 CONCLUSIONS

To design and control pipelines or procedure apparatus, understanding of the flow regime is important since significant flow features for example average and unstable pressure drop, steadiness of throughput and homogeneity of wall refrigerating or heating fluctuate prominently depending upon the flow regime. Inappropriately, forecast of flow regime is a demanding problem that has not yet been solved. The governing system is solved analytically. The main conclusions are

- Entropy generation is greater nearby the cloud porous plate in contrast to the hot porous plate.
- The escalating values of suction/injection parameter boost up the fluid temperature.
- The enhancement of magnetic field parameter affects to decrease the momentum boundary layer.
- The Brinkman number improves the thermal boundary thickness.
- The magnetic field parameter, suction/injection and Brinkmann number accelerates the entropy generation in both cases.
- An increase in Brinkmann number and magnetic field parameter improves the entropy generation.

Conflict of interest: The authors declare no conflict of interest from this submission.

Data availability: All the data are available in the manuscript.

Author contributions: All authors are equally contributed in the research work.
REFERENCES


15. Dileep Singh Chauhan and Vinita Khemchandani, Entropy generation in the Poiseuille flow of a Temperature dependent viscosity fluid through a channel with a naturally permeable wall under thermal radiation, Advances in Applied Science Research, 2016, 7(4): 104-120.


**Nomenclature**

- $\nu$ kinematic viscosity,
- $v_0$ velocity of suction /Injection,
- $\sigma$ electrical conductivity of the fluid,
- $\rho$ fluid density,
- $\nu$ fluid velocity,
- $B_0$ magnetic of strength,
- $C_p$ specific heat at constant pressure,
- $T$ fluid temperature,
$U$ porous plate uniform velocity,

$T_0$ temperature at the lower plate

$T_w$ temperature at the upper plate.

$S$ dimensionless suction/Injection velocity,

$M$ magnetic field parameter,

$Pr$ Prandtl number,

$Ec$ Eckert number,

$(N_c)$- symbolises entropy generation by thermal transport due to axial conduction,

$(N_u)$- denotes entropy generation by thermal transport across various fluid portions inside the channel,

$(N_v)$- reflects the participation of viscous dissipation to entropy generation.
Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Appendix.docx