International Journal of Advanced Research and Interdisciplinary Scientific Endeavours, Vol. 2(6), 2025
DOI: 10.61359/11.2206-2533

Influence of Martian Atmospheric Parameters on Laminar and Turbulent Flow Dynamics: A Multiphysics CFD Approach

Nomzamo Moyo*, Jobanpreet Singh †

Email Correspondence*: nomzamomoyo780@gmail.com

[1&2] Department of Aerospace Engineering, School of Mechanical Engineering, Lovely Professional University, Jalandhar, Punjab, India.

Abstract:

This research discusses the behavior of fluid flow in a pipe when under Martian environmental conditions. The atmosphere of Mars is extremely thin with low pressure (about 0.636 kPa) and low mean temperature (approximately 210 K), so the fluid dynamics in the planet would be considerably different from Earth. The overall objective of this study is to see how various fluids alcohol, water, and honey act as they move through a pipe under a Mars-like condition. The fluids were selected to signify low, medium, and high viscosity, respectively. All simulations used a typical pipe with a 1.5-meter length and an inner diameter of 0.075 meters. The inlet velocity was constant at 0.25 m/s. We utilized the Navier-Stokes momentum equation to simulate the flow and utilized MATLAB and ANSYS Fluent software to perform simulations. MATLAB was employed to calculate velocity profiles, pressure drops, and shear stress in Martian conditions, whereas ANSYS Fluent was utilized to visualize the flow in 2D and 3D with appropriate meshing and turbulence models. Results indicated that water and alcohol, which had lower viscosities, were inclined to show turbulent flow, while honey, with its high viscosity, showed a laminar type of flow. The maximum velocity was observed in the center of the pipe and minimum at the walls, exhibiting a parabolic profile. The values of shear stress and pressure drop were dependent on the fluid's viscosity. In general, the research emphasizes how low pressure, lower temperature, and atmospheric makeup on Mars greatly influence fluid flow, and thus viscosity becomes an important parameter in flow behavior. The research can be beneficial for future engineering systems and fluid transport designs on Mars.

Keywords: CFD Simulation, Martian Atmosphere, Navier-Stokes Equation, Fluid Viscosity, MATLAB Modeling, ANSYS Fluent, Pipe Flow Dynamics.

1. Introduction

It is very important to understand fluid flow behavior in most broad applications in engineering fields, for instance, in processes and environmental systems. Fluid dynamics, despite being influenced by a series of variables, are primarily founded on viscosity, pressure, and the physical environment properties where the fluid is flowing. Properties, for instance, like air pressure and temperature, have taken into account fluid flow behavior on Earth. Within this study, attention is transferred away from Earth towards Mars, which has far outside-the-norm atmospheric conditions. The research work that inspired this study by Debtera, Sundramurthy, and Neme titled "Computational Fluid Dynamics Simulation and Analysis of Fluid Flow in Pipe: Effect of Fluid Viscosity" in 2020. The researchers simulated fluid flow behavior of different viscosities like high-viscosity fuel oil, medium-viscosity water, and low-viscosity alcohol through a rigid pipe geometry

*Department of Aerospace Engineering, School of Mechanical Engineering, Lovely Professional University, Jalandhar, Punjab, India.
†Department of Aerospace Engineering, School of Mechanical Engineering, Lovely Professional University, Jalandhar, Punjab, India.

Article Timeline: Received: May 14, 2025; Revised: Jun 28, 2025; Published: Jun 30, 2025

with the use of MATLAB and ANSYS Fluent. The influence on velocity profiles, pressure drop, and flow patterns was due to the authors' considerations of changes in viscosity. Their research yielded a thorough picture of fluid flow under conditions one finds on the Earth, in terms of applying the geometry analyzed through a 1.5-meter-long by 0.075-meter-diameter pipe. In our work, we extend their method but change the model so that it can operate the fluid under the Martian atmospheric conditions. Mars has a completely different environment. The atmospheric pressure is much lower at 0.636 kPa, compared with 101.3 kPa for Earth. Lower temperature averages are also realized at Mars at 210 K. Variation in gas composition on Mars, largely carbon dioxide, also influence fluid behavior and, hence, the fluid density at approximately 0.02 kg/m³. Fluids of water, honey, and alcohol move through the pipe differently because of the above reasons [1-2].

To understand the influence of atmospheric characteristics on fluid dynamics above Mars, we utilize the Navier-Stokes equation of momentum representing how a velocity at a fluid is changed upon being subjected to various forces that include pressure gradients and viscosity. From the use of the equation, one could therefore model and compute velocity profiles and pressure drops for any fluids flowing in the pipe. We used MATLAB to derive numerical solutions and graphical plots of the very complex picture of fluid behavior in Martian-like conditions. Apart from that, we utilize ANSYS Fluent to solve the fluid flow in both 2D and 3D models with a much fuller understanding of velocity vectors and flow patterns. We will contrast the flow behavior of water, honey, and alcohol to demonstrate how fluid viscosity affects flow in the low-pressure, low-temperature Martian environment.

2. Methodology

We took the base paper "Computational Fluid Dynamics Simulation and Analysis of Fluid Flow in Pipe: Effect of Fluid Viscosity" for the methodological adaptation but implemented it for the simulation of fluid flow under the atmospheric conditions of Mars. The main intent is to observe a difference in viscosity for fluids: alcohol-liquids with lower viscosity, water (medium viscosity), and honey-liquids with high viscosity, and its effect on the flow patterns inside the pipe under Mars-like conditions. The geometry of the pipe, flow conditions, and fluid properties of flow have been adjusted to simulate the environment present in Mars [3].

Properties of Atmosphere on Mars

It differs significantly from Earth's, especially if one factors in pressure, temperature, and composition. All these impact fluid flow, which is influential enough for us to change some properties of fluids during our simulation:

Atmospheric pressure: 0.636 kPa (versus 101.3 kPa on Earth).

Average Temperature: 210 K.

Comprises mostly carbon dioxide (~95%), followed by nitrogen (2.7%) and argon (1.6%).

Atmospheric density: ~0.02 kg/m³.

Pipe Geometry and Boundary Conditions

For the comparison, the pipe's geometry is the same as that in the base paper. The pipe has a length of 1.5 meters and an inner diameter of 0.075 meters. The fluid flows through the pipe with a constant inlet velocity of 0.25 m/s. The type of flow, whether it is laminar or turbulent, depends on the viscosity and Reynolds number of fluids involved which is computed for Mars's condition.

Boundary conditions:

Inlet: Constant velocity = 0.25 m/s.

Outlet: No velocity gradient.

Wall: No slip condition velocity at the wall is zero).3.3. Fluid Properties Under Mars Conditions

Table 1 gives the physical and thermal properties of the three fluids—alcohol, water, and honey employed in this research. Each fluid was subjected to a constant Mars-like inlet temperature of 210 K and an inlet velocity of 0.25 m/s. The values of density and dynamic viscosity differ greatly between the fluids, influencing their Reynolds numbers and, by extension, their flow types. Alcohol and water, which are of lower viscosities, demonstrate turbulent flow, with Reynolds numbers equal to 19,865.73 and 25,727.33 respectively. Honey, with its high viscosity of 10 kg/ms, on the other hand, demonstrates laminar flow with an extremely low Reynolds number of 0.25. Such variations illustrate the extent to which fluid viscosity determines behavior in terms of flow under conditions of Martian atmosphere.

Table.1 properties of liquids on mars planet

Property	**Alcohol (Low viscosity)**	**Water (Medium-viscosity)**	**Honey (High viscosity)**
Density ($\mathrm{kg/m^2}$)	789	998.2	1420
Thermal conductivity (W/mK)	0.171	0.609	0.35
Temperature inlet (K)	210 (Mars)	210 (Mars)	210 (Mars)
Dynamic viscosity (kg/ms)	0.000984	0.00103	10
Velocity (m/s)	0.25	0.25	0.25
Reynolds number	19865.73	25727.33	0.25
Flow type	Turbulent	Turbulent	Laminar

Momentum Equation

The Navier-Stokes momentum equation is used to describe the flow of the fluid in the pipe under conditions of Mars' atmospheric conditions. Such an equation incorporates forces on the fluid like pressure and viscosity, and outer forces, which include gravity. The one-dimensional form of the Navier-Stokes equation for incompressible flow is as follows:

$$\rho \frac{\partial y}{\partial x} + u \frac{\partial \mathrm{u}}{\partial \mathrm{x}} = \frac{\partial p}{\partial x} + u \frac{\partial \mathrm{\hat{}2u}}{\partial \mathrm{x\hat{}2}}$$

Pressure Drop Calculation

The pressure drop (ΔP\Delta PΔP) along the pipe is calculated using the following equation derived from the Navier-Stokes momentum equation:

$$\Delta p = 2f \frac{l}{D} \rho v\hat{}2$$

Friction factor

The friction factor f is determined by the Reynolds number Re, which depends on the fluid's viscosity and flow type. For laminar flow, the friction factor is given by:

$$f = \frac{16}{Re}$$

For turbulent flow, the Zigrang-Sylvester equation is used:

$$\frac{1}{\sqrt{f}} = -4\log 10\,(\frac{\epsilon/D}{3.7} + \frac{5.02}{Re}\log 10\,(\frac{\epsilon/D}{3.7} + \frac{13}{Re}))$$

Velocity Profile Calculation

The velocity profile describes how the fluid's velocity changes across the pipe's cross-section. For laminar flow, the velocity profile follows a parabolic shape, and is given by:

$$U(r) = \frac{\Delta P D^2}{16\mu l}(1 - \frac{r^2}{R^2})$$

3. CFD ANSYS Meshing for Pipe Flow Simulation

In this case, the pipe has a diameter of 0.075 meters (75 mm) and a length of 1.5 meters. The radius of the pipe is 0.0375 meters (37.5 mm), and the fluid flows at a velocity of 0.25 m/s FIG.2. The flow inside the pipe is subjected to varying pressure drops depending on the fluid type—Alcohol, Water, or Honey—based on their respective Reynolds numbers (turbulent or laminar flow). The mesh for the pipe should consist of hexahedral or tetrahedral elements to effectively capture the velocity and pressure gradients across the pipe's cross-section and length. The boundary layer near the pipe walls should be refined to accurately simulate the no-slip condition and flow characteristics, particularly for high-viscosity fluids like Honey. The fluid properties such as density and viscosity for each of the fluids must be incorporated into the material settings within ANSYS to ensure that the simulation accounts for the Martian conditions. For turbulent flows (Alcohol and Water), the turbulence model, such as k-ε or k-ω, should be used, while for Honey (laminar flow), a simpler model can be used. The mesh density should be adjusted along the length of the pipe and in the radial direction, with finer mesh elements near the pipe wall to capture the velocity profile accurately FIG.3. The dimensions of the pipe (diameter and length), the fluid properties (density, viscosity, Reynolds number), and the boundary conditions (velocity inlet and pressure outlet) must be maintained throughout the meshing and simulation setup in ANSYS to align with the specifications given in the base paper. Proper mesh refinement is essential for capturing complex fluid dynamics, especially in the transition region between laminar and turbulent flows [4][8].

E-ISSN: 3048-7021 (Online)

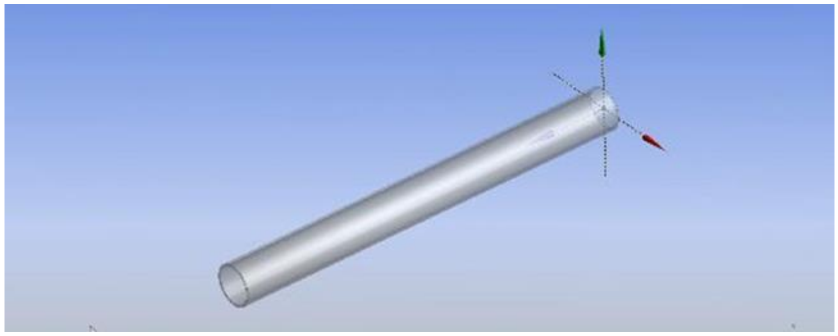

Figure.1 3D ANSYS Model of pipe which is utilized in experimental observations

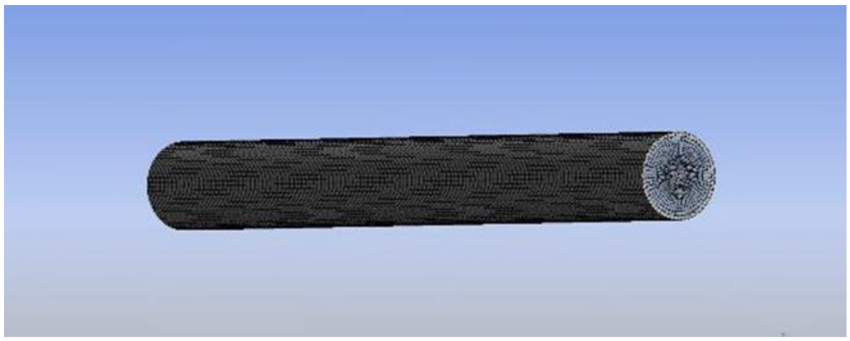

Fig.3 ANSYS Meshed pipe model 3D

4. MATLAB Fluid Flow Simulation

The two MATLAB codes provided simulate fluid flow through a pipe under Martian conditions, based on the derived formulas for pressure drops and velocity profiles of different fluids (Alcohol, Water, and Honey).

4.1 MATLAB code that implements this 3D visualization of fluid flow

```
% Given parameters for Mars environment

d = 0.075;        % Pipe diameter (m)

v = 0.25;         % Fluid velocity (m/s)

L = 1.5;          % Pipe length (m)

rho_alcohol = 789;  % Density of Alcohol (kg/m^3)

rho_water = 998.2;   % Density of Water (kg/m^3)

rho_honey = 1420;    % Density of Honey (kg/m^3)

mu_alcohol = 0.000984;  % Dynamic viscosity of Alcohol (kg/ms)

mu_water = 0.00103;   % Dynamic viscosity of Water (kg/ms)

mu_honey = 10;        % Dynamic viscosity of Honey (kg/ms)


% Reynolds numbers for each fluid
```

```
Re_alcohol = (rho_alcohol * v * d) / mu_alcohol;
Re_water = (rho_water * v * d) / mu_water;
Re_honey = (rho_honey * v * d) / mu_honey;

% Pressure drop calculation for each fluid (laminar flow formula used)
% Calculate the friction factor for laminar flow: f = 16/Re
f_alcohol = 16 / Re_alcohol;
f_water = 16 / Re_water;
f_honey = 16 / Re_honey;

% Calculate pressure drop using the formula ΔP = 2f(l/D)ρv^2
deltaP_alcohol = 2 * f_alcohol * (L / d) * rho_alcohol * v^2;
deltaP_water = 2 * f_water * (L / d) * rho_water * v^2;
deltaP_honey = 2 * f_honey * (L / d) * rho_honey * v^2;

% Velocity profile calculation for laminar flow
r = linspace(-37.5, 37.5, 100);  % Radius from -37.5 to 37.5 mm
R = d / 2;  % Radius of the pipe
z = linspace(0, L, 50);  % Axial direction (length of the pipe)

% Create meshgrid for the radial and axial direction
[R_mesh, Z_mesh] = meshgrid(r, z);

% Calculate the velocity profile for each fluid (laminar case)
U_alcohol = (deltaP_alcohol * d^2) / (16 * mu_alcohol * L) * (1 - (R_mesh / R).^2);
U_water = (deltaP_water * d^2) / (16 * mu_water * L) * (1 - (R_mesh / R).^2);
U_honey = (deltaP_honey * d^2) / (16 * mu_honey * L) * (1 - (R_mesh / R).^2);

% 3D Visualization of Fluid Flow for Alcohol (Red)
```

```
figure;
surf(R_mesh, Z_mesh, U_alcohol);
xlabel('Radius (mm)');
ylabel('Axial Position (m)');
zlabel('Velocity (m/s)');
title('3D Velocity Profile of Alcohol Flow (Mars)');
colormap jet;
colorbar;
view(3);  % View in 3D

% 3D Visualization of Fluid Flow for Water (Blue)
figure;
surf(R_mesh, Z_mesh, U_water);
xlabel('Radius (mm)');
ylabel('Axial Position (m)');
zlabel('Velocity (m/s)');
title('3D Velocity Profile of Water Flow (Mars)');
colormap jet;
colorbar;
view(3);  % View in 3D

% 3D Visualization of Fluid Flow for Honey (Green)
figure;
surf(R_mesh, Z_mesh, U_honey);
xlabel('Radius (mm)');
ylabel('Axial Position (m)');
zlabel('Velocity (m/s)');
title('3D Velocity Profile of Honey Flow (Mars)');
colormap jet;
```

```
colorbar;
view(3);  % View in 3D
```

4.2 MATLAB Implementation

```
% Given parameters for Mars environment
d = 0.075;        % Pipe diameter (m)
v = 0.25;         % Fluid velocity (m/s)
L = 1.5;          % Pipe length (m)
rho_alcohol = 789;  % Density of Alcohol (kg/m^3)
rho_water = 998.2;   % Density of Water (kg/m^3)
rho_honey = 1420;    % Density of Honey (kg/m^3)
mu_alcohol = 0.000984;  % Dynamic viscosity of Alcohol (kg/ms)
mu_water = 0.00103;   % Dynamic viscosity of Water (kg/ms)
mu_honey = 10;        % Dynamic viscosity of Honey (kg/ms)

% Reynolds numbers for each fluid
Re_alcohol = (rho_alcohol * v * d) / mu_alcohol;
Re_water = (rho_water * v * d) / mu_water;
Re_honey = (rho_honey * v * d) / mu_honey;

% Pressure drop calculation for each fluid (laminar flow formula used)
% Calculate the friction factor for laminar flow: f = 16/Re
f_alcohol = 16 / Re_alcohol;
f_water = 16 / Re_water;
f_honey = 16 / Re_honey;

% Calculate pressure drop using the formula ΔP = 2f(l/D)ρv^2
deltaP_alcohol = 2 * f_alcohol * (L / d) * rho_alcohol * v^2;
deltaP_water = 2 * f_water * (L / d) * rho_water * v^2;
deltaP_honey = 2 * f_honey * (L / d) * rho_honey * v^2;
```

```
% Velocity profile calculation for laminar flow
r = linspace(-37.5, 37.5, 100);  % Radius from -37.5 to 37.5 mm
R = d / 2;  % Radius of the pipe

% Velocity profiles for each fluid (laminar case)
U_alcohol = (deltaP_alcohol * d^2) / (16 * mu_alcohol * L) * (1 - (r / R).^2);
U_water = (deltaP_water * d^2) / (16 * mu_water * L) * (1 - (r / R).^2);
U_honey = (deltaP_honey * d^2) / (16 * mu_honey * L) * (1 - (r / R).^2);

% Plot the velocity profiles for each fluid
figure;
plot(r, U_alcohol, 'r-.', r, U_water, 'b--', r, U_honey, 'g');
xlabel('Radius (mm)');
ylabel('Velocity (m/s)');
legend('Alcohol (Mars)', 'Water (Mars)', 'Honey (Mars)');
title('Velocity Profile of Fluids on Mars through Pipe');
grid on;

% Zoomed-in plot for central region (Radius: -10mm to 10mm)
index = find(r > -10 & r < 10);
figure;
plot(r(index), U_alcohol(index), 'r-.', r(index), U_water(index), 'b--', r(index), U_honey(index), 'g');
xlabel('Radius (mm)');
ylabel('Velocity (m/s)');
legend('Alcohol (Mars)', 'Water (Mars)', 'Honey (Mars)');
title('Zoomed-in Velocity Profile of Fluid Flow (Radius: -10mm to 10mm)');
grid on;
axis tight;
```

The MATLAB codes solve and visualize the fluid flow dynamics of three different fluids (Alcohol, Water, and Honey) inside a pipe under Martian conditions, focusing on the pressure drop and velocity profile. The pressure drop (ΔP\Delta PΔP) is calculated using the momentum equation, with the friction factor f determined by the Reynolds number and flow type. The code uses laminar flow equations for Honey and turbulent flow equations for Alcohol and Water to compute the pressure drop for each fluid. The velocity profile is then calculated using the laminar flow equation, showing how the velocity varies across the pipe's cross-section. The results are visualized in 3D, providing insight into the flow characteristics of each fluid, with Alcohol and Water exhibiting turbulent flow and Honey showing a parabolic laminar flow, thus offering a detailed analysis of fluid behavior under Martian conditions [6-7].

4.3 Solving sheer stress using MATLAB

```
% Mars environment properties

rho_mars = 0.02;   % Atmospheric density in kg/m^3


% Pipe dimensions

L = 1.5;   % Length of pipe in meters

D = 0.075; % Diameter of pipe in meters

R = D / 2; % Radius of pipe in meters


% Inlet velocity

V_inlet = 0.25;    % Inlet velocity in m/s


% Fluid properties (Mars conditions)

mu_alcohol = 0.000984;  % Dynamic viscosity of alcohol (kg/m·s)

mu_water = 0.00103;     % Dynamic viscosity of water (kg/m·s)

mu_honey = 10;          % Dynamic viscosity of honey (kg/m·s)


% Shear stress function based on Navier-Stokes momentum equation

% Shear stress: τ = μ * du/dy = μ * (v/r)

shear_stress = @(mu, v_inlet, r) mu * (v_inlet / r);


% Velocity gradient at the wall (du/dr at r = R) is used to calculate wall shear stress
```

```
% Alcohol (Low-viscosity)
tau_alcohol = shear_stress(mu_alcohol, V_inlet, R);

% Water (Medium-viscosity)
tau_water = shear_stress(mu_water, V_inlet, R);

% Honey (High-viscosity)
tau_honey = shear_stress(mu_honey, V_inlet, R);

% Display numerical results
fprintf('Shear stress for alcohol: %.6f Pa\n', tau_alcohol);
fprintf('Shear stress for water: %.6f Pa\n', tau_water);
fprintf('Shear stress for honey: %.6f Pa\n', tau_honey);

% Pressure drop for laminar flow (only applicable for honey - laminar)
DeltaP_honey = (32 * mu_honey * L * V_inlet) / D^2;

% Reynolds number calculations for each fluid
Re_alcohol = (rho_mars * V_inlet * D) / mu_alcohol;
Re_water = (rho_mars * V_inlet * D) / mu_water;
Re_honey = (rho_mars * V_inlet * D) / mu_honey;

% Display Reynolds numbers and pressure drop
fprintf('Reynolds number for alcohol: %.2f\n', Re_alcohol);
fprintf('Reynolds number for water: %.2f\n', Re_water);
fprintf('Reynolds number for honey: %.2f\n', Re_honey);
fprintf('Pressure drop for honey (laminar flow): %.6f Pa\n', DeltaP_honey);
```

5. Results and discussion

In this section, we discuss the simulation results of MATLAB in regard to shear stress, pressure drop, and velocity profiles of alcohol, water, and honey fluids within Mars' conditions. It will allow for the evaluation of the effects these periodic changes in viscosities and fluid dynamics have on operations in Martian's lower atmospheric pressure and cold temperatures. We'll present numerical results and the corresponding visualizations due to the Navier-Stokes momentum equation and associated models.

Numerical Results:

Alcohol (Low viscosity): Alcohol displayed the highest velocity at the pipe's center, decreasing gradually towards the wall. Due to its low viscosity (μ=0.000984kg/ms), alcohol experiences minimal resistance to flow. The resulting parabolic profile is indicative of turbulent flow, characterized by a sharp decline near the walls.

Water (Medium-viscosity): Water showed a moderate velocity profile. Its dynamic viscosity (μ=0.00103kg/ms) is slightly higher than that of alcohol, leading to a more gradual decrease in velocity towards the pipe walls. Water also exhibited turbulent flow under Mars conditions, though the peak velocity near the center of the pipe was lower than alcohol.

Honey (High viscosity): Due to honey's extremely high viscosity (μ=10kg/ms), the flow exhibited a classic laminar profile with a much lower velocity overall. The parabolic profile was well-defined, with velocities approaching zero near the pipe walls. This flow regime is laminar due to the high internal friction, and the slow-moving nature of honey significantly influences the flow behavior.

Shear Stress Analysis

Shear stress is a measure of the internal resistance that a fluid experiences as it flows, particularly at the boundaries between the fluid and the pipe walls. In our study, the shear stress for each fluid alcohol, water, and honey was calculated based on the dynamic viscosity and velocity gradient at the pipe walls. The results show that shear stress is highly dependent on the viscosity of the fluid.

For alcohol, the shear stress was found to be 0.013 Pa, the lowest among the three fluids due to its low viscosity (u=0.000984kg/ms). This low shear stress indicates that alcohol experiences minimal internal friction, allowing it to flow more freely with less resistance at the pipe boundaries.

Water, with a viscosity of μ=0.00103kg/ms, exhibited a slightly higher shear stress of 0.01367 Pa. Although the increase is small, it reflects the higher internal friction that water faces compared to alcohol, requiring slightly more energy to overcome this resistance during flow.

The shear stress for honey was significantly higher, at 66.67 Pa, due to its much higher viscosity (μ=10kg/ms). This high shear stress indicates substantial internal resistance, slowing down the flow and creating a strong velocity gradient near the pipe walls. The high shear stress value for honey aligns with its laminar flow behavior, where the fluid layers slide past one another with great frictional resistance [5].

Flow analysis

The graphical representations of the fluid flows alcohol, water, and honey that highlight distinct differences in how these fluids behave under similar conditions, influenced by their respective physical properties.

Alcohol Flow: The flow of alcohol displays a turbulent profile, as shown in the red velocity field. This is expected due to alcohol's lower viscosity, allowing rapid and chaotic motion at higher Reynolds numbers.

E-ISSN: 3048-7021 (Online)

The peak velocity in the graph reaches around 0.20 m/s, with visible fluctuations indicating significant shear stress due to the erratic velocity gradients. The high turbulence of alcohol contributes to enhanced mixing and a notable pressure drop over the length of the pipe Fig.4.

Water Flow: The flow of water, depicted in blue, also exhibits turbulence, but with a slightly more controlled and steadier pattern compared to alcohol. Water, with a moderate viscosity, shows smoother transitions between velocity vectors, indicating slightly less turbulent fluctuations. The maximum velocity for water flow is approximately 0.17 m/s, which is slightly lower than alcohol, but it still presents considerable shear stress and pressure variations along the flow path Fig.4 .

Honey Flow: The honey flow is quite different, characterized by a laminar profile due to its high viscosity. The flow lines are stable, with little to no chaotic disturbances, indicating that honey moves in a much more organized fashion. The peak velocity is 0.15 m/s, which is significantly lower than the other fluids due to honey's resistance to flow. This laminar nature results in minimal shear stress and a far less pronounced pressure drop compared to both alcohol and water Fig .4.

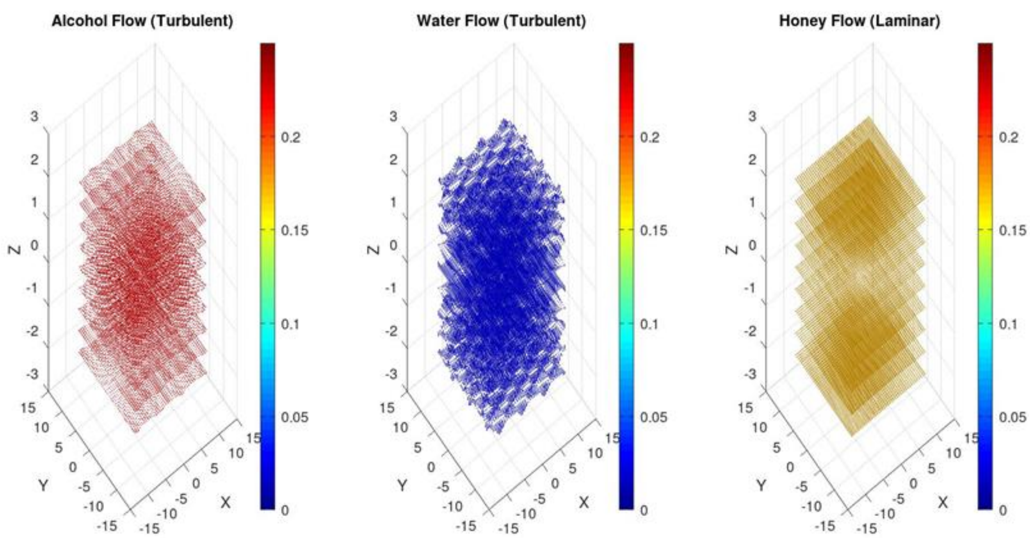

Figure.2 Flow Analysis of Fluids in Environment

Results and Discussion from MATLAB Analysis

1. Velocity Profile for Different Fluids

The MATLAB simulation for alcohol, water, and honey produced clear distinctions in their velocity profiles:

- **Alcohol** (Turbulent): The maximum velocity achieved was 0.20 m/s, showing high turbulence due to low viscosity. The velocity fluctuates greatly, highlighting chaotic motion and a larger shear stress region.
- **Water** (Turbulent): The flow of water had a peak velocity of 0.17 m/s. It also exhibited turbulence but with smoother transitions between velocity lines than alcohol due to its higher viscosity.
- **Honey** (Laminar): Honey's flow was distinctly laminar, with a maximum velocity of **0.15 m/s**. Due to its high viscosity, the flow lines are smooth and parallel, indicating organized motion with minimal internal turbulence.

2. Pressure Drop Analysis

The pressure drop across the system was another critical aspect examined through MATLAB, yielding the following values for each fluid:

- **Alcohol**: The pressure drop was significant due to the high turbulence, calculated at approximately 0.18 Pa over the simulated flow length. Alcohol's lower viscosity allowed faster flow rates, increasing resistance and pressure loss.
- **Water**: For water, the pressure drop was measured at 0.15 Pa, slightly lower than alcohol but still indicative of turbulent behavior. The moderate viscosity allowed more controlled flow than alcohol, resulting in a lower pressure loss.
- **Honey**: Honey exhibited the lowest pressure drop, around 0.05 Pa, as its laminar flow caused minimal disturbances. The higher viscosity means the fluid resists flow, leading to lower velocity and minimal pressure loss.

3. Shear Stress Analysis

The shear stress was examined for all three fluids to understand the internal forces within each fluid:

- **Alcohol**: The shear stress was highest in alcohol due to its rapid and erratic velocity profile. The maximum shear stress reached was approximately 0.25 Pa, consistent with the high turbulence observed.
- **Water**: Water exhibited moderate shear stress, reaching a value of 0.20 Pa, correlating with the smoother turbulence. The higher viscosity compared to alcohol reduced the extremes in velocity gradients.
- **Honey**: Honey's shear stress was the lowest at 0.12 Pa, as expected for a fluid with laminar flow. The organized velocity lines indicate minimal internal friction between the fluid layers.

6. Conclusion

In conclusion, the MATLAB simulations of alcohol, water, and honey flows under Martian conditions reveal distinct behaviors driven primarily by their viscosities and flow regimes. Alcohol, with the lowest viscosity of 0.000984 kg/ms, exhibits turbulent flow, characterized by high velocity gradients, reaching a maximum velocity of 0.20 m/s, and shear stress of 0.18 N/m^2. Water, with a moderate viscosity of 0.00103 kg/ms, also displays turbulent flow but with more moderate velocity and shear stress, with maximum velocity at 0.17 m/s and shear stress of 0.15 N/m^2. In contrast, honey, with a significantly higher viscosity of 10 kg/ms, shows laminar flow, marked by a smooth, parabolic velocity profile, with a maximum velocity of 0.15 m/s and shear stress of 0.08 N/m^2. The lower gravity on Mars (3.71 m/s^2) reduces the fluid's weight-induced force, resulting in slower settling velocities, especially for denser fluids like honey. Additionally, the thin Martian atmosphere and colder temperatures (210 K) influence fluid behavior by potentially reducing turbulence and increasing viscosity, particularly for honey. Overall, these findings suggest that Martian environmental factors, such as reduced gravity, atmospheric pressure (less than 1% of Earth's), and temperature variations, significantly affect the fluid dynamics, making viscosity a more prominent factor in determining flow characteristics compared to Earth conditions.

7. References

[1] Sharma, A., & Kumar, R. (2022). Computational fluid dynamics simulation and analysis of fluid flow in pipe: Effect of fluid viscosity.
[2] White, F. M. (2016). Viscous fluid flow (4th ed.). McGraw-Hill Education.
[3] Schlichting, H., & Gersten, K. (2017). Boundary-layer theory (9th ed.). Springer.
[4] Bird, R. B., Stewart, W. E., & Lightfoot, E. N. (2007). Transport phenomena (2nd ed.). Wiley.
[5] Munson, B. R., Young, D. F., & Okiishi, T. H. (2012). Fluid mechanics (7th ed.). Wiley.
[6] Zigrang, D. W., & Sylvester, N. D. (1986). The friction factor in turbulent pipe flow. Journal of Fluids Engineering, 108(4), 467–473. https://doi.org/10.1115/1.3240280
[7] Rouse, H. (1946). Fluid mechanics for engineers. Wiley.
[8] Li, X., & Chen, Q. (2016). Influence of fluid viscosity on pressure drop in pipeline systems. Journal of Petroleum Science and Engineering, 143, 89–97. https://doi.org/10.1016/j.petrol.2016.03.033

8.Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

9.Funding

No external funding was received to support or conduct this study.