# PROJECT

## Nozzle Expansion Ratio and Thrust Analysis using MATLAB

## Aim

Calculate Thrust using isentropic flow relations. Observe the changes with different nozzle expansion ratios, then visualize them by plotting them through MATLAB.

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## Introduction

Rocket Propulsion systems require controlled expansion of gases to generate the required thrust. The nozzle design plays a significant role in the thrust generated.
In this Project, we will simulate thrust as a function of the nozzle's expansion ratio. Then see how it varies with varying exit areas of the nozzle.

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## Procedure:

- Open a New MATLAB script.
- Define the required constants:
    - Gravitational acceleration.
    - Specific Heat Ratio.
    - Specific Gas Constant.
    - Combustion chamber temperature.
    - Combustion chamber pressure.
    - Exit pressure.
    - Ambient pressure.
    - Throat Area.

      (The narrowest point in the nozzle where the flow is choked)
- Create an array of area ratios of the nozzle.
- Use the following formulas to calculate the exit pressure, exhaust velocity, mass flow, and thrust. Then plot the calculated thrust against the area ratios.

  Exit Pressure formula:

  $$v_2 = \sqrt{\frac{2gk}{k-1} RT_1 \left[1 - \left(\frac{p_2}{p_1}\right)^{(k-1)/k}\right] + {v_1}^2}$$

  Mass flow formula:

  $$\mathbf{Q} = \mathbf{VA}$$

  $$\mathbf{m} = \boldsymbol{\rho}\mathbf{Q} = \boldsymbol{\rho}\mathbf{VA}$$

  Thrust formula:

  $$\boxed{\text{Thrust :} \quad F = \dot{m}\, V_e + (p_e - p_0)\, A_e}$$

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<u>This is the Matlab code required</u>

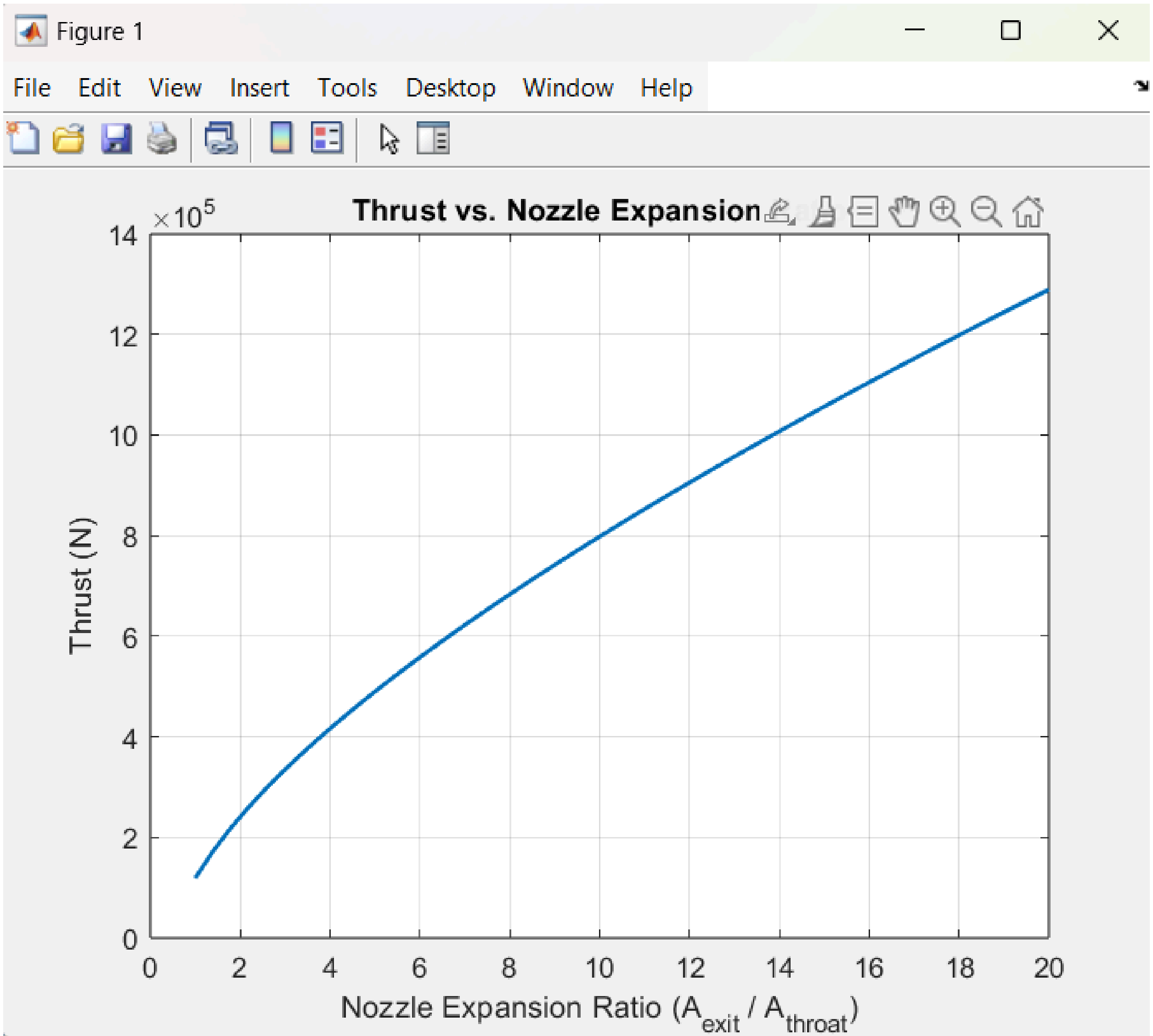
```
% Required constant
g = 9.81;            % Gravitational acceleration (m/s²)
heatRatio_gamma = 1.33;         % Specific heat ratio (Cp/Cv)
R = 259;             % Specific gas constant for air (or any working
fluid) (J/kg·K)
Temp_chamber = 3200;    % combustion chamber temperature (K)
Pressure_chamber = 8e6;    % combustion chamber pressure (Pa)
Pressure_ambient = 5e4;     % Ambient pressure, this basically includes
the atmospheric effects on thrust (Pa)
throatArea = 0.015;     % throat area, this is the narrowest point of
the nozzle where flow is choked (m²)
%  range for area ratio and calculating the exit area
areaRatios = linspace(1, 20, 50); % Range of expansion ratios (A_exit /
A_throat)
areaExits = throatArea * areaRatios;
% creating the thrust array
thrusts = zeros(size(areaRatios));
for i = 1:length(areaRatios)
   % calculating exit pressure using isentropic flow relations
   P_exit = Pressure_chamber * (1 / areaRatios(i))^((heatRatio_gamma -
1) / heatRatio_gamma);

   % ideal exhaust velocity
   v_exit = sqrt((2 * heatRatio_gamma / (heatRatio_gamma - 1)) * R *
Temp_chamber * (1 - (P_exit / Pressure_chamber)^((heatRatio_gamma - 1) /
heatRatio_gamma)));

   % mass flow rate calculation
   rho = Pressure_chamber / (R * Temp_chamber);  % Density of gas in the
chamber
   m_dot = rho * throatArea * v_exit;    % Mass flow rate (kg/s)

   % calculate thrust
   thrusts(i) = m_dot * v_exit + (P_exit - Pressure_ambient) *
areaExits(i);
end
% plotting thrust vs area ratio
figure;
plot(areaRatios, thrusts, 'LineWidth', 1.5);
grid on;
xlabel('Nozzle Expansion Ratio (A_{exit} / A_{throat})');
ylabel('Thrust (N)');
title('Thrust vs. Nozzle Expansion Ratio');
```

## Results / Observations:




- The graph seems to be non-linear due to isentropic conditions.
- Thrust rises as the Nozzle Expansion Ratio increases, this in turn optimizes exhaust flow.
- We also note that thrust maximizes when exit pressure matches ambient pressure.

## Limitation:

- This code assumes ideal gas behavior and ignores losses due to heat and pressure.
- We assume ambient pressure to be constant, but for practical real-life applications, ambient pressure is subject to vary.

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## Conclusion:

The MATLAB code calculates and visualizes the effects on the thrust generated as the nozzle expansion ratio is changed. The results highlight the importance of optimizing the nozzle expansion ratio to maximize thrust.

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