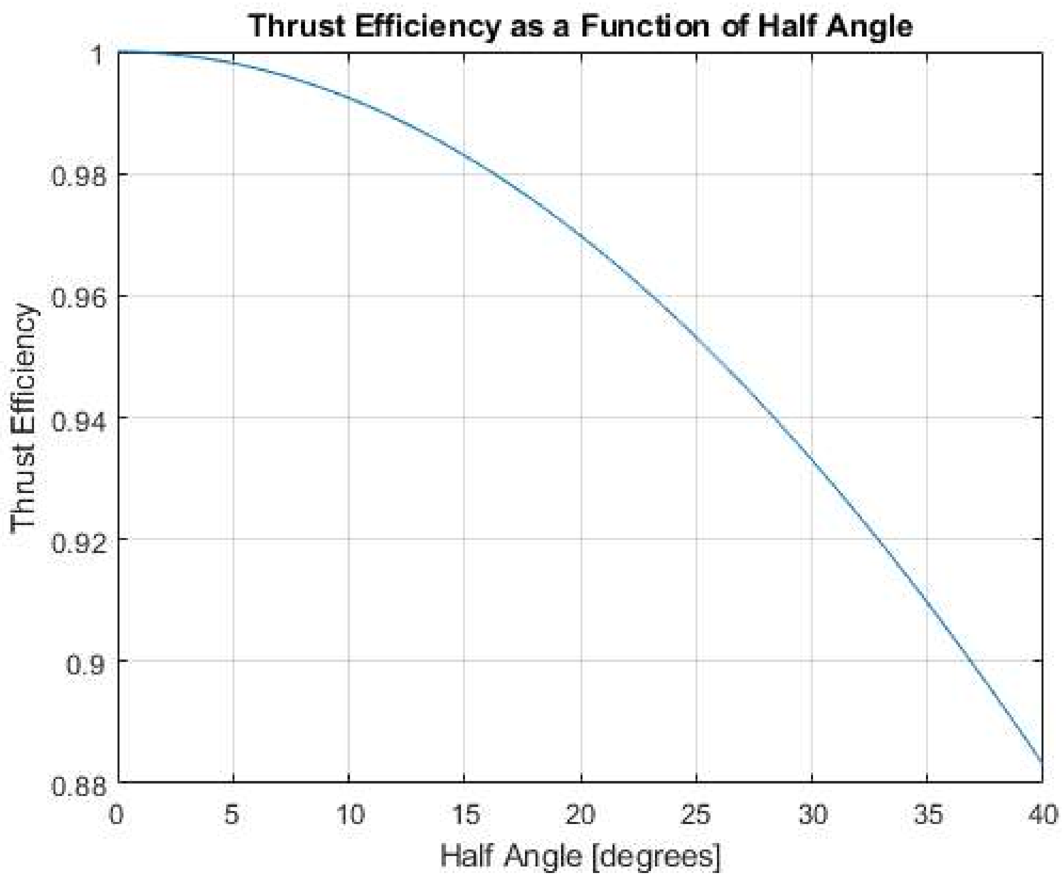
Contents


```
clear all; close all;

pamb_ground = 90000;  pamb_apogee = 18000;  Pa = 10000; % [Pascals]

Pc = 2068000;    % [Pascals]
Tc = 700;        % [Kelvin]

R = 188.91;                           % [J/kgK] Gas Constant for Nitrous Oxide
Cp = 50.5/.046;  Cv = Cp-R;           % [J/kgK]  of NO2 @ ~700 Kelvin 300psi
k = Cp/Cv;                            % Ratio of specific heats nitrous oxide

mass_prop = 0.0053536538*920;         % [kg] Total mass of HTPB
q = (mass_prop/6)+1;                      % [kg/s] HTPB mass flow rate: assume all mass used ov
er 6 seconds evenly

g = 9.81;                             % gravity constant [m/s]
Ldiv = .1524;                         % length of diverging section [m] 6 inches
At = pi*(.019/2)^2;                   % [meters^2] setting throat diameter at .75 inches

Pt = Pc*(1+((k-1)/2))^(-k/(k-1));     % [Pascals] Throat pressure
Tt = Tc/(1+((k-1)/2));                % [Kelvin] Throat temperature

% At = (q/Pt)*sqrt((R*Tt)/(g*k));     % [meters^2]

Nm = sqrt((2/(k-1))*(((Pc/Pa)^((k-1)/k))-1));                      % Mach Number of flow at Nozz
le Exit

Ae = (At/Nm)*((1+((k-1)/2)*Nm^2)/((k+1)/2))^((k+1)/(2*(k-1)));  % [meters^2] exit area

ER = Ae/At;                           % [ ] Expansion ratio

Dt = 2*sqrt(At/pi);                   % [m] Throat Diameter
De = 2*sqrt(Ae/pi);                   % [m] Exit Diameter

alpha = atand(((De-Dt)/2)/Ldiv);      % [degrees] Half Angle

lambda = (1+cosd(alpha))/2;           % [ ] Thrust efficiency
```

Varying Parameters alpha and lambda

```
alpha1 = linspace(0,40,100);     % [degrees] Half Angle
lambda1 = (1+cosd(alpha1))/2;    % [ ] Thrust efficiency

figure('name','Lambda Plot')
plot(alpha1,lambda1)
title('Thrust Efficiency as a Function of Half Angle')
xlabel('Half Angle [degrees]')
ylabel('Thrust Efficiency')
```

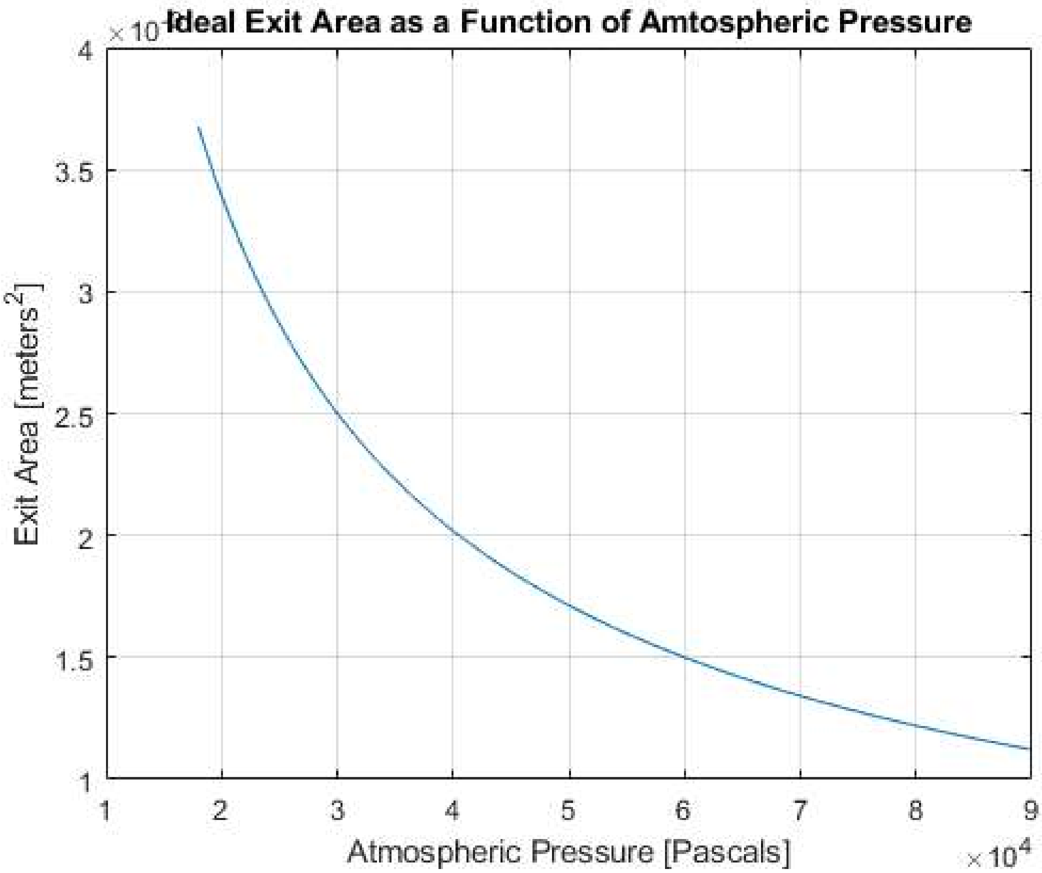
```
grid on
```



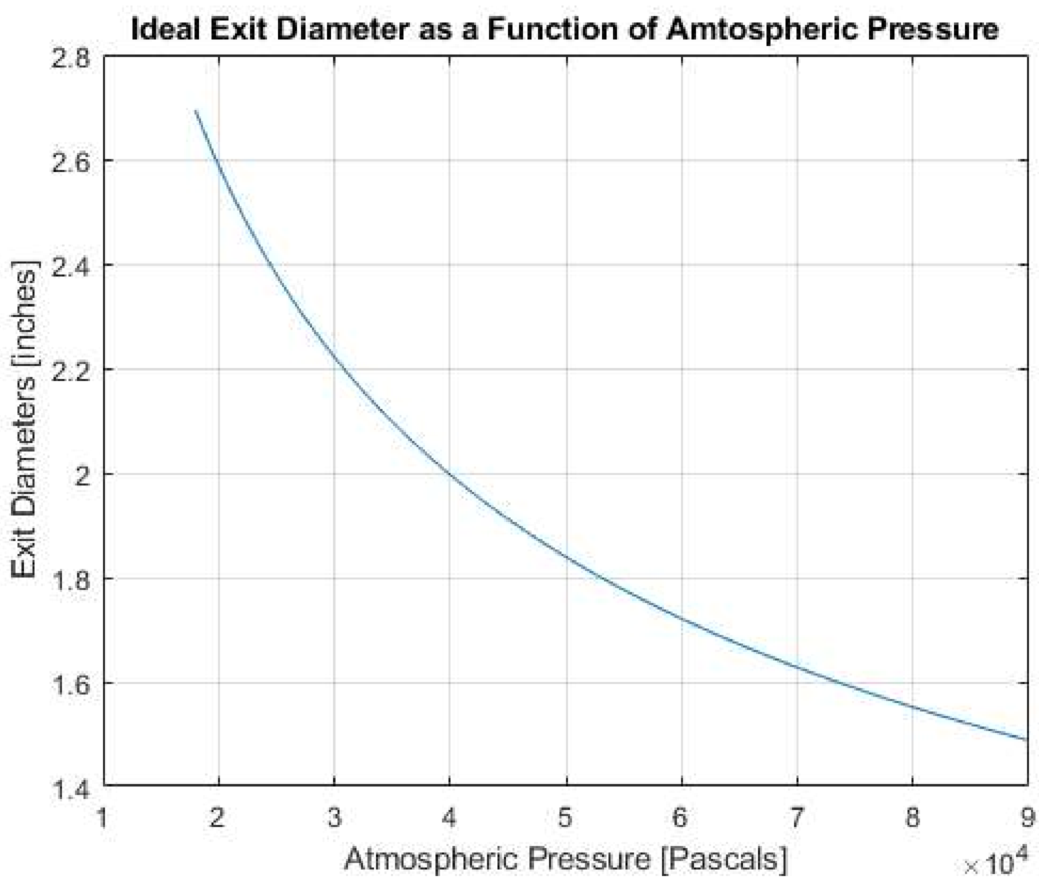
Varying Parameters atmospheric pressure vs optimal diameter

```
clear all;

pamb_ground = 90000;  pamb_apogee = 18000;

Pa = linspace(pamb_apogee,pamb_ground,100); % [Pascals]

Pc = 2068000;   % [Pascals]
Tc = 700;       % [Kelvin]

R = 188.91;                           % [J/kgK] Gas Constant for Nitrous Oxide
Cp = 50.5/.046;  Cv = Cp-R;           % [J/kgK]  of NO2 @ ~700 Kelvin 300psi
k = Cp/Cv;                            % Ratio of specific heats nitrous oxide

mass_prop = 0.0053536538*920;         % [kg] Total mass of HTPB
q = (mass_prop/6)+1;                      % [kg/s] HTPB mass flow rate: assume all mass used ov
er 6 seconds evenly

g = 9.81;                             % gravity constant [m/s]
Ldiv = .1524;                         % length of diverging section [m] 6 inches
At = pi*(.019/2)^2;                   % [meters^2] setting throat diameter at .75 inches

Pt = Pc*(1+((k-1)/2))^(-k/(k-1));    % [Pascals] Throat pressure
Tt = Tc/(1+((k-1)/2));                % [Kelvin] Throat temperature
```

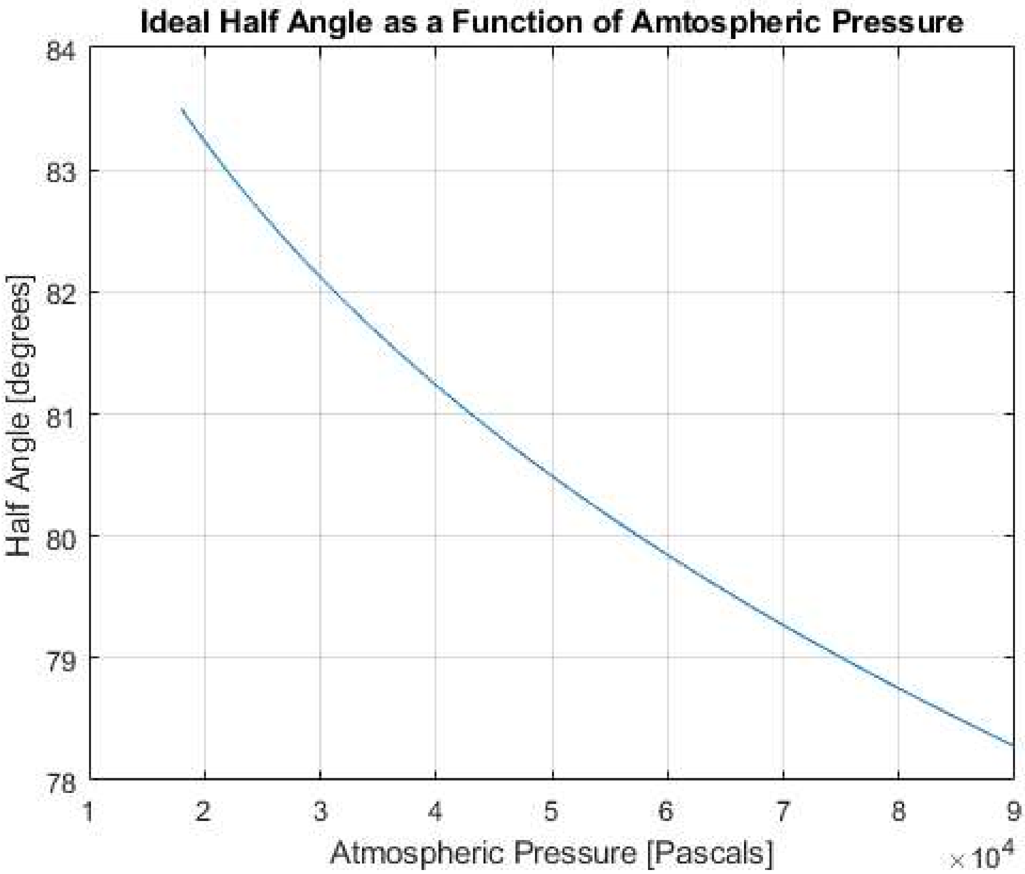
```
% At = (q/Pt)*sqrt((R*Tt)/(g*k));   % [meters^2]

for i = 1:length(Pa)
    Nm(i) = sqrt((2/(k-1))*(((Pc/Pa(i))^((k-1)/k))-1));                   % Mach Number of fl
ow at Nozzle Exit
end

for i = 1:length(Pa)
    Ae(i) = (At/Nm(i))*((1+((k-1)/2)*Nm(i)^2)/((k+1)/2))^((k+1)/(2*(k-1)));  % [meters^2] exi
t area
end

for i = 1:length(Pa)
    ER(i) = Ae(i)/At;                                % [ ] Expansion ratio
end

Dt = 2*sqrt(At/pi);                 % [m] Throat Diameter
De = (2*sqrt(Ae/pi))/.0254;                 % [m] Exit Diameter

alpha = atand(((De-Dt)/2)/Ldiv);    % [degrees] Half Angle

lambda = (1+cosd(alpha))/2;         % [ ] Thrust efficiency

figure('name','Ae plot')
plot(Pa,Ae)
title('Ideal Exit Area as a Function of Amtospheric Pressure')
xlabel('Atmospheric Pressure [Pascals]')
ylabel('Exit Area [meters^2]')
grid on

figure('name','De plot')
plot(Pa,De)
title('Ideal Exit Diameter as a Function of Amtospheric Pressure')
xlabel('Atmospheric Pressure [Pascals]')
ylabel('Exit Diameters [inches]')
grid on

figure('name','Alpha plot')
plot(Pa,alpha)
title('Ideal Half Angle as a Function of Amtospheric Pressure')
xlabel('Atmospheric Pressure [Pascals]')
ylabel('Half Angle [degrees]')
grid on
```



Ideal Exit Area as a Function of Amtospheric Pressure
Exit Area [meters^2]
Atmospheric Pressure [Pascals]
$\times 10^4$



Ideal Exit Diameter as a Function of Amtospheric Pressure
Exit Diameters [inches]
Atmospheric Pressure [Pascals]
$\times 10^4$



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