X-43 Scram Jet Analysis: Dan Lawson

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%% Constants and Variable Initialization

% Initialize Variables and Constants

M0 = 7;
V0 = 2107; % (m/s)
T0 = 225.5; % (K)
H = 28974; % Altitude of operation (m)
P0 = 1397; % (Pa)
h_pr = 43903000.25; % fuel heat of reaction for JP-7 (J/kg)
%h_pr = 87806000 % h_pr of hydrogen as example
f = 0.04; % Fuel to Air ratio
R = 289.3; % Gas Constant (m/s)^2 / K
C_pc = 1090; % Spec Heat for engine combustion (J/KgK)
C_pb = 1510; % Spec Heat for engine burning (J/KgK)
C_pe = 1510; % Spec Heat for engine expansion region (J/KgK)
grav = 9.8; % gravity constant (m/s^2)

Vfx_V3 = 0.5; % Ratio of fuel injection axial velocity to combustion
entrance velocity
Vf_V3 = 0.5; % Ratio of fuel injection total velocity to combustion
entrance velocity
CfAw_A3 = 0.1; % Burner effective drag coefficent
eta_c = 0.9; % Inlet compression system efficiency
eta_b = 0.9; % burner efficiency
eta_e = 0.9; % Expansion efficiency
P10_P0 = 1.4; % Ratio of exit static pressure and freestream pressure
gamma_c = 1.362; % Spec heats ratio, compression
gamma_e = 1.238; % Spec heats ratio, expansion
gamma_b = 1.238; % Spec heats ratio, burner

L = 14020; % Lift force (N) at AoA = 4 deg
D = 3942; % Drag force (N) at AoA = 4 deg
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% Stages 0 -> 1, Compression

% Stream Thrust Function, station zero
Sa0 = V0 * (1 + ((R*T0) / (V0^2)));


phi = 2.75;


% Combustor Entrance Temp (K)
T3 = phi * T0;

% Combustor Entrance Velocity (m/s)
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V3 = sqrt(V0^2 - (2 * C_pc * T0 * (phi - 1)));

% Stream Thrust at combustor entrance
Sa3 = V3 * (1 + (R*T3 / V3^2));

% Combustor to Free stream pressure ratios
P3_P0 = ( phi / ((phi - phi*eta_c) + eta_c))^(C_pc / R);

% Combustor Pressure
P3 = P3_P0 * P0;

% Combustor to freestream area ratio
A3_A0 = phi * (P0 / P3) * (V0 / V3);
```

```
% Stages 3 -> 4, Combustion

% Combustor Exit Velocity
V4 = V3 * ((1 + f*Vfx_V3) / (1 + f)) - ((CfAw_A3 / (2*(1 + f))));

%V4 = 1863.7

hf = 0; % No value lsited, found this intitialized as zero

% Combustor Exit Temperature
T4 = (T3 / (1 + f)) * (1 + (1 / (C_pb*T3)) * (eta_b * f * h_pr + f * hf + f
* C_pb * T0 + (1 + f * (Vf_V3^2)) * 0.5 * V3^2)) - (V4^2 / (2*C_pb));

% Combustor exit to combustor inlet ratio
A4_A3 = (1 + f) * (T4 / T3) * (V3 / V4);

% Stream Thrust, Combustor Exit
Sa4 = V4 * (1 + ((R*T4) / (V4^2)));
```

```
% Stages 4 -> 10, Expansion

P4 = P3;

% Engine Exit Temp (K)
T10 = T4 * (1 - eta_e * (1 - (P10_P0 * (P0/P4))^(R / C_pe)));

% Engine Exit Velocity (m/s)
V10 = sqrt(V4^2 + 2*C_pe*(T4 - T10));

% Stream Thrust Function, Engine Exit
Sa10 = V10 * (1 + ((R*T10) / (V10^2)));

% Engine Exit to freestream entrance area ratio
```

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A10_A0 = (1 + f) * (1 / P10_P0) * (T10 / T0) * (V0 / V10);
```

```
% Performance Metrics

% Engine Specific Thrust (N/(Kg/sec)) or (N*sec / Kg)
F_mdot0 = Sa10*(1 + f) - Sa0 - (R * T0)/V0 * (A10_A0 - 1);

% Engine Specific Fuel Consumption (Kg / N*sec)
S = f / (F_mdot0);

% Overall Engine Efficiency
eta_0 = (V10/V0 - 1) * (V0^2 / (f*h_pr));

% Engine Specific Impulse (sec)
Isp = (h_pr / (grav*V0)) * eta_0;

% Engine Thermal Efficiency
eta_th = ((V10^2) - (V0^2)) / (2 * f * h_pr);

% Engine Propulsion Efficiency
eta_p = eta_0 / eta_th;

% Station 3 Mach Number - Compression
M3 = V3 / sqrt(gamma_c * R * T3);

% Station 4 Mach Number - Burner
M4 = V4 / sqrt(gamma_b * R * T4);

% Station 10 Mach Number - Exit
M10 = V10 / sqrt(gamma_e * R * T10);

fprintf('M =  %g', M0)
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```
M =  7
```

```
fprintf('V0 =  %g', V0)
```

```
V0 =  2107
```

```
fprintf('T0 =  %g', T0)
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```
T0 =  225.5
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fprintf('F / m_dot =  %g', F_mdot0)
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```
F / m_dot =  326.244
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```
fprintf('S =  %g', S)
```

```
S =  0.000122608
```

```
fprintf('Isp =  %g', Isp)
```

```
Isp =  501.501
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```
fprintf('Eta_0 =  %g', eta_0)
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```
Eta_0 =  0.235868
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```
fprintf('Eta_th =  %g', eta_th)
```

```
Eta_th =  0.246871
```

```
fprintf('Eta_p =  %g', eta_p)
```

```
Eta_p =  0.955428
```

```
fprintf('M3 =  %g', M3)
```

```
M3 =  3.82727
```

```
fprintf('M4 =  %g', M4)
```

```
M4 =  2.43407
```

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fprintf('M10 =  %g', M10)
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```
M10 =  3.83918
```

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fprintf('T3 =  %g', T3)
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```
T3 =  620.125
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fprintf('T4 =  %g', T4)
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```
T4 =  1622.4
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```
fprintf('T10 =  %g', T10)
```

```
T10 =  1005.23
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% For level flight at AoA = 4 deg, Thrust = Drag = 3942 N
% Determine fuel mass flow rate, m_dot

m_dot = D / F_mdot0;


fprintf('m_dot =  %g kg/s at level flight with AoA = 4 deg', m_dot)
```

```
m_dot =  12.083 kg/s at level flight with AoA = 4 deg
```