AERO 360
Design Project
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Spring 1996

Given: Air enters the combustor of a jet engine at $u_1 = 100 \ \frac{m}{s}$ $P_1 = 100.0 \ kPa$, $T_1 = 300 \ K$

Design: A combustor and converging-diverging nozzle with circular cross section for a thruster.

Rank-Ordered Design Criteria:

1. $F_{thrust} = \frac{Your \ Social \ Security \ Number}{1 \times 10^7} \ kN$
2. shockless supersonic flow when $P_b = 100 \ kPa$
3. combustion in a constant area section of duct; maximum heat addition $= 10,000 \ \frac{kJ}{kg}$
4. $T_{max} < 1500 \ K$
5. minimum combustor length $= 0.2 \ m$
6. no condensed N_2 in duct
7. $\left|\frac{dr}{dx}\right| < 0.15$ in the converging section
8. $\left|\frac{dr}{dx}\right| < 0.05$ in the diverging section
9. minimum overall duct length
10. minimum peak cross-sectional area

Assumptions:

- the air is modelled well by properties of diatomic nitrogen N_2.
- the mass of the combustion gases is negligbly small; the combustion process can be modelled by specifying a wall heat flux, q_w

Final design due: April 30, 1996, Give $A(x)$, $P(x)$, $T(x)$, $M(x)$ under supersonic design conditions. Give $P(x)$ for the same $A(x)$ for one intermediate back pressure, $P_{supersonic \ design} < P_b < P_o$. For full credit include the effects of Darcy friction, normal shocks in duct, and non-ideality. I recommend a van der Waals state equation, with a temperature dependent specific heat. With a as one of the van der Waals coefficients which can be determined for critical point data, a good fit for Nitrogen is

$$e = -88.6 \ \frac{kJ}{kg} + \left(0.7448 \frac{kJ}{kg \ K}\right)(T - 298 \ K) + a(\rho_o - \rho), \qquad 0 \ K < T < 500 \ K$$

$$e = -88.6 \ \frac{kJ}{kg} + \left(0.7448 \frac{kJ}{kg \ K}\right)(T - 298 \ K) + \left(0.00008 \frac{kJ}{kg \ K^2}\right)(T - 298 \ K)^2 + a(\rho_o - \rho)$$
$$500 \ K < T < 2000 \ K$$

The report must be prepared as formal technical memoranda (written using LaTeX). Include a brief statement of the problem in your own words and a summary of your results. Number all figures and refer to each figure in the text. Your text should indicate if and how you met all design criteria. Include footnoted references if necessary. Detailed analysis should be included as you feel necessary. This should be relegated to appendices which can be done either in LaTeX or neatly handwritten.