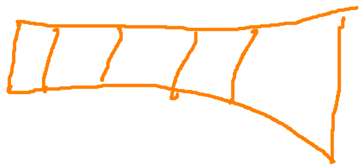


$$\frac{d\rho}{\rho} + \frac{du}{u} + \frac{dA}{A} = 0$$

$$\frac{dp}{\rho} + u\,du = \frac{-\tau_w\, c\, dA}{\rho A} + \eta\,\delta\dot{w}$$

$$C_p\,dT + u\,du = \delta q + \delta\dot{w}$$

$$\frac{dp}{p} = \frac{d\rho}{\rho} + \frac{dT}{T}$$

$$\frac{d\rho}{\rho} \Rightarrow \frac{\rho_i - \rho_{i-1}}{\rho_i} + \frac{u_i - u_{i-1}}{u_i} + \frac{A_i - A_{i-1}}{A_i} = 0$$

$$\frac{\rho_i - \rho_{i-1}}{\rho_i} + u_i(u_i - u_{i-1}) = \frac{-\tau_w\, c\,(A_i - A_{i-1})}{\rho_i A_i} + \eta\,\delta\dot{w}$$

$$C_p(T_i - T_{i-1}) + u_i(u_i - u_{i-1}) = \delta q + \delta\dot{w}$$

$$\frac{p_i - p_{i-1}}{p_i} = \frac{\rho_i - \rho_{i-1}}{\rho_i} + \frac{T_i - T_{i-1}}{T_i}$$

$$\begin{bmatrix} 1 - \rho_{i-1} & 1 - u_{i-1} & 0 & 0 \\ & & & \\ & & & \end{bmatrix} \begin{bmatrix} \rho_i \\ u_i \\ p_i \\ T_i \end{bmatrix} \quad \frac{-(A_i - A_{i-1})}{A_i}$$

(1) $$[J]^k \{\Delta x\}^k = -\{f\}^k$$

(2) $$\bar{x}^k = \Delta x^k + x^k$$

Solve (1) with gauss-Seidel

$$\frac{A_1}{A^*} \div \frac{A_2}{A^*} \qquad \frac{A_2}{A_1} \cdot \frac{A_1}{A^*} \qquad .8\bar{3} \times 1.09$$

1) $\frac{A_2}{A_1} = 5.32 \Rightarrow M_2 = .99$

302.4 K

5)

$\frac{T_{te}}{T_{ti}} = 4.29$

$T_{te} = 1297\text{ K}$

2) M2 = 0.55696
3) M2 = 035467

$T_{ti} = 334.656\text{ K}$

$\frac{T_{te}}{T_{Ti}} = .5587$

$T_{te} = 185.328$

$P_{ti} = 171371\text{ pa}$

$\frac{P_{tp}}{P_{ti}} = .126385$

7)

$$\frac{d\rho}{\rho} + \frac{du}{u} + \frac{dA}{A} = 0$$

$$\frac{dP}{\rho} + u\,du = -\frac{\tau_w\, c\, dx}{\rho A} + \eta\, \delta w$$

$$c_p\, dT + u\,du = \delta q + \delta w$$

$$\delta q_{conv} = C_p C_f (T_w - T_t)\frac{dx}{D}$$

$$\frac{dP}{P} = \frac{d\rho}{\rho} + \frac{dT}{T}$$

Q1

Monday, April 12, 2021 3:05 PM

$$\frac{d\rho}{\rho} + \frac{du}{u} + \frac{dA}{A} = 0$$

$$\frac{dP}{\rho} + u\,du = 0$$

$$c_p\,dT + u\,du = 0$$

$$\frac{dP}{P} = \frac{d\rho}{\rho} + \frac{dT}{T}$$

$$\frac{G(M_e^2)}{G(M_i^2)} = \frac{A_e}{A_i} \Rightarrow M_e$$

$\delta w = 0$

$\delta q = 0$, revers.

$U_i = M_i\sqrt{\gamma R T_i} = 238.1219\ m/s$

$\dot{m} = \rho u A = 29.1699\ kg/s$

$G(M_i^2) = 1.09437$

$M_e = .099945$

$T_{ti} = \left(1 + \frac{\gamma-1}{2} M_1^{\,2}\right) T_i = 316.224\ K$

$P_{ti} = \left(1 + \frac{\gamma-1}{2} M_i^2\right)^{\gamma/(\gamma-1)} P_i = 140548.043\ pa$

$$P_e = \frac{P_{te}}{\left(1 + \frac{\gamma-1}{2} M_e^2\right)^{\gamma/(\gamma-1)}} = 139568.7153\ pa$$

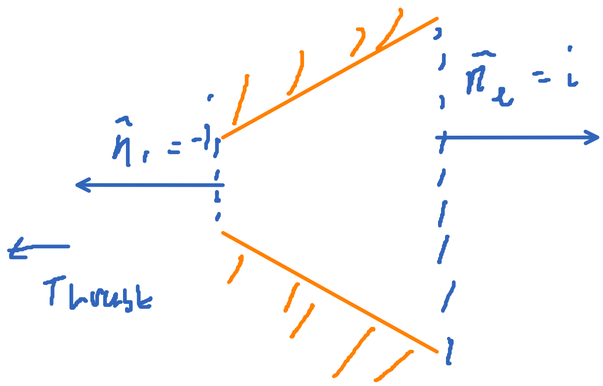
$$T_e = \frac{T_{te}}{1 + \frac{\gamma-1}{2} M_e^2} = 315.593$$

$U_e = M_e\sqrt{\gamma R T_e} = 35.608\ m/s$

$\text{Thrust} = -\left[\dot{m}(u_e - u_i) + P_e A_e - P_i A_i\right]$

$= -\left[29.1699\,(35.608 - 238.1219) + 139568.7153 \times .532 - 101325 \times .1\right]$

$= -5821.0\ N$



$$\sum F_x = \int_{cs} u \rho \bar{u} \cdot \hat{n} \, dA = \int_{S_{cv}} p \hat{n} \, dA + \int_{S_{cv}} \tau_w \, dA$$

$$\text{Thrust} = -\int_{cs_{wet}} p \hat{n} \, dA - \int_{cs_{wet}} \tau_w \, dA$$

$$\text{Thrust} = \int_{cs} u \rho \bar{u} \cdot \hat{n} \, dA + \int_{cs_{in/out}} p \hat{n} \, dA$$

Q2

Monday, April 12, 2021 5:59 PM

$$\frac{d\rho}{\rho} + \frac{du}{u} + \cancel{\frac{dA}{A}} = 0$$

$$\frac{dp}{\rho} + u\,du = -\cancel{\frac{\tau_w \, c \, dx}{\rho A}} + \cancel{\eta\,\delta w}$$

$$c_p\,dT + u\,du = \delta q + \cancel{\delta w}$$

$$\frac{dp}{p} = \frac{d\rho}{\rho} + \frac{dT}{T}$$

$$f(M_1^2) = \left\{\frac{1+\frac{\gamma-1}{2}M_1^2}{(1+\gamma M_1^2)^2}\right\} M_1^2 = .036175$$

$$T_{ti} = t_i\left(1+\frac{\gamma-1}{2}M_1^2\right) = 290.304 \qquad P_{ti} = 104190.5846\,pa$$

$$\frac{T_{te}}{T_{ti}} = 1 + \frac{q_{1\to 2}}{c_p T_{ti}} = 1 + \frac{10e6}{1004.5 \cdot 290.304} = 4.4292$$

$$f(M_e^2) = .160147 \Rightarrow M_e = .5569$$

$$u_e = M_e\sqrt{\gamma R T_e} = 388.46228$$

$$T_{te} = 1285.824\ K$$

$$T_e = \frac{T_{te}}{1+M_e^2\frac{\gamma-1}{2}} = 1210.709\ K$$

$$\frac{P_2}{P_1} = \frac{1+\gamma M_1^2}{1+\gamma M_2^2} = .7362507 \Rightarrow P_2 = 74600.60408\ Pa$$

$$P_{t2} = P_2\left(1+\frac{\gamma-1}{2}\right)^{\gamma/(\gamma-1)} = 92095.48146\ pa$$

$$\dot m = \rho U A = 83.3426\ kg/s \qquad U_i = 68.0348\ m/s$$

$$\text{thrust} = -\left[\dot{m}(u_e - u_i) + (P_e - P_i)A_e\right]$$

$$= -[8.3426(388.465 - 68.0348) + (74600.60408 - 101325) \times 0.1)]$$

$= -1.775638$ N thrust

Q3

Monday, April 12, 2021 8:50 PM

$$\frac{d\rho}{\rho} + \frac{du}{u} + \frac{dA}{A} = 0$$

$$\frac{dP}{\rho} + u\,du = -\frac{\tau_w\, C\, dx}{\rho A} + \cancel{\eta\, \delta w}\ 0$$

$$c_p\, dT + u\,du = \cancel{\delta q} + \cancel{\delta w}$$

$$\frac{dP}{P} = \frac{d\rho}{\rho} + \frac{dT}{T}$$

$$f_v(M_1^2) = \frac{\gamma+1}{2} \ln\left[\frac{1+\frac{\gamma-1}{2}M_1^2}{M_1^2}\right] - \frac{1}{M_1^2} = -21.128$$

$$\gamma\, C_f\, \frac{C}{A} L = f_{v_2} - f_{v_1}$$

$$\gamma\, C_f\, \frac{4}{D} L + f_{v_1} = 5.4327 \qquad f_v(M_2^2) \Rightarrow M_2 = .3564$$

$$T_{t1} = T_{t2} = (1+.2^3) \times 288 = 290.304\ k$$

$$T_2 = \frac{T_{t2}}{\left(1+\frac{\gamma-1}{2}M_2^2\right)} = \frac{290.304}{1+.2\cdot .3564^2} = 283.1117k$$

$$P_2 = P_1 \frac{M_1}{M_2}\left[\frac{1+\frac{\gamma-1}{2}M_1^2}{1+\frac{\gamma-1}{2}M_2^2}\right]^{1/2} = 56375.659\ pa$$

$$Pt_2 = P_2\left(1+\frac{\gamma-1}{2}M_2^2\right)^{\gamma/\gamma-1} = 61549.488\ Pa$$

$$u_2 = M_2\sqrt{\gamma R T_2} = 120.2047\ m/s$$

$$u_0 = 68.0348\ m/s \qquad \dot{m} = 8.7343\ kg/s$$

$$\text{thrust} = -\left[\dot{m}(u_2 - u_1) + (p_2 - p_1)A_2\right]$$

$$= -\left[8.3343\left(1120.2047 - 68.0348\right) + \left(56375.659 - 101325\right) \cdot 0.1\right]$$

$$= 4000.134\ \text{N}$$

$$\frac{d\rho}{\rho} + \frac{du}{u} + \frac{dA}{A} = 0$$

$$\frac{dp}{\rho} + u\,du = -\frac{\tau_w\, C\, dx}{\rho A} + \cancel{\delta w} \quad \Rightarrow$$

$$c_p\, dT + u\,du = \delta q + \cancel{\delta w}$$

$$\frac{dp}{p} = \frac{d\rho}{\rho} + \frac{dT}{T}$$

$$\frac{d\rho}{\rho} + \frac{du}{u} + \cancel{\frac{dA}{A}} = 0$$

$$\frac{dp}{\rho} + u\,du = -\frac{\tau_w\, C\, dx}{\rho A}$$

$$c_p\, dT + u\,du = \delta q = 2 c_p c_f (T_w - T_t)\frac{dx}{D}$$

$$\frac{dp}{p} = \frac{d\rho}{\rho} + \frac{dT}{T}$$

No work interaction or Area variation

Q5

Tuesday, April 13, 2021 4:04 PM

$$\frac{d\rho}{\rho} + \frac{du}{u} + \frac{dA}{A} = 0$$

$$\frac{dP}{\rho} + u\,du = \eta\,\delta w \;;\; \eta = 1$$

$$c_p\,dT + u\,du = \delta w$$

$$\frac{dP}{P} = \frac{d\rho}{\rho} + \frac{dT}{T}$$

$$\frac{T_{T2}}{T_{t1}} = 1 + \frac{W_{1\to 2}}{c_p T_{t1}} \;;\; T_{t1} = T_1\left(1 + \frac{\gamma-1}{2}M_1^2\right) = (1 + .2 \cdot .5^2) \cdot 288 = 302.4\text{ K}$$

$$\frac{T_{t2}}{T_{T1}} = 1 + \frac{10e6}{1004.5(302.4)} = 4.2921 \Rightarrow T_{T2} = 1297.92026\text{ K}$$

$$P_{t1} = P_1\left(1 + \frac{\gamma-1}{2}M_1^2\right)^{\gamma/\gamma-1} = 120192.9955\text{ pa}$$

$$P_{t2} = P_{t2}\left(\frac{T_{t2}}{T_{t1}}\right)^{\gamma/\gamma-1} = 19688418.31\text{ pa}$$

$$M_e \Rightarrow P_{te}\sqrt{\gamma/R\,\frac{1}{T_{te}}}\,M_e\left(1 + \frac{\gamma-1}{2}M_e^2\right)^{\frac{-(\gamma+1)}{2(\gamma-1)}} = \dot{m} = 20.8357\text{ kg/s}$$

$$M_e = .1099703$$

$$P_2 = \frac{P_{t2}}{\left(1 + \frac{\gamma-1}{2}M_2^2\right)^{\gamma/\gamma-1}} \approx 19522651.36\text{ pa}$$

$$T_2 = \frac{T_{t2}}{\left(1 + \frac{\gamma-1}{2}M_2^2\right)} = 1294.78848\text{ K}$$

$$u_2 = M_2\sqrt{\gamma R T_2} = 79.319467\text{ m/s}$$

$$u_1 = 170.087\text{ m/s}$$

$thrust = \dot{m}(u_e - u_1) + P_e A_e - P_i A_i$

$= -(8.334(79.319467 - 170.87) + 19640903.66(.005) - 101325*.1) = -86717.77616$ N

Q6

Friday, April 9, 2021 9:56 PM

$$\frac{d\rho}{\rho} + \frac{du}{u} + \frac{dA}{A} = 0$$

$$\frac{dp}{\rho} + u\,du = -\frac{\tau_w \cancel{\epsilon}\, dx}{\cancel{\rho} A} + \eta\, \delta w$$

$$c_p\, dT + u\,du = \cancel{\delta q} + \delta w$$

$$\frac{dp}{p} = \frac{d\rho}{\rho} + \frac{dT}{T}$$

$$T_{ti} = T_i\left(1 + \frac{\gamma-1}{2} M_i^2\right) = 288 \cdot (1 + .2 \times .9^2) = 334.654\ k$$

$$\frac{T_{Te}}{T_{Ti}} = 1 + \frac{w_{i\to e}}{c_p T_{ti}}$$

$$= 1 + \frac{-1.5 \times 10^5}{1004.5 \cdot T_{ti}} = .554 \implies T_{Te} = 185.328\ k$$

$$P_{ti} = p_i\left(1 + \frac{\gamma-1}{2} M_i^2\right)^{\gamma/(\gamma-1)} = 101325(1 + .2 \times .9^2)^{1.4/.4} = 171371\ pa$$

$$\frac{P_{te}}{P_{ti}} = \left(\frac{T_{te}}{T_{ti}}\right)^{1.4/.4} = .12639 \implies P_{te} = 21658.897\ pa$$

$$M_e = P_{te}\sqrt{\gamma/R \frac{1}{T_{te}}}\, M_e \left(1 + \frac{\gamma-1}{2} M_e^2\right)^{\frac{-(\gamma+1)}{2(\gamma-1)}} \implies M_e = .598$$

$$T_e = T_{Te} / \left(1 + \frac{\gamma-1}{2}\right) \implies T_e = 172.957\ k \quad P_e = 17007\ N/m^2$$

$$u_e = M\sqrt{\gamma R T_e} = 157.644\ m/s$$

$$\text{Thrust} = m(u_e - u_i) + P_e A_e - P_i A_i$$

$$-[37.5042(157.644 - 306.1367) + 17007 \times .7 - 101325 \cdot .1 = +3223.148\ N$$

drag

$$\dot{m}\, c_p (T_{te} - T_{ti}) = \qquad \left(\frac{\dot{w}}{\dot{m}}\right)\dot{m} = \dot{w}$$

$\Rightarrow \dot{m} C_p (T_{hi} - T_{h1})$

Q7

Tuesday, April 13, 2021 4:06 PM

$$\frac{d\rho}{\rho} + \frac{du}{u} + \frac{dA}{A} = 0$$

$$\frac{dp}{\rho} + u\,du = -\frac{\tau_w\, C\, dx}{\rho A} + \eta\, \delta w$$

$$c_p\, dT + u\,du = 2 c_p c_f (T_w - T_t)\frac{dx}{D} + \delta w$$

$$\frac{dp}{p} = \frac{d\rho}{\rho} + \frac{dT}{T}$$

Work interaction with area variation with irreversibility with convective heat transfer, i.e., all the terms

$$c_p\, dT_t = q + w$$

$$q = c_p\, dT_t - w$$

$$\dot{Q} = (c_p\, dT_t - w)\,\dot{m}$$