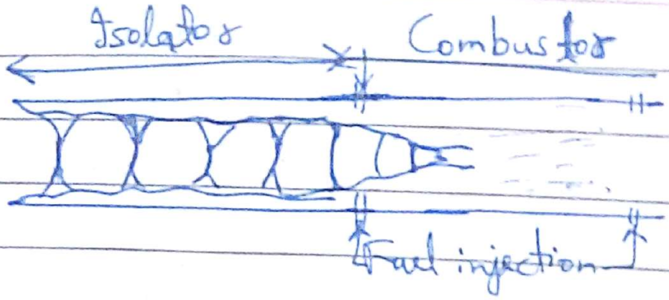
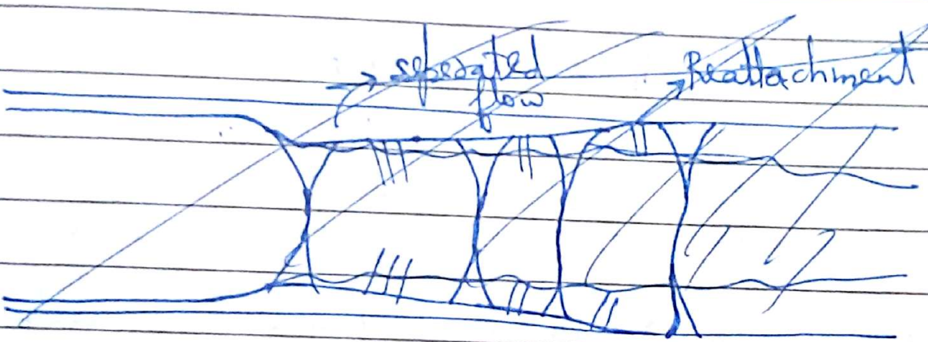
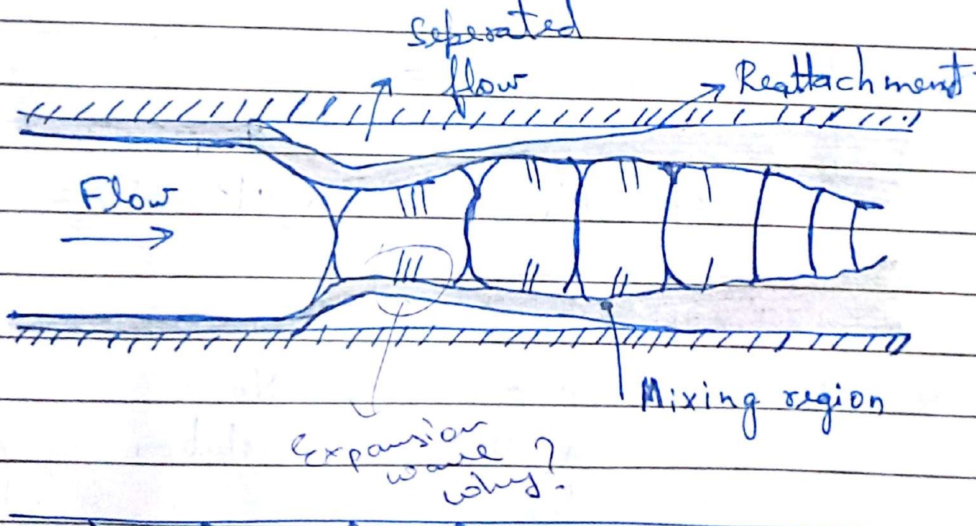
Isolator

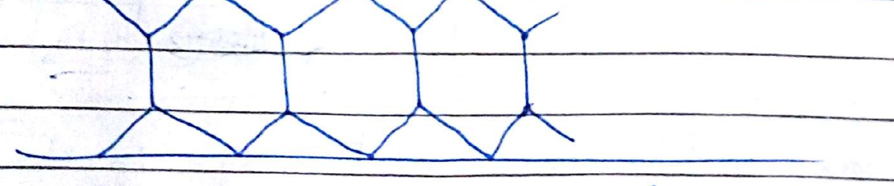
Geometry:

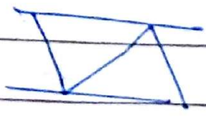


Function: The disturbances generated by heat-release in the combustor can propagate upstream and affect the operation of the inlet. 'Isolator' is used to avoid that.

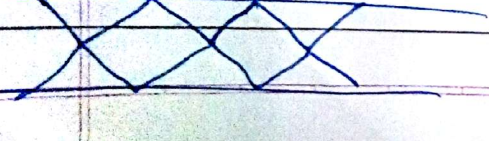








Simplistic Model



Questions:

3 1 why does the boundary layer reattach?
2 2 How to add Fanno analysis to the isolator?
1 3 How does it work (isolator)?

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$$\frac{dP}{dx} = \frac{8g}{D_h} C_{f_0} \frac{\rho V^2}{2} \rightarrow (1)$$

$$dH_0 = Q_R f_{st} d\phi - dQ$$

$$\tau_w = \frac{C_f \rho V^2}{2}, \quad A_w = \frac{4 A\, dx}{D_h}$$

$$\frac{d\rho}{\rho} + \frac{dV}{V} + \frac{dA_c}{A_c} = 0$$

$$\frac{dp}{p} + \ldots$$

$M, p, A_c, x, T_0,$

$M = \frac{V}{a}$

$a = \left(\frac{V}{M}\right)$

Derivation of equation ③:

$$h_0 = h + \frac{1}{2}V^2$$

$$C_p T_0 = C_p T + \frac{1}{2}V^2$$

$$T_0 = T + \frac{V^2}{2C_p} = T + \frac{TV^2(\gamma-1)}{2\gamma RT}$$

$$T_0 = T + \frac{TV^2(\gamma-1)}{2a^2}$$

$$T_0 = T + \frac{T(\gamma-1)M^2}{2} = T\left(1+\frac{(\gamma-1)}{2}M^2\right)$$

$$\log(T_0) = \log T + \log\left(1+\frac{(\gamma-1)}{2}M^2\right)$$

$$\frac{dT_0}{T_0} = \frac{dT}{T} + \frac{1}{1+\left(\frac{\gamma-1}{2}\right)M^2}\, d(M^2)\left(\frac{\gamma-1}{2}\right)$$

$$\boxed{\left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{dT_0}{T_0}} = \left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{dT}{T} + d\left(V^2/a^2\right)\left(\frac{\gamma-1}{2}\right)$$

$$= \left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{dT}{T} + \left(\frac{\gamma-1}{2}\right)\left(\frac{d(V^2)a^2 - V^2 d(a^2)}{a^4}\right)$$

$$= \left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{dT}{T} + \left(\frac{\gamma-1}{2}\right)\left(\frac{d(V^2)}{a^2} - \frac{M^2 d(a^2)}{a^2}\right)$$

$$= \left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{dT}{T} + \left(\frac{\gamma-1}{2}\right)\left(\frac{M^2 d(V^2)}{V^2} - \frac{M^2 dT}{T}\right)$$

$$= \boxed{\frac{dT}{T} + \left(\frac{\gamma-1}{2}\right)M^2\frac{d(V^2)}{V^2}}$$

$$\cancel{= \left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{dT}{T} + \frac{\gamma RT}{V^2}\,\frac{d(V^2)\,a^2 - d(a^2)V^2}{a^4}}$$

$$\cancel{= \left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{dT}{T} + \frac{d(V^2)}{V^2} - \frac{d(a^2)}{a^2}}$$

$$\cancel{= \left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{dT}{T} + \frac{d(V^2)}{V^2} - \frac{\gamma R(dT)}{\gamma RT}}$$

$$\cancel{= \left(\frac{\gamma-1}{2}\right)M^2\frac{dT}{T} + \frac{d(V^2)}{V^2}}$$

$\underline{M}, p, \underline{A_c}, x, T_0, \boxed{\rho, T, V}$

(indep. var.)

$$\frac{d\rho}{\rho} + \frac{dV}{V} + \frac{dA_c}{A_c} = 0 \rightarrow (1)$$

$$\frac{dp}{p} - \frac{d\rho}{\rho} - \frac{dT}{T} = 0 \rightarrow (2)$$

$$\frac{d(M^2)}{M^2} = -\left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\left[\frac{dp/p}{\frac{\gamma M^2}{2}\frac{A_c}{A}} + \frac{4C_f\,dx/D}{\frac{A_c}{A}} + \frac{dT_0}{T_0}\right] \rightarrow (3)$$

$$\frac{d(A_c/A_2)}{(A_c/A_2)} = \left[\frac{1-M^2\{1-\gamma(1-A_c/A_2)\}}{\gamma M^2 A_c/A_2}\right]\frac{dp}{p} + \frac{\left(1+(\gamma-1)M^2\right)}{2A_c/A_2}\frac{4C_f\,dx}{D}$$

$$+\left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{dT_0}{T_0} \rightarrow (4)$$

$$\frac{dM^2}{M^2} - \frac{dV^2}{V^2} + \frac{dT}{T} = 0 \rightarrow (5)$$

$$\frac{dp}{dx} = \frac{89}{D_h}C_{f_0}\left(\frac{\rho V^2}{2}\right) \rightarrow (6)$$

$$T_0 = T_{02} + \frac{(Q_R f_{st}\,\phi\,\eta_c - dQ)}{c_p}$$

$$\eta_c = \eta_{c,tot}\left[\frac{\theta X}{1+(\theta-1)X}\right] \Rightarrow \eta_c = ✓$$

$$X = \frac{(x-x_3)}{(x_4-x_3)}$$

$x_3 = 0.2\ m$

$x_4 = 0.5\ m$ $\Rightarrow X = \dfrac{(x-0.2)}{0.3}$

$\theta = 5$

$\eta_{c\,tot} = 0.8$

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$$\frac{dp}{p} + \frac{\gamma M^2}{2}\frac{4C_f\,dx}{D} + \frac{\gamma M^2}{2}\frac{A_c}{A}\frac{dV^2}{V^2} = 0$$

$$\frac{dp/p}{\frac{\gamma M^2}{2}\frac{A_c}{A}} + \frac{\frac{4C_f\,dx}{D}}{\frac{A_c}{A}} + \frac{dV^2}{V^2} = 0$$

$$\frac{dV^2}{V^2} = \frac{\left(\left(1+\frac{\gamma-1}{2}M^2\right)\frac{dT_t}{T_t} - \frac{dT}{T}\right)}{\left(\frac{\gamma-1}{2}\right)M^2}$$

$$\Rightarrow \left(\frac{dp/p}{\frac{\gamma M^2}{2}\frac{A_c}{A}} + \frac{\frac{4C_f\,dx}{D}}{A_c/A}\right) + \frac{\left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{dT_t}{T_t} - \frac{dT}{T}}{\left(\frac{\gamma-1}{2}\right)M^2} = 0$$

$$\rightarrow \quad \frac{dp}{dx} = \frac{8g}{D_h}C_{f_0}\left(\frac{\rho V^2}{2}\right).$$

$$\rightarrow \left(\ \cdots\ \right) + \left(\frac{1}{\left(\frac{\gamma-1}{2}\right)M^2} + 1\right)\frac{dT_t}{T_t} - \frac{\frac{dT}{T}}{\left(\frac{\gamma-1}{2}\right)M^2} = 0$$

$$\left[\left(\ \cdots\ \right) + \frac{dT_t}{T_t}\right] = \frac{\left(\frac{dT}{T}\right)}{\left(\frac{\gamma-1}{2}\right)M^2} - \frac{dT_t/T_t}{\left(\frac{\gamma-1}{2}\right)M^2}$$

$$\frac{dp/p}{\frac{\gamma M^2}{2}\frac{A_c}{A}} + \frac{\frac{4C_f\,dx}{D}}{A_c/A} + \frac{dM^2}{M^2} + \frac{dT}{T} = 0$$

$$\cancel{T_t = T\left(1+\frac{\gamma-1}{2}M^2\right)}$$

$$\cancel{\frac{dT_t}{T_t} = \frac{dT}{T}\left(\quad\cdots\quad\right) + T}$$

Derivation of equation (9):

$$\frac{dp}{p} + \frac{\gamma M^2}{2}\frac{4C_f\,dx}{D} + \frac{\gamma M^2}{2}\frac{A_c}{A}\frac{dV^2}{V^2} = 0 \rightarrow (5)$$

$$\frac{dT}{T} + \left(\frac{\gamma-1}{2}\right)M^2\frac{dV^2}{V^2} = \left(1+\frac{\gamma-1}{2}M^2\right)\frac{dT_t}{T_t} \rightarrow (6)$$

$$\frac{dM^2}{M^2} - \frac{dV^2}{V^2} + \frac{dT}{T} = 0 \rightarrow (8)$$

From (6), $\frac{dT}{T} = \left(1+\frac{\gamma-1}{2}M^2\right)\frac{dT_t}{T_t} - \left(\frac{\gamma-1}{2}\right)M^2\frac{dV^2}{V^2}$

∴ ~~Putting th~~ Put this in (8)

$$\Rightarrow \frac{dM^2}{M^2} - \frac{dV^2}{V^2} + \left(1+\frac{\gamma-1}{2}M^2\right)\frac{dT_t}{T_t} - \left(\frac{\gamma-1}{2}\right)M^2\frac{dV^2}{V^2} = 0$$

$$\Rightarrow \frac{dM^2}{M^2} + \left(1+\frac{\gamma-1}{2}M^2\right)\left(\frac{dT_t}{T_t} - \frac{dV^2}{V^2}\right) = 0 \rightarrow (i)$$

From (5),

$$\frac{dV^2}{V^2} = \frac{-dp/p}{\frac{\gamma M^2}{2}\frac{A_c}{A}} - \frac{\frac{4C_f\,dx}{D}}{(A_c/A)} \rightarrow (ii)$$

Put (ii) in (i).

$$\boxed{\frac{dM^2}{M^2} = -\left(1+\frac{\gamma-1}{2}M^2\right)\left[\frac{dp/p}{\frac{\gamma M^2}{2}\frac{A_c}{A}} + \frac{\frac{4C_f\,dx}{D}}{A_c/A} + \frac{dT_0}{T_0}\right]} \rightarrow (9)$$

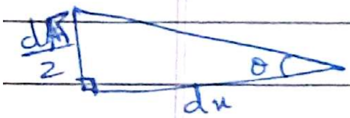
Derivation of equation (2) :

ΣF_x = rate of change of momentum

$$\Sigma F_x = PA_0 - (P+dP)(A_0+dA_0)$$

$$-\frac{1}{2}\rho V^2 C_f \frac{(A+A+dA)\,dx}{2}$$

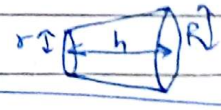
$$-\frac{1}{2}\rho V^2 C_f\,\pi(R+R+dR)\sqrt{(R+dR-R)^2+(dx)^2}\cdot 1$$



$$\cos\theta = \frac{dx}{\sqrt{(dx)^2+\left(\frac{dR}{2}\right)^2}} \approx 1$$

C.S.A. of a frustum of cone

$$= \pi(R+r)\sqrt{(R-r)^2+h^2}$$



$$\Sigma F_x = PA_0 - (P+dP)A_0 - \frac{1}{2}\rho V^2 C_f\, 2\pi R\, dx$$

$$= -A_0\,dP - \frac{1}{2}\rho V^2 C_f\, 2\pi R\, dx$$

Rate of change of momentum = mom. flux exiting − mom. flux entering

$$= \dot m(V+dV) - \dot m V$$

$$= \dot m\, dV$$

$$= \rho V A_c\, dV$$

$$\Rightarrow \left[-A_0\,dP - \frac{1}{2}\rho V^2 C_f\, 2\pi R\, dx = \rho V A_c\, dV\right] \div A_c$$

$$dP\frac{A}{A_c} + \rho V dV = -\rho V^2 C_f \frac{\pi R}{A_c}\,dx = -\rho V^2 C_f \frac{A}{R A_c}\,dx$$

$$\Rightarrow \frac{A}{A_c} dP + \rho V dV = -2\rho V^2 \frac{C_f}{D} \frac{A}{A_c} dx$$

$$\frac{A}{A_c} dP + \rho V dV = -\frac{1}{2}\rho V^2 \left(\frac{4 C_f dx}{D}\right)\left(\frac{A}{A_c}\right) \rightarrow (i)$$

$$\frac{1}{2}\rho V^2 = \frac{1}{2}\frac{P}{RT} V^2 = \frac{1}{2} P\gamma M^2 \longrightarrow (ii)$$

$$d(V^2) = 2VdV$$

$$\Rightarrow \rho V dV = \frac{P\gamma}{\gamma RT}\frac{d(V^2)}{2} = \frac{P\gamma M^2}{2}\frac{d(V^2)}{V^2} \rightarrow (iii)$$

$$\Rightarrow \frac{A}{A_c} dP + \frac{P\gamma M^2}{2}\frac{dV^2}{V^2} = -\frac{1}{2} P\gamma M^2 \left(\frac{4 C_f dx}{D}\right) \frac{A}{A_c}$$

$$\Rightarrow \boxed{\frac{dP}{P} + \frac{\gamma M^2}{2}\frac{4C_f dx}{D} + \frac{\gamma M^2}{2}\frac{A_c}{A}\frac{dV^2}{V^2}}$$

Hence Proved.

$$\frac{dp}{dx} = \frac{89}{D_h} C_{f_0} \frac{\rho V^2}{2}$$

$$= \frac{89}{D_h} C_{f_0} \frac{P}{RT} \frac{V^2}{2} = \frac{89}{D_h} C_{f_0} \frac{P\gamma M^2}{2}$$

$$\Rightarrow \frac{dp}{p} = \frac{89}{D_h} C_{f_0} \frac{\gamma M^2}{2} dx$$

$$\Rightarrow \frac{d(M^2)}{M^2} = -\left(1+\frac{\gamma-1}{2} M^2\right)\left[\frac{\frac{89}{D_h} C_{f_0}\, dx}{\left(\frac{A_c}{A}\right)} + \frac{\frac{4C_f\, dx}{D}}{\left(\frac{A_c}{A}\right)} + \frac{dT_t}{T_t}\right]$$

Let $\frac{A_c}{A} = r_A(x)$

$$\Rightarrow \frac{d(M^2)}{M^2} = -\left(1+\frac{\gamma-1}{2} M^2\right)\left[\frac{\frac{89}{D_h} C_{f_0}\, dx}{r_A} + \frac{\frac{4C_f\, dx}{D}}{r_A} + \frac{dT_t}{T_t}\right]$$

$\hookrightarrow$ (1)

$$\frac{dq}{dx} = \frac{C_p\, dT_0}{dx} = K$$

$$\Rightarrow \frac{d(M^2)}{M^2} = -\left(1+\frac{\gamma-1}{2}M^2\right)\left[\frac{dp/p}{\frac{\gamma M^2}{2}\gamma_a} + \frac{\frac{4C_f\,dx}{D}}{\gamma_a}\right]$$

$$\frac{dp}{dx} = \frac{89}{D_h}C_{f_0}\frac{\rho V^2}{2} \Rightarrow \frac{dp}{p} = \frac{89C_{f_0}}{D_h}\frac{\gamma M^2}{2}dx$$

$$\frac{d(\gamma_a)}{\gamma_a} = \left[\frac{1-M^2\{1-\gamma(1-\gamma_a)\}}{\gamma M^2\gamma_a}\right]\frac{dp}{p} + \left(\frac{1+(\gamma-1)M^2}{2\gamma_a}\right)\frac{4C_f\,dx}{D}$$

$$\Rightarrow \frac{2\,dM}{M} = -\left(1+\frac{\gamma-1}{2}M^2\right)\left[\frac{4C_f\,dx}{D\gamma_a} + \frac{\frac{89C_{f_0}}{D_h}\cancel{\frac{\gamma M^2}{2}}dx}{\cancel{\frac{\gamma M^2}{2}}\gamma_a}\right]$$

$$\frac{2\,dM}{M} = -\left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\left[\frac{4C_f\,dx}{D\gamma_a} + \frac{89C_f\,dx}{D\gamma_a}\right]$$

$$\frac{2\,dM}{M} = -\left(1+\frac{\gamma-1}{2}M^2\right)\left[\frac{93C_f\,dx}{D\gamma_a}\right]$$

$$\boxed{\frac{dM}{dx} = -\frac{M}{2}\left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{93.C_f}{D\gamma_a}} \rightarrow (1)$$

$$\boxed{\frac{d\gamma_a}{dx} = \frac{C_f}{2D}\left[93+M^2\{93(\gamma-1)-89\gamma\gamma_a\}\right]} \rightarrow (2)$$

$M(x)$ ... a

$$p_0 = p\left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)^{\gamma/(\gamma-1)}$$

$$\ln p_0 = \ln p + \frac{\gamma}{(\gamma-1)}\ln\left(1+\frac{\gamma-1}{2}M^2\right)$$

$$\cancel{\frac{1}{p_0}dp_0 = \frac{1}{p}dp + \frac{\gamma}{(\gamma-1)}\frac{1}{1+\left(\frac{\gamma-1}{2}\right)M^2}\left(\frac{\gamma-1}{2}\right)2M\,dM}$$

$$\frac{dp_0}{p_0} = \frac{dp}{p} + \frac{\gamma}{\cancel{(\gamma-1)}}\cdot\frac{1}{\left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)}\left(\frac{\cancel{\gamma-1}}{\cancel{2}}\right)2M\,dM$$

$$\frac{dp_0}{dx} = \frac{\gamma M\,dM}{1+\left(\frac{\gamma-1}{2}\right)M^2} + \frac{89}{D_h}C_f\frac{\gamma M^2}{2}dx$$

$$\frac{1}{p_0}\frac{dp_0}{dx} = \frac{89}{D_h}C_f\frac{\gamma M^2}{2} + \frac{\gamma M}{1+\left(\frac{\gamma-1}{2}\right)M^2}\frac{dM}{dx}$$

$$= \frac{89}{D_h}C_f\frac{\gamma M^2}{2} + \frac{\gamma M}{\cancel{\left(1+\frac{\gamma-1}{2}M^2\right)}}\left[-\frac{M}{2}\cancel{\left(1+\frac{\gamma-1}{2}M^2\right)}\frac{93C_f}{D_h\gamma}\right]$$

$$= \frac{89}{D_h}C_f\frac{\gamma M^2}{2} - \frac{\gamma M^2}{2}\frac{93C_f}{D_h\gamma}$$

$$\frac{dp_0}{dx} = \frac{C_f}{D}\frac{\gamma M^2}{2}\times\left(89 - \frac{93}{\gamma}\right)\times p_0$$

$$\Rightarrow \boxed{\frac{dp_0}{dx} + \frac{C_f}{D}\frac{\gamma M^2}{2}\left(\frac{93}{\gamma}-89\right)p_0} \rightarrow (4)$$

$$\boxed{\frac{dp}{dx} = -\frac{89}{D_h}C_f\frac{\gamma M^2}{2}p} \rightarrow (3)$$

$1 + 2\times4 + 4\times4 + 6\times4 + \cdots$

$$p(x) = \frac{p_2}{\gamma_a(x)} \frac{M_2}{M(x)} \sqrt{\frac{T(x)}{T_2}}$$

?

$$\log p = \log\left(\frac{p_2 M_2}{\sqrt{T_2}}\right) - \log(\gamma_a) - \log(M) + \frac{1}{2}\log T$$

$$\frac{dp}{p} = -\frac{d\gamma}{\gamma} - \frac{dM}{M} + \frac{1}{2}\frac{dT}{T}$$

$$T_0 = \left(1 + \left(\frac{\gamma-1}{2}\right)M^2\right)T$$

$$\cancel{dT_0 = d}$$

$$\log T_0 = \log\left(1 + \left(\frac{\gamma-1}{2}\right)M^2\right) + \log T$$

$$0 = \frac{dT_0}{T_0} = \frac{1}{\left(1 + \left(\frac{\gamma-1}{2}\right)M^2\right)}\left(\frac{\gamma-1}{\cancel{2}}\right)\cancel{2}M\,dM + \frac{dT}{T}$$

$$\Rightarrow \frac{dT}{T} = \frac{-(\gamma-1)M\,dM}{\left(1 + \left(\frac{\gamma-1}{2}\right)M^2\right)}$$

$$\Rightarrow \frac{dp}{p\,dx} = -\frac{d\gamma}{\gamma\,dx} - \frac{dM}{M\,dx} - \frac{(\gamma-1)M\,dM}{(2 + (\gamma-1)M^2)\,dx}$$

$s = 1$

$s = 1 + [(1+2) + (1+2+2) + (1+2+2+2) + (1+2+2+2+2)] = s_1$

$s = s_1 + [(9+4) + (9+4+4) + (9+4+4+4) + (9+4+4+4+4)]$

$n = 3 \rightarrow j_{max} = 1$

$n = 5 \rightarrow j_{max} = 3$

$n = 7 \rightarrow j_{max} = 3$

$(j_{max} \times 3 + 1) = n$

0, 0.5, 1

0, 0.25, 0.5, 0.75, 1

$$\rightarrow \frac{2M\,dM}{M^2} = -\left(1+\frac{\gamma-1}{2}M^2\right)\left(\frac{dp/p}{\frac{\gamma M^2}{2}\sigma} + \frac{\frac{4C_f\,dx}{D}}{\sigma}\right)$$

$$\frac{dM}{dx} \quad = -\left(1+\frac{\gamma-1}{2}M^2\right)\left(\frac{\frac{89}{D}C_f\cancel{\left(\frac{\gamma M^2}{2}\right)}dx}{\cancel{\left(\frac{\gamma M^2}{2}\right)}\sigma} + \frac{4C_f\,dx}{D\sigma}\right)$$

$$\boxed{\frac{dM}{M} = -\frac{M}{2}\left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{93\,C_f\,dx}{D\sigma}}$$

$$\rightarrow \frac{d\sigma}{\sigma} = \left(\frac{1-M^2\{1-\gamma(1-\sigma)\}}{\gamma M^2\sigma}\right)\frac{dp}{p} + \left(\frac{1+(\gamma-1)M^2}{2\sigma}\right)\frac{4C_f\,dx}{D}$$

$$= \left(\frac{1-M^2\{1-\gamma(1-\sigma)\}}{\cancel{\gamma M^2}\sigma}\right)\frac{89}{D}C_f\frac{\cancel{\gamma M^2}}{2}dx$$

$$\frac{d\sigma}{dx} \qquad + \left(\frac{1+(\gamma-1)M^2}{2\sigma}\right)\frac{4C_f\,dx}{D}$$

$$\frac{d\sigma}{\sigma} = \frac{(C_f\,dx)\left[89 - M^2\{89-\gamma.89(1-\sigma)\} + 4 + 4M^2(\gamma-1)\right]}{2D\sigma}$$

$$d\sigma = \frac{(C_f\,dx)}{2D}\left[93 - 89M^2 + 89\gamma M^2 - 89\gamma\sigma M^2 + 4M^2\gamma - 4M^2\right]$$

$$\boxed{\frac{d\sigma}{dx} = \frac{C_f}{2D}\left[93 + M^2\left(93(\gamma-1) - 89\gamma\sigma(x)\right)\right]}$$

0, 0.5, 1

0, 0.25, 0.5, 0.75, 1

$$\rightarrow \frac{2M\,dM}{M^2} = -\left(1+\frac{\gamma-1}{2}M^2\right)\left(\frac{dp/p}{\frac{\gamma M^2}{2}\delta} + \frac{\frac{4C_f\,dx}{D}}{\delta}\right)$$

$$\frac{dM}{dx} = -\left(1+\frac{\gamma-1}{2}M^2\right)\left(\frac{\frac{89}{D}C_f\cancel{\left(\frac{\gamma M^2}{2}\right)}dx}{\cancel{\left(\frac{\gamma M^2}{2}\right)}\delta} + \frac{4C_f\,dx}{D\delta}\right)$$

$$\boxed{\frac{dM}{M} = -\frac{M}{2}\left(1+\left(\frac{\gamma-1}{2}\right)M^2\right)\frac{93\,C_f\,dx}{D\delta}}$$

$$\rightarrow \frac{d\delta}{\delta} = \left(\frac{1-M^2\{1-\gamma(1-\delta)\}}{\gamma M^2\delta}\right)\frac{dp}{p} + \left(\frac{1+(\gamma-1)M^2}{2\delta}\right)\frac{4C_f\,dx}{D}$$

$$\frac{d\delta}{dx} = \left(\frac{1-M^2\{1-\gamma(1-\delta)\}}{\cancel{\gamma M^2}\delta}\right)\frac{89}{D}C_f\frac{\cancel{\gamma M^2}}{2}dx + \left(\frac{1+(\gamma-1)M^2}{2\delta}\right)\frac{4C_f\,dx}{D}$$

$$\frac{d\delta}{\delta} = \frac{(C_f\,dx)\left[89 - M^2\{89-\gamma.89.(1-\delta)\} + 4 + 4M^2(\gamma-1)\right]}{2D\delta}$$

$$d\delta = \frac{(C_f\,dx)}{2D}\left[93 - 89M^2 + 89\gamma M^2 - 89\gamma\delta M^2 + 4M^2\gamma - 4M^2\right]$$

$$\boxed{\frac{d\delta}{dx} = \frac{C_f}{2D}\cdot\left[93 + M^2\left(93(\gamma-1) - 89\gamma\delta(x)\right)\right]}$$

Ans. $\rho A V = \text{const}$

$\ln\rho + \ln A + \ln V = \ln K$

$$\boxed{\frac{d\rho}{\rho} + \frac{dA}{A} + \frac{dV}{V} = 0}$$

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$p = \rho R T$

$$\frac{dM^2}{M^2} = -\left(1 + \frac{\gamma-1}{2}M^2\right)\left[\frac{dp/p}{\frac{\gamma M^2}{2}\left(\frac{A_c}{A}\right)} + \frac{\frac{4C_f\,dx}{D}}{A_c/A} + \frac{dT_t}{T_t}\right]$$

$$\frac{dp}{p} + \frac{\gamma M^2}{2}\frac{4C_f\,dx}{D} + \frac{\gamma M^2}{2}\frac{A_c}{A}\frac{dV^2}{V^2} = 0.$$

$$\frac{dT}{T} + \frac{\gamma-1}{2}M^2\frac{dV^2}{V^2} = \left(1 + \frac{\gamma-1}{2}M^2\right)\frac{dT_t}{T_t}$$

$$\frac{dM^2}{M^2} - \frac{dV^2}{V^2} + \frac{dT}{T} = 0$$

$$\frac{dp}{dx} \approx \frac{89}{D_H} C_{fo}\left(\frac{\rho V^2}{2}\right) \quad (2)$$

$$\frac{dp}{p} - \frac{d\rho}{\rho} - \frac{dT}{T} = 0 \quad (7)$$

$$\frac{d\rho}{\rho} + \frac{dV}{V} + \frac{dA_c}{A_c} = 0 \quad (4)$$

$$\boxed{\frac{dM^2}{M^2} = \frac{dv^2}{v^2} - \frac{dT}{T}}$$

$$\frac{dM^2}{M^2} = \frac{-\left(\frac{dp}{p} + \frac{\gamma M^2}{2}\left(\frac{4C_f\,dx}{D}\right)\right)}{\left(\frac{\gamma M^2}{2}\cdot\frac{A_c}{A}\right)} - \frac{dT}{T}$$

$$\frac{dM^2}{M^2} = -\left(\frac{(dp/p)}{\frac{\gamma M^2}{2}\left(\frac{A_c}{A}\right)} + \frac{\frac{4C_f\,dx}{D}}{A_c/A}\right) - \frac{dT}{T}$$

June 1st week of June

T_0

T_t

$\frac{T_0}{T} = \left(1+\frac{r-1}{2}M^2\right)$

$$\frac{dM^2}{M^2} = +\left(\frac{dV^2}{V^2}\right) - \left[1+\frac{r-1}{2}M^2\right]\frac{dT_t}{T_t} + \left(\frac{r-1}{2}M^2\frac{dV^2}{V^2}\right)$$

$$= \frac{dV^2}{V^2}\left(1+\frac{r-1}{2}M^2\right) - \left(1+\frac{r-1}{2}M^2\right)\frac{dT_t}{T_t}$$

$$\frac{dM^2}{M^2} = -\left(1+\frac{r-1}{2}M^2\right)\left(-\frac{dV^2}{V^2} + \frac{dT_t}{T_t}\right)$$

$$\frac{dM^2}{M^2} = -\left(1+\frac{r-1}{2}M^2\right)\left(\frac{dP/p}{\left(\frac{rM^2}{2}\right)\left(\frac{A_c}{A}\right)} + \frac{\left[\cancel{\frac{rM^2}{2}}\right]\cdot\left[\frac{4C_f\,dx}{D}\right]}{\left(\cancel{\frac{rM^2}{2}}\right)\left(A_c/A\right)} + \frac{dT_t}{T_t}\right)$$

$$\boxed{\frac{dM^2}{M^2} = -\left(1+\frac{r-1}{2}M^2\right)\left(\frac{dP/p}{\left(\frac{rM^2}{2}\right)\left(A_c/A\right)} + \frac{\left(\frac{4C_f\,dx}{D}\right)}{(A_c/A)} + \frac{dT_t}{T_t}\right)}$$