JET PROPULSION

→ Thrust equation: $F = \dot{m}_a[(1+f)C_j - C_i] + (P_e - P_a)A_e$

(momentum thrust: $\dot{m}_a[(1+f)C_j - C_i]$; pressure thrust: $(P_e - P_a)A_e$)

where, $f = \dfrac{\dot{m}_f}{\dot{m}_a}$ (fuel-air ratio)

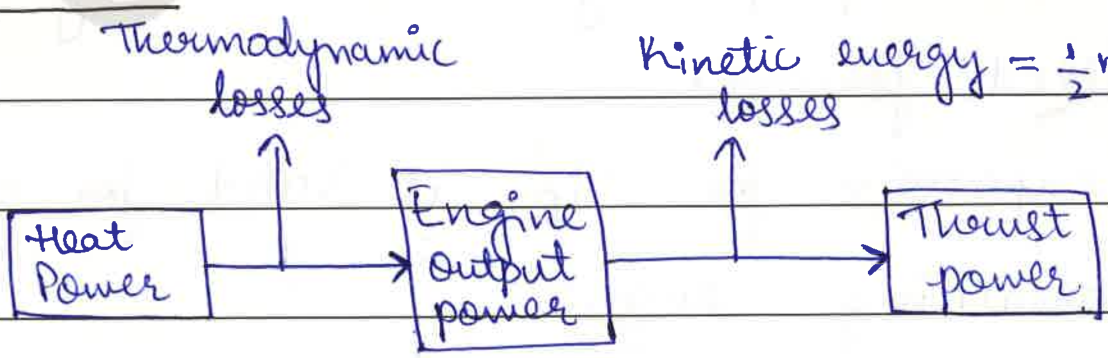
Now, neglecting fuel air ratio as $f \ll 1$

$$F = \dot{m}_a(C_j - C_i) + (P_e - P_a)A_e$$

For optimum expansion, $P_e \approx P_a$ $\therefore F = \dot{m}_a(C_j - C_i)$

where, $\dot{m} C_i$ = inlet momentum drag

→ Efficiencies:



Kinetic energy $= \frac{1}{2}\dot{m}_a(C_j - C_i)^2$

Propulsive power $= \frac{1}{2}\dot{m}_a(C_j - C_i)$

Thrust power $= F \cdot C_i$

1. Propulsive efficiency (η_p) (Froude efficiency):

$$\eta_p = \frac{\text{thrust power}}{\text{propulsive power or engine output power}} = \frac{F \cdot C_i}{\frac{1}{2}\dot{m}_a (C_j^2 - C_i^2)}$$

$$\therefore \eta_p = \frac{\dot{m}_a (C_j - C_i) C_i}{\frac{1}{2}\dot{m}_a (C_j + C_i)(C_j - C_i)} = \frac{2 C_i}{C_j + C_i}$$

$$\therefore \eta_p = \frac{2 (C_i / C_j)}{1 + (C_i / C_j)}$$

$$\therefore \boxed{\eta_p = \frac{2\alpha}{1+\alpha}}, \quad \text{where } \alpha = C_i / C_j$$

→ 'η_p' is the measure of effectiveness with which the propelling duct is being propelled forward.

→ This expression for 'η_p' is valid for all air-breathing engine.

→ For maximum thrust $C_i = 0$ or $\alpha = 0 \Rightarrow \eta_p = 0$

→ For maximum η_p, $\alpha = 1$ or $C_j = C_i \Rightarrow F = 0$

→ For maximum thrust power,

Thrust power $= F \cdot C_i = \dot{m}_a (C_j - C_i) C_i$

$$= \dot{m}_a C_j C_i \left(1 - \frac{C_i}{C_j}\right)$$

$$= \dot{m}_a C_j^2 (1-\alpha)\alpha$$

$$\frac{d(T.P.)}{d\alpha} = \dot{m}_a C_j^2 (1 - 2\alpha) = 0$$

$$\therefore \boxed{\alpha = 1/2}$$

$$\therefore \frac{C_i}{C_j} = \frac{1}{2} \Rightarrow C_j = 2C_i$$

$$\therefore \eta_p = \frac{2}{3} \Rightarrow \boxed{\eta_p = 66.67\%}$$

2- Thermal efficiency (η_{th}):

$$\eta_{th} = \frac{\text{Engine output}}{\text{Heat energy or power}} = \frac{F \cdot C_i}{\dot{m}_f Q}$$

$$\therefore \boxed{\eta_{th} = 98\%}$$

3. Overall efficiency (η_{ov}):

$$\eta_{ov} = \frac{\text{thrust power}}{\text{heat energy}}$$

Also, $\boxed{\eta_p \times \eta_{th} = \eta_{ov}}$

NOTE:

→ Specific fuel consumption (SFC):

$$SFC = \frac{\dot{m}_f}{F} = \frac{\dot{m}_f}{F} \times 3600 \quad kg/N\text{-}hr$$

→ Thrust power specific fuel consumption (TSFC):

$$TSFC = \frac{\dot{m}_f}{\text{thrust power}} \times 3600 \quad kg/W\text{-}hr$$

→ Specific thrust: (F_s)

$$F_s = \frac{F}{\dot{m}_a} = \frac{\dot{m}_a (C_j - C_i)}{\dot{m}_a}$$

$$F_s = (C_j - C_i) \quad m/s$$

→ Non-dimensional thrust:

$$= \frac{\text{specific thrust}}{\text{speed of sound (a)}} = \frac{F_s}{a}$$

where, $a = \sqrt{\gamma R T}$

1.) DIFFUSER OR INTAKE:

→ Total pressure decreases due to loss of energy (frictional losses)

→ If friction is neglected then 'P_0' remains constant.

→ Total temperature remains constant.

→ Main function of intake is to minimize pressure ratio loss upto the compressor while ensuring flow enters the compressor with uniform pressure