GATE Aerospace Coaching by Team IGC

Aircraft Propulsion Basics

JET PROPULSION

Thrust equation:-

$$F = \dot{m}_a\,[(1+f)c_j - c_i] + (p_e - p_a)\,A_e$$

here,

Momentum thrust

$$\dot{m}_a\,[(1+f)c_j - c_i\,]$$

Pressure thrust

$$(p_e - p_a)$$

Where,

Fuel air ratio

$$f = \dot{m}_f/\dot{m}_a$$

now, neglecting fuel air ratio as f<<1

$$F = \dot{m}_a\,(c_j - c_i) + (p_e - p_a)\,A_e$$

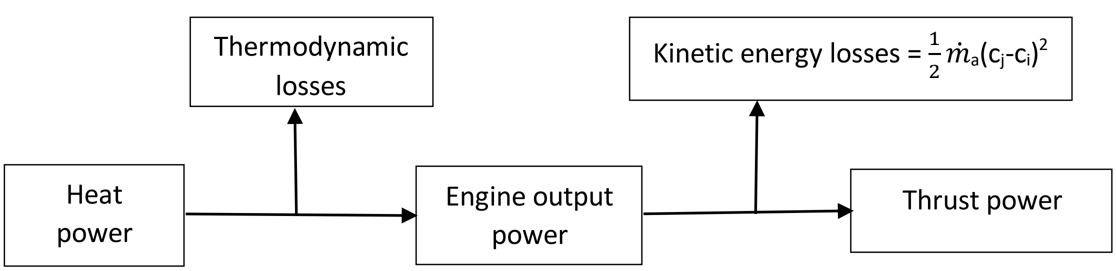
For optimum expansion $p_e \approx p_a$

$$F = \dot{m}_a\,(c_j - c_i)$$

Where,

$$\dot{m}c_i = \text{inlet momentum drag}$$

Efficiencies



Propulsive power

$$= \frac{1}{2}\dot{m}_a(c_j - c_i)$$

Thrust power

$$= F.c_i$$

Propulsive efficiency (η_p)(Froude efficiency)

$$\eta_p = \frac{thrust\ power}{\begin{matrix} proplsive\ power \\ or \\ engine\ otput\ power \end{matrix}} = (F.c_i)/(1/2\ \dot{m}_a(c_j\text{-}c_i))$$

$$\eta_p = \dot{m}_a(c_j-c_i)c_i/(1/2\ \dot{m}_a(c_j+c_i)(c_j-c_i)$$

$$\eta_p = \frac{2ci}{cj+ci}$$

$$\eta_p = 2(c_i/c_j)/(1+(c_i/c_j))$$

$$\eta_p = \frac{2\propto}{1+\propto}$$

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 $\alpha = 0$, $c = 0$

For maximum η_p ,$\alpha = 1$ or $c_j = c_i$, $F = 0$

For maximum thrust power,

$$\text{Thrust power} = F.c_i$$

$$= \dot{m}_a\ (c_j-c_i)c_i$$

$$= \dot{m}_a c_j c_i\ (1-(c_i/c_j))$$

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

$$\frac{d(thrust\ power)}{d\alpha} = \dot{m}_a c_j\ (1-2\alpha) = 0$$

$$\alpha = ½$$

$$c_i/c_j = ½$$

$$c_j = 2c_i$$

$$\eta_p = 2/3 \text{ or } 66.67\%$$

Thermal efficiency (η_{th})

$$\eta_{th} = \frac{engine\ output}{heat\ energy\ or\ power} = F\ c_i/\dot{m}\ Q$$

η_{th} = 98%

Overall efficiency (η_{ov})

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

also, $\eta_p \times \eta_{th} = \eta_{ov}$

NOTE

Specific fuel consumption (SFC)

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

Thrust power specific fuel consumption (TSFC)

$$TSFC = (\dot{m}_f/\text{thrust power}) \times 3600 \text{ kg/w-hr}$$

Specific thrust (F_s)

$$F_s = F/\dot{m}_a = (\dot{m}_a(c_j - c_i))/\dot{m}_a$$

$$F_s = (c_j - c_i) \text{ m/s}$$

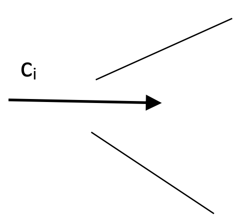
Non-dimensional thrust

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

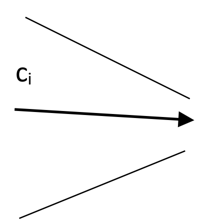
Where,

$$a = \sqrt{\gamma RT}$$

Diffuser or intake



Subsonic



supersonic

- Total pressure decrease due to loss o energy (frictional losses)
- If friction is neglected then 'p_o' remains constant
- Total temperature remains constant
- Main function of intake is to minimize pressure ratio loss upto the compressor while ensuring flow enter the compressor with uniform pressure