Powerplant design

Group-1

Mission Statement

Design an power plant configuration for an light combat unmanned aircraft for some combat at 5000m and reconnaissance at 15 km altitude.

Plane chosen : MQ9 Reaper

Engine : Honeywell TPE 331-10

It's a turbo-prop engine with a pusher configuration

Design of the Engine

We find out the engine configuration at 2 points i.e. the low altitude and high altitude.

The design point is taken as the low altitude (5000m) because it requires maximum thrust during combat and also we can choke it at the this point.

Airflow Calculations

- Velocity at 5000 m = 134 m/s (Known)
- Diameter of engine = 11 inches
- Density = 0.7364 kg/m^3
- Airflow = 5.5 kg/s

Parameters

We need 2 turbines, one turbine drives the compressor and the other drives the propeller. (Power turbine)

- To1 = 264.48 K (assumed)
- Po1 = 6.092 E+4(assumed)
- Mach no = 0.42

Compressor Parameters

- Power = 596 .5 kW (Given)
- Compressor pressure ratio = 10 (Assumed)
- Thrust = 4.44 kN
- Po2= 60.92 E+4
- T02 = 510.64 K

Combustor

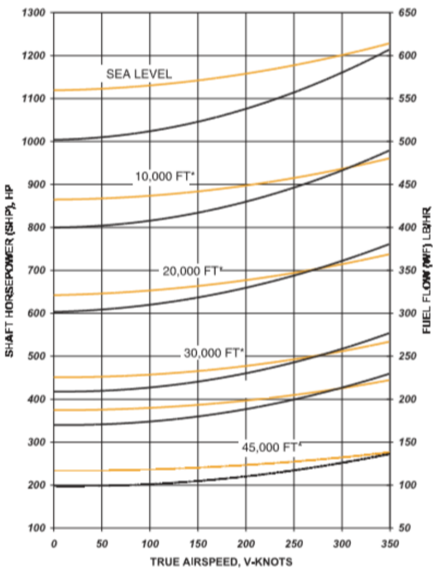
Fuel flow= 50.5 g/s (Given)

Q = 42.8 MJ/kg (Given)

From energy balance in combustion chamber

To3 = 888.73 K (Turbine inlet temp)

Po3 = Po2 (No loss assumed)



Turbine

There are 2 turbines in the engines which are on separate spools.

- Rpm of the turbine = 40000 rpm (Assumed)
- Propeller rpm =2000 rpm (Given)
- Rpm of the power turbine = 30000 rpm (Gear ratio – 15:1)
- Work by turbines = compressor work + Propeller work
- Power turbine specific work =

$$\overline{W}_T = \eta_T . C_{p\text{-}gas} \Delta T_{034} = \eta_T C_{p\text{-}gas} T_{03} \left[1 - \frac{1}{\left(\frac{P_{03}}{P_{04}} \right)^{\frac{\gamma_{gas}-1}{\gamma_{gas}}}} \right]$$

=106051 J-s/kg

- Hp turbine specific work = 959.29 J-s/kg
- Compressor specific work =

$$= \frac{C_{p\text{-air}}\Delta T_{012}}{\eta_c} = \frac{C_{p\text{-air}} T_{01}}{\eta_c}\left[\left(\frac{P_{02}}{P_{01}}\right)^{\frac{\gamma_{air}-1}{\gamma_{air}}} - 1\right]$$ = 954.4 J-s/kg (Efficiency 0.98)

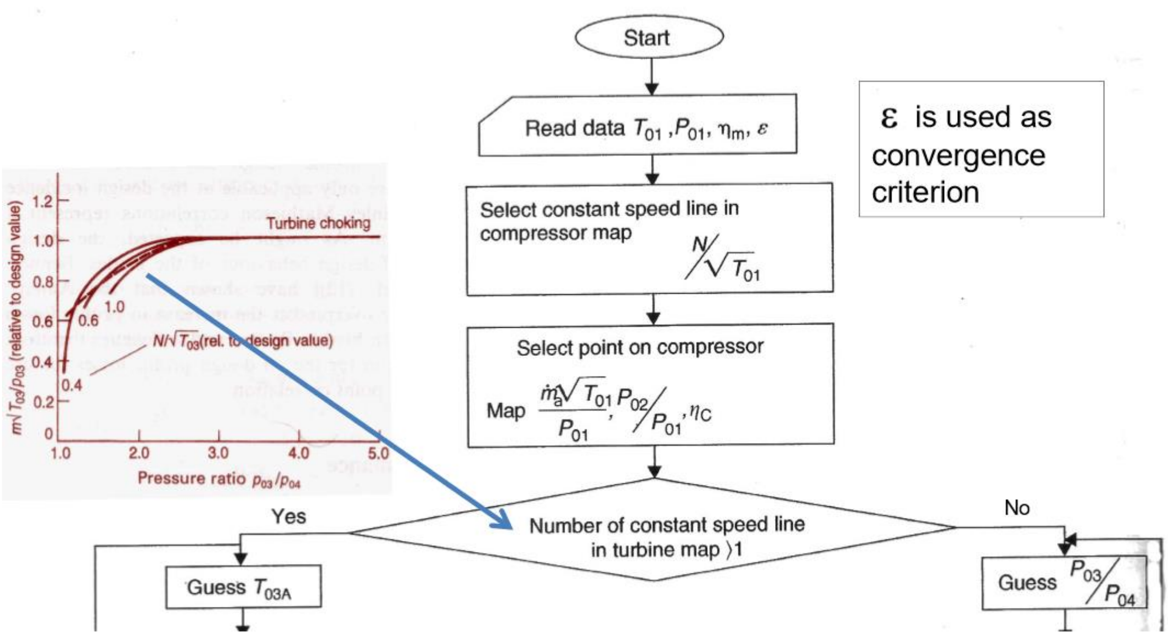
Non dimensionalized parameters

- Mass flow = 5.62 kg/s(wrt turbine inlet conditions)
- Non dimensional mass flow = $\frac{\dot{m}\sqrt{T_{01}}}{P_{01}}$ = 2.748E-4 at design point (wrt turbine inlet)
- Non dimensional rpm = 1400.367

Off design matching

- Altitude = 15000m
- Pressure = 1.211 * 10^4 Pa
- Density = 0.1948
- Mass flow = 1.052 kg/s

PROCEDURE



Code For parameters at the cruise point

```
import math

import matplotlib.pyplot as plt

t_01 = 216.5 * (1+0.2* 0.303 ** 2)
```

```
#print(t_01)
p_01 = 1.211*10 ** 4 * (1+0.2*0.303 ** 2) ** (1.4/0.4)
v = 89.4
n_m = 0.986
n_c = 0.95
n_t = 0.97
epsilon = 1 # its 3 kelvin

t_03 = 500 #initial guess

#print(t_01)

m_g = 0.1948 * 3.14 * (89.4/4)*(2.46*11/100)**2 + 0.0505
m_a = 0.1948 * 3.14 * (89.4/4)*(2.46*11/100)**2

p_03 = 10 * p_01

while(1):
ratio = 0.2 * t_03 ** 0.5
print(ratio)
t_03_new = t_01/n_m/n_c/n_t * (m_a/m_g)*(10 ** (0.4/1.4) -1 )/ (1-(1/ratio) ** (0.33/1.33))
print(t_03_new)
if (abs(t_03_new - t_03) <= epsilon):
#print(t_03_new)
break

else:
t_03 = t_03_new
#print(t_03_new)


print(t_03)
```

T_03 = 646.6K (after converging)

P_03/P_04 = 5.085

Non-dimensionalized mass flow = 2.073 * 10^-4

The power generated by the power turbine may be computed from

$$P_T = \dot{m}_4.C_{p\text{-}gas}\Delta T_{045} = \eta_{PT}.\dot{m}_4.C_{p\text{-}gas}T_{04}.\left[1-\left(\frac{1}{P_{04}/P_a}\right)^{\frac{\gamma_{gas}-1}{\gamma_{gas}}}\right]$$

Power generated = 105.9KW

And Required shaft power at cruise = 148 HP = 110.408 KW

Which is almost same. Hence, engine is matched.