ASE 376K Homework # 5

1. Start with expressions for specific thrust and thrust for a turbofan engine. Assume f << 1 and pe=pa. Assuming $U_{e,p} = 4u$ and $U_{e,f} = 2u$, and flight speed of u, derive expressions for

   (a) Thrust Ratio (<u>thrust of bypass flow to primary flow</u>)
   (b) Specific Thrust (use the total mass flow of air for this)
   (c) Thrust Specific Fuel Consumption

   <u>Solution:</u>
   The total thrust of a Turbofan engine is given by

$$\Im = \dot{m}_a \left\{ \underbrace{\left[\left(1+f_b\right) u_{e,p} - u \right]}_{\text{Core thrust}} + \underbrace{B\left[u_{e,f} - u \right]}_{\text{Bypass Thrust}} \right\} + \cancel{\left(p_{e,p} - p_a\right)}_{0(2)} A_{e,p} + \cancel{\left(p_{e,f} - p_a\right)}_{0(2)} A_{e,f}$$

Assuming f (or f_b) << 1,

(a) Thrust ratio of bypass flow to primary flow is

$$\left\{ \frac{\dot{m}_a B\left[u_{e,f} - u\right]}{\dot{m}_a \left[u_{e,p} - u\right]} \right\}$$

For $U_{e,f} = 2u$ and $U_{e,p} = 4u$, this reduces to $\dfrac{B}{3}$

(b) Specific Thrust is given by

$$\frac{\Im}{\dot{m}_{tot}} = \frac{1}{1+B} \left\{ \left[\left(1+f_b\right) u_{e,p} - u \right] + B\left[u_{e,f} - u \right] \right\} + \cancel{\left(p_{e,p} - p_a\right)}_{0(2)} A_{e,p} + \cancel{\left(p_{e,f} - p_a\right)}_{0(2)} A_{e,f}$$

which reduces to

$$\frac{1}{1+B}\left\{3u + Bu\right\} = \left(\frac{B+3}{B+1}\right)u$$

(c) By similar manipulation, TSFC is given by

$$\frac{f}{(B+3)u}$$

2. An engine has been designed for a V/STOL aircraft. The maximum take off (MTO) weight in Vertical Take Off (VTO) condition is 9415 kg. Assuming the engine is designed for maximum thrust in VTO condition, compute the exhaust velocity when the vehicle is flying at its top speed

of 1083 km/hr. The engine is a low-bypass turbofan with a bypass ratio of 1.2, maximum incoming airflow of 196 kg/s and fuel air ratio of 0.03 at maximum thrust. Assume exhaust velocity for both streams is the same.

Solution:

The maximum thrust is designed for the VTO condition. At that condition, the engines are providing enough thrust to lift the craft against gravity,

Therefore, maximum thrust = 9415 * 9.8 = 92.2kN

Assuming pe=pa,

The thrust for forward flight is,

$$\Im = \dot{m}_a \left\{ \left[(1+f_b) u_{e,p} - u \right] + B \left[u_{e,f} - u \right] \right\}$$

where,

m-dot-a = m-dot-total/(1+B) = 196/2.2 = 89 kg/s

f = 0.03

$U_{e,f} = U_{e,p} =$ Ue

U = 1083 km/hr = 300.8 m/s

B = 1.2

Using these values,

92200 = 89 [(1.03 * Ue – 300.8)+1.2 * (Ue-300.8)]

Ue = 761 m/s

3. For Problem 3, if the thrusters are turned by 25^{o} from the horizontal, calculate the vertical component of thrust developed.

Solution

The vertical component of thrust is given by T * Sin (θ), where θ is the angle of the thrusters from horizontal.

Therefore, the vertical component of thrust is 92.2 * sin (25) = 39 kN.

4.

Configuration	M2	P2/P1	Po2/Po1
Normal Shock Inlet	0.475	10.33	0.323

Configuration	M2	P2/P1	Po2/Po1
Oblique Shock 5^0 ramp	2.75	1.454	0.995
Oblique Shock 8^0 ramp	2.29	1.956	0.97
Normal	0.536	5.95	0.588
Total Oblique Shock Inlet	0.536	16.92	0.567

While the oblique shock system results in better pressure recovery and higher compression, it has a higher Mach number than the Normal shock system. The higher Mach number could be more disadvantageous for both compressor and combustor performance. However, overall that oblique shock system would be preferred since the Mach number difference in the two cases is not substantial.