Intake design

Group 1

Mission: supersonic intake for M=2 MRCA(BPR< 1.0)- side intake fuselage buried twin engine aircraft possibly serpentine .

Airplane selection

- Aircraft – F22 Raptor
- Cruise: Mach 2
- Engine – Pratt and Whitney F-119
- Intake – Fuselage buried, Side mounted, twin engine, serpentine
- Bypass ratio: 0.3

This airplane meets the requirements of the project assigned

Parameters to design the intake

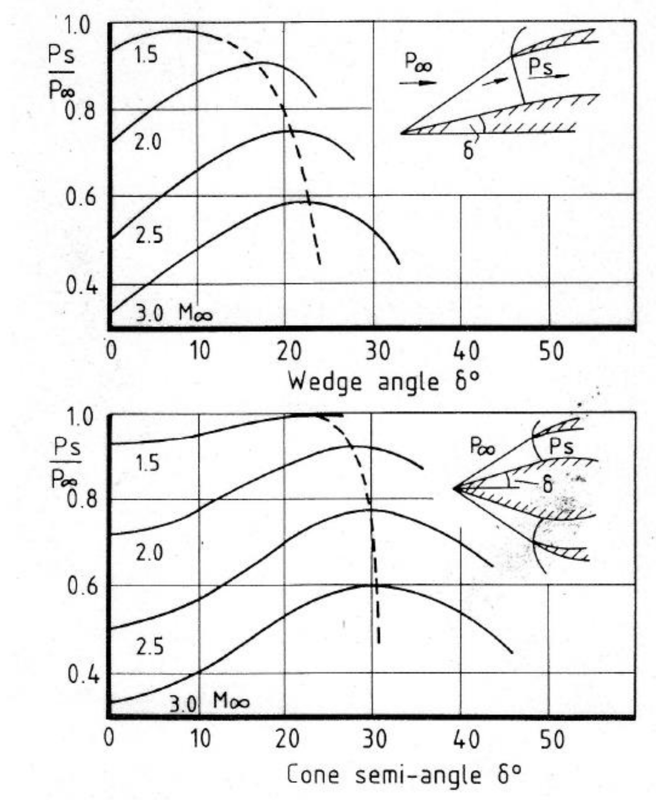
- Flight Mach no: 2
- Density at service ceiling 15000m: 0.194 kg/m3
- Velocity =M * a= 590.66 m/s

Mach no at compressor face = 0.3 (Assumed a subsonic number)

Intake configuration

2-D wedge intake is selected because

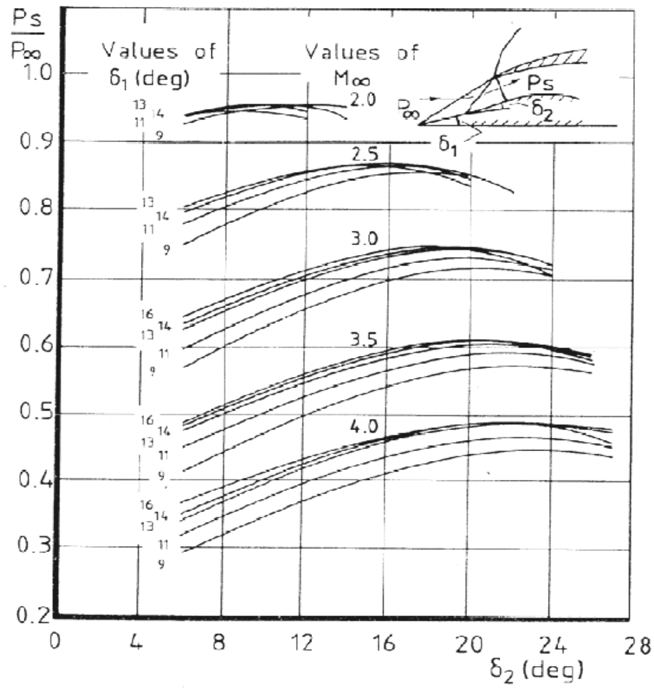
- More pressure recovery at low solid angles
- High solid angles will cause the shock to separate at lower Mach numbers , good to have them as less separated as possible
- Shock wave analysis and computation is simple

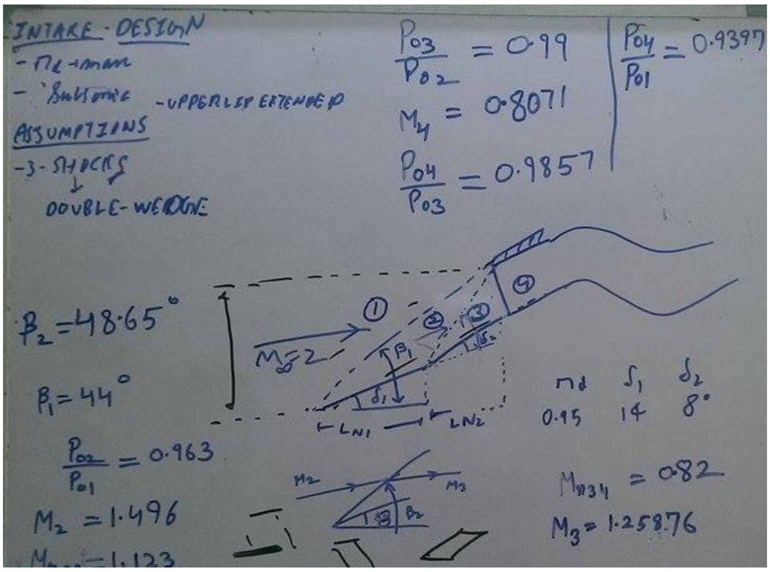


- Lip shape – Sharp in supersonic intake. Attached oblique shock
- Cowling – Extended upper lip . The plane undergoes high angle of attack maneuvers

Designing the serpentine intake

- Area ratio – 2 (From empirical relations an area ratio of more than 3 will cause flow separation)
- Mach no at exit of the S-Duct is assumed to be 0.3.
- L/D = 3.5
- Y/D =1.55
- W/H= 7.55 (From the intake-design lecture)
- To calculate the exact areas and lengths we first computed the mach no after deciding the shock structure.
- 3 shocks are to be created with a double wedge intake.
- The wedge angles are chosen to maximize the pressure recovery
- From the plot we choose max recovery as 0.95, and then choose the 2 wedge angles.
- The 2 wedge angles have to be as low as possible
- The 2 wedge angles are 14 degrees and 8 degrees

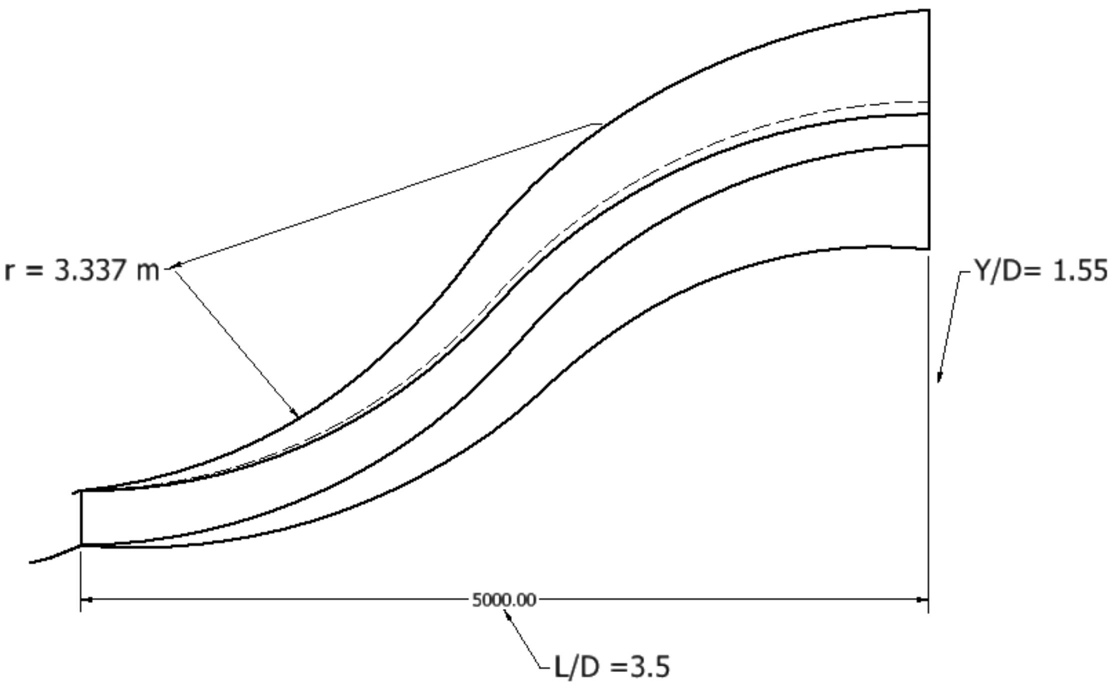




Computations

- From the oblique shock relations the two shock angles were obtained as 44 degrees and 48 degrees
- Now using the normal shock relations the Mach no at the serpentine inlet is obtained.
- M = 0.8 (downstream of the shocks)
- Now from isentropic relations we get the areas in the serpentine duct. (using the concept of A*)
- A1 = 0.8 m^2, A2 = 1.56 m^2
- Mass flow = 109.75 kg/s

Supersonic intake



Calculation of losses

- No approach loss as flow ratio assumed 1 for the design point. This goes for all the pre entry drag and other losses.
- The total pressure loss through the shock is already computed through the oblique shock relations.

Shock pressure recovery = 0.94

Duct losses

The losses in serpentine duct occur due to 2 factors

- The losses due to bends
- Friction losses

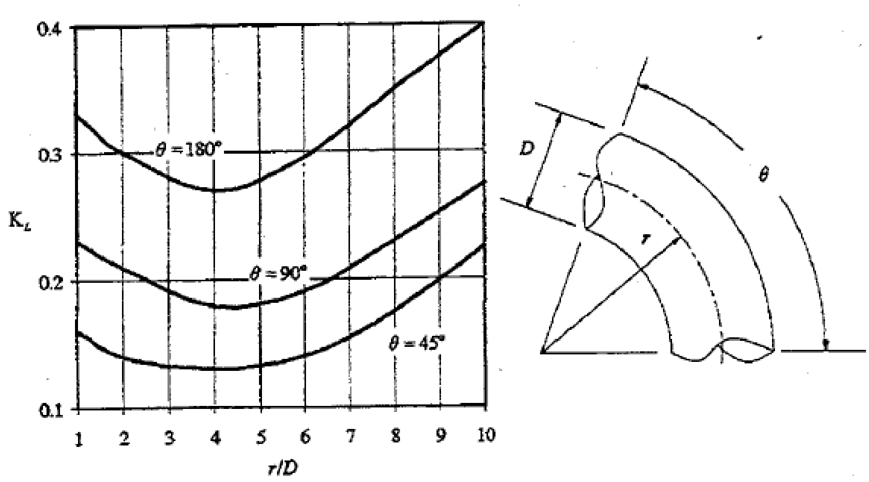
We calculate both the losses

Losses due to the bends

Density at the subsonic duct start = 0.48 kg/m3 (From oblique shock relations)

Density at the subsonic duct exit = 0.63 kg/m3

We calculate bend loss for two curves (2 arcs)



- We get the pressure loss coefficient from the plot.
- Now we take velocity of the start and end to compute losses in the 2 bends
- r=3.337 m D= 1.8 , 2.2m (Averaged)
- r/D = 1.67
- Kl1= 0.18 and Kl2 =0.17

Bend losses

- Pressure loss = 0.5* density * v^2*Kl
- Loss in Bend 1 = 3533.6 Pa
- Loss in Bend 2 =681 Pa

Friction losses

- We calculate the friction coefficient from the Darcy–Weisbach equation

$$\frac{1}{\sqrt{f_{\rm D}}} = -1.930 \cdot \log\left(\frac{1.90}{\mathrm{Re}\sqrt{f_{\rm D}}}\right).$$

- Pressure loss = f*0.5*density*v^2*L/D
- For the Reynolds number we find out the area at the center of the duct (Average), and then found out Mach no (A* concept).
- Then we find out Reynolds number after getting velocity
- Friction loss = 201 Pa

Total losses

- Total pressure loss = 4415.8 Pa
- Freestream stagnation pressure = 44167.6 Pa

- Pressure at the end of subsonic duct = 36945.5 Pa
- Pressure recovery factor = 0.86

CONCLUSION

Since f-22 raptor has two engines so we don’t need to design the mixing of the intakes and pressure at the end of subsonic duct is close enough to the actual data with a pressure recovery factor of 0.86. There is a high pressure loss due to serpentine intake and high operating mach no. nearly 2.