Integrated Supersonic Inlent and Diffuser Design for a Mach 2.3 Fighter-Class Aircraft

Firstly, the gas properities and freestream conditions at 11 km altitude are defined. These values help set the boundary conditions for the later calculations.

```
clear
clc
close all

%constants
gamma = 1.4;
R = 287;

%values found at 11 km altitude
temp = 216.65;
pressure = 22632;
mach_free = 2.3;

speedsound = sqrt(gamma * R * temp);

%M = V/a
flowspeed = mach_free * speedsound;
density = pressure / (R*temp);
```

Ramp 1: First external-compression oblique shock

The freestream area is weakly compressed while attempting to mimize total pressure loss

```
%optimal deflection angle for first ramp at mach 2.3 is 8.8 degrees
rampdeflectangle1 = deg2rad(8.8);

%combine terms into anonymous function
shockfun = @(beta) 2*cot(beta) * (mach_free^2 * sin(beta)^2 - 1)/
(mach_free^2*(gamma + cos(2*beta)) + 2) - tan(rampdeflectangle1);

%find beta by guessing a little above smallest possible beta value
%since smaller beta has weaker shock and therefore less loses
betaguess1 = asin(1/mach_free) + deg2rad(5);
beta1 = fzero(shockfun,betaguess1);

%calculate mach speeds before and after shock
normal_mach1 = mach_free*sin(beta1);
downstream_normal_mach1 =  sqrt((1+((gamma-1)/2)* normal_mach1^2)/
(gamma*normal_mach1^2-((gamma - 1)/2)));
downstream_flow_mach1 = downstream_normal_mach1/sin(beta1-rampdeflectangle1);

static_pressure_ratio1 = 1 + (2*gamma/(gamma+1))*(normal_mach1^2 - 1);
```

```
total_pressure_ratio1 = static_pressure_ratio1 * ((1 + ((gamma-1)/
2)*downstream_normal_mach1^2) / (1 +((gamma-1)/2)*normal_mach1^2))^(gamma/
(gamma-1));
```

Ramp 2: Second external-compression oblique shock

The same process as beforehand, the air is further compressed while keeping the terminal normal shock weak.

```
%optimal deflection angle for ramp 2 mach 2.3 is a little less than ramp 1,
%around 5.5
rampdeflectangle2 = deg2rad(5.5);

%combine terms into anonymous function again
shockfun = @(beta) 2*cot(beta) * (downstream_flow_mach1^2 * sin(beta)^2 - 1)/
(downstream_flow_mach1^2*(gamma + cos(2*beta)) + 2) - tan(rampdeflectangle2);

%find beta by guessing a little above smallest possible beta value
%since smaller beta has weaker shock and therefore less loses again
betaguess2 = asin(1/downstream_flow_mach1) + deg2rad(5);
beta2 = fzero(shockfun,betaguess2);

%calculate mach speeds before and after shock again
normal_mach2 = downstream_flow_mach1*sin(beta2);
downstream_normal_mach2 =  sqrt((1+((gamma-1)/2)* normal_mach2^2)/
(gamma*normal_mach2^2-((gamma - 1)/2)));
downstream_flow_mach2 = downstream_normal_mach2/sin(beta2-rampdeflectangle2);

static_pressure_ratio2 = 1 + (2*gamma/(gamma+1))*(normal_mach2^2 - 1);
total_pressure_ratio2 = static_pressure_ratio2 * ((1 + ((gamma-1)/
2)*downstream_normal_mach2^2) / (1 +((gamma-1)/2)*normal_mach2^2))^(gamma/
(gamma-1));

%pressure loss of first 2 ramps
accumlate_pressure_loss = total_pressure_ratio1 * total_pressure_ratio2;
```

Terminal Normal Shock

This final shock brings the flow from supersonic to subsonic, before it enters the diffuser.

```
%the downstream mach after ramp 2 becomes the mach speed at the terminal
%area
mach3 = downstream_flow_mach2;

% Downstream Mach after normal shock
downstream_mach_3to4 = sqrt((1+((gamma-1)/2)*mach3^2)/(gamma*mach3^2-((gamma-1)/
2)));

% Static pressure ratio across normal shock
static_pressure_ratio_3to4 = 1 + (2*gamma/(gamma+1))*(mach3^2 - 1);

% Total pressure ratio across normal shock
```

```
total_pressure_ratio_3to4 = static_pressure_ratio_3to4*((1 + ((gamma-1)/
2)*downstream_mach_3to4^2)/(1 + ((gamma-1)/2)*mach3^2))^(gamma/(gamma-1));
```

Finally, the total inlet pressure from the freestream to engine face is found.

```
overall_pressure_recovery =
total_pressure_ratio1*total_pressure_ratio2*total_pressure_ratio_3to4;
```

Results

```
fprintf('\n      Ramp 1 Oblique Shock: \n');
```

```
      Ramp 1 Oblique Shock:
```

```
fprintf('Ramp 1 deflection angle (deg) = %.2f\n', rad2deg(rampdeflectangle1));
```

```
Ramp 1 deflection angle (deg) = 8.80
```

```
fprintf('Shock angle (deg)             = %.2f\n', rad2deg(beta1));
```

```
Shock angle (deg)             = 33.17
```

```
fprintf('Downstream Mach               = %.3f\n', downstream_flow_mach1);
```

```
Downstream Mach               = 1.959
```

```
fprintf('Total pressure ratio          = %.4f\n', total_pressure_ratio1);
```

```
Total pressure ratio          = 0.9859
```

```
fprintf(" \n")
```

```
fprintf('\n      Ramp 2 Oblique Shock: \n');
```

```
      Ramp 2 Oblique Shock:
```

```
fprintf('Ramp 2 deflection angle (deg) = %.2f\n', rad2deg(rampdeflectangle2));
```

```
Ramp 2 deflection angle (deg) = 5.50
```

```
fprintf('Shock angl (deg)              = %.2f\n', rad2deg(beta2));
```

```
Shock angl (deg)              = 35.54
```

```
fprintf('Downstream Mach               = %.3f\n', downstream_flow_mach2);
```

```
Downstream Mach               = 1.764
```

```
fprintf('Total pressure ratio          = %.4f\n', total_pressure_ratio2);
```

```
Total pressure ratio          = 0.9973
```

```
fprintf(" \n")
```

```
fprintf('\n      Terminal Normal Shock:\n');
```

```
      Terminal Normal Shock:
```

```
fprintf('Mach before normal shock      = %.3f\n', mach3);
```

```
Mach before normal shock      = 1.764
```

```
fprintf('Engine-face Mach              = %.3f\n', downstream_mach_3to4);
```

```
Engine-face Mach              = 0.625
```

```
fprintf('Total pressure ratio          = %.4f\n', total_pressure_ratio_3to4);
```

```
Total pressure ratio          = 0.8286
```

```
fprintf(" \n")
```

```
fprintf('\n      Overall Inlet Performance: \n');
```

```
      Overall Inlet Performance:
```

```
fprintf('Overall pressure recovery     = %.4f\n', overall_pressure_recovery);
```

```
Overall pressure recovery     = 0.8147
```

```
fprintf(" \n")
```

```
fprintf('\nDesign summary: Mach %.1f inlet achieves %.1f%% total pressure
recovery\n', mach_free, overall_pressure_recovery*100);
```

```
Design summary: Mach 2.3 inlet achieves 81.5% total pressure recovery
```