```
%Turbomachinery

clc
clear all
close all

%Reading input file; if it doesnt work, change path
filename='5HP_data_points.txt'

fid = fopen(filename,'r');
[line1,count] = fscanf(fid,'%s',[1,32]);
col = 18; % number of columns
[A,count] = fscanf(fid,'%g',[col,inf]); % reading parameters into Matrix A
fclose(fid);

A=A';

% Post Processing
% polar coordinates -> cartesian coordiantes
Theta=10-reshape(A(:,3),16,[]);
Theta=pi*Theta./180; % Grad -> Radiant
radius=300.5-reshape(A(:,4),16,[]);
[x,y]=pol2cart(Theta,radius);

% Constants
kappa=1.4;
R=287; %specific cas constant of air
T_S=22+273.15;



% Figures
% 2D plot Ptot
f1 = figure(1);
set(f1, 'Position', [0 0 1500 400])
subplot(1,2,1)
Ptot=reshape(A(:,8),16,[]);
contourf(y,x,Ptot, 30)
shading flat
colorbar
axis off
text(-60,277,'1')
text(-55,183+23.5*3,'0.75')
text(-50,183+23.5*2,'0.50')
text(-45,183+23.5,'0.25') % (277-183)*25%/100=23.5
text(-40,183,'0')
text(-32,181,'-0.5','HorizontalAlignment','center')
text(-32/2,183,'-0.25','HorizontalAlignment','center')
text(0,185,'0','HorizontalAlignment','center')
text(32/2,183,'0.25','HorizontalAlignment','center')
text(32,181,'0.5','HorizontalAlignment','center')
text(0,175,'Pitch [-]','HorizontalAlignment','center')
text(-65,183+23.5*2,'Span [-]','Rotation',↵
90,'HorizontalAlignment','center')
title('P_{tot}')

% 2D plot Pstat
f2 = figure(2);
set(f2, 'Position', [0 0 1500 400])
subplot(1,2,1)
Pstat=reshape(A(:,9),16,[]);
contourf(y,x,Pstat, 30)
shading flat
colorbar
axis off
text(-60,277,'1')
```

```
text(-55,183+23.5*3,'0.75')
text(-50,183+23.5*2,'0.50')
text(-45,183+23.5,'0.25') % (277-183)*25%/100=23.5
text(-40,183,'0')
text(-32,181,'-0.5','HorizontalAlignment','center')
text(-32/2,183,'-0.25','HorizontalAlignment','center')
text(0,185,'0','HorizontalAlignment','center')
text(32/2,183,'0.25','HorizontalAlignment','center')
text(32,181,'0.5','HorizontalAlignment','center')
text(0,175,'Pitch [-]','HorizontalAlignment','center')
text(-65,183+23.5*2,'Span [-]','Rotation',↙
90,'HorizontalAlignment','center')
title('P_{stat}')


% 2D plot Mach Number
f3 = figure(3);
set(f3, 'Position', [0 0 1500 400])
subplot(1,2,1)
Mach=reshape(A(:,10),16,[]);
contourf(y,x,Mach, 30)
shading flat
colorbar
axis off
text(-60,277,'1')
text(-55,183+23.5*3,'0.75')
text(-50,183+23.5*2,'0.50')
text(-45,183+23.5,'0.25') % (277-183)*25%/100=23.5
text(-40,183,'0')
text(-32,181,'-0.5','HorizontalAlignment','center')
text(-32/2,183,'-0.25','HorizontalAlignment','center')
text(0,185,'0','HorizontalAlignment','center')
text(32/2,183,'0.25','HorizontalAlignment','center')
text(32,181,'0.5','HorizontalAlignment','center')
text(0,175,'Pitch [-]','HorizontalAlignment','center')
text(-65,183+23.5*2,'Span [-]','Rotation',↙
90,'HorizontalAlignment','center')
title('Mach Number')

% 2D plot Yawangle
f4 = figure(4);
set(f4, 'Position', [0 0 1500 400])
subplot(1,2,1)
Yawangle=reshape(A(:,6),16,[]);
Yawangle=2*pi/360.*Yawangle;
contourf(y,x,Yawangle, 30)
shading flat
colorbar
axis off
text(-60,277,'1')
text(-55,183+23.5*3,'0.75')
text(-50,183+23.5*2,'0.50')
text(-45,183+23.5,'0.25') % (277-183)*25%/100=23.5
text(-40,183,'0')
text(-32,181,'-0.5','HorizontalAlignment','center')
text(-32/2,183,'-0.25','HorizontalAlignment','center')
text(0,185,'0','HorizontalAlignment','center')
text(32/2,183,'0.25','HorizontalAlignment','center')
text(32,181,'0.5','HorizontalAlignment','center')
text(0,175,'Pitch [-]','HorizontalAlignment','center')
text(-65,183+23.5*2,'Span [-]','Rotation',↙
90,'HorizontalAlignment','center')
title('Yaw angle')

% 2D plot Pitchangle
f5 = figure(5);
```

```
set(f5, 'Position', [0 0 1500 400])
subplot(1,2,1)
Pitchangle=reshape(A(:,7),16,[]);
Pitchangle=2*pi/360.*Pitchangle;
contourf(y,x,Pitchangle, 30)
shading flat
colorbar
axis off
text(-60,277,'1')
text(-55,183+23.5*3,'0.75')
text(-50,183+23.5*2,'0.50')
text(-45,183+23.5,'0.25') % (277-183)*25%/100=23.5
text(-40,183,'0')
text(-32,181,'-0.5','HorizontalAlignment','center')
text(-32/2,183,'-0.25','HorizontalAlignment','center')
text(0,185,'0','HorizontalAlignment','center')
text(32/2,183,'0.25','HorizontalAlignment','center')
text(32,181,'0.5','HorizontalAlignment','center')
text(0,175,'Pitch [-]','HorizontalAlignment','center')
text(-65,183+23.5*2,'Span [-]','Rotation',↙
90,'HorizontalAlignment','center')
title('Pitch angle')

% 2D plot v_x
v_x=Mach.*sqrt(kappa*R*T_S)./sqrt(1.+tan(Pitchangle).^2.+tan(Yawangle).↙
^2);
f6 = figure(6);
set(f6, 'Position', [0 0 1500 400])
subplot(1,2,1)
contourf(y,x,v_x, 10)
shading flat
colorbar
axis off
text(-60,277,'1')
text(-55,183+23.5*3,'0.75')
text(-50,183+23.5*2,'0.50')
text(-45,183+23.5,'0.25') % (277-183)*25%/100=23.5
text(-40,183,'0')
text(-32,181,'-0.5','HorizontalAlignment','center')
text(-32/2,183,'-0.25','HorizontalAlignment','center')
text(0,185,'0','HorizontalAlignment','center')
text(32/2,183,'0.25','HorizontalAlignment','center')
text(32,181,'0.5','HorizontalAlignment','center')
text(0,175,'Pitch [-]','HorizontalAlignment','center')
text(-65,183+23.5*2,'Span [-]','Rotation',↙
90,'HorizontalAlignment','center')
title('v_x')

% 2D plot Vr
v_r=v_x.*tan(Pitchangle);
f7 =figure(7);
set(f7, 'Position', [0 0 1500 400])
subplot(1,2,1)
contourf(y,x,v_r, 10)
shading flat
colorbar
axis off
text(-60,277,'1')
text(-55,183+23.5*3,'0.75')
text(-50,183+23.5*2,'0.50')
text(-45,183+23.5,'0.25') % (277-183)*25%/100=23.5
text(-40,183,'0')
text(-32,181,'-0.5','HorizontalAlignment','center')
text(-32/2,183,'-0.25','HorizontalAlignment','center')
text(0,185,'0','HorizontalAlignment','center')
text(32/2,183,'0.25','HorizontalAlignment','center')
```

```
text(32,181,'0.5','HorizontalAlignment','center')
text(0,175,'Pitch [-]','HorizontalAlignment','center')
text(-65,183+23.5*2,'Span [-]','Rotation',↵
90,'HorizontalAlignment','center')
title('v_r')

% 2D plot Vtetha
v_tetha=abs(v_x.*tan(Yawangle));
f8 = figure(8);
set(f8, 'Position', [0 0 1500 400])
subplot(1,2,1)
contourf(y,x,v_tetha, 10)
shading flat
colorbar
axis off
text(-60,277,'1')
text(-55,183+23.5*3,'0.75')
text(-50,183+23.5*2,'0.50')
text(-45,183+23.5,'0.25') % (277-183)*25%/100=23.5
text(-40,183,'0')
text(-32,181,'-0.5','HorizontalAlignment','center')
text(-32/2,183,'-0.25','HorizontalAlignment','center')
text(0,185,'0','HorizontalAlignment','center')
text(32/2,183,'0.25','HorizontalAlignment','center')
text(32,181,'0.5','HorizontalAlignment','center')
text(0,175,'Pitch [-]','HorizontalAlignment','center')
text(-65,183+23.5*2,'Span [-]','Rotation',↵
90,'HorizontalAlignment','center')
title('|v_{\theta}|')

%2D Plot Vtot
v_tot=sqrt(v_x.^2+v_tetha.^2+v_r.^2);
f9 = figure(9);
set(f9, 'Position', [0 0 1500 400])
subplot(1,2,1)
contourf(y,x,v_tot, 10)
shading flat
colorbar
axis off
text(-60,277,'1')
text(-55,183+23.5*3,'0.75')
text(-50,183+23.5*2,'0.50')
text(-45,183+23.5,'0.25') % (277-183)*25%/100=23.5
text(-40,183,'0')
text(-32,181,'-0.5','HorizontalAlignment','center')
text(-32/2,183,'-0.25','HorizontalAlignment','center')
text(0,185,'0','HorizontalAlignment','center')
text(32/2,183,'0.25','HorizontalAlignment','center')
text(32,181,'0.5','HorizontalAlignment','center')
text(0,175,'Pitch [-]','HorizontalAlignment','center')
text(-65,183+23.5*2,'Span [-]','Rotation',↵
90,'HorizontalAlignment','center')
title('v_{tot}')


%Mass averaging
%v_n=v_x (bcs v_n velocity normal to the measuring plane)
for i=1:20
    for j=1:15
        v_x_mean(j,i)=(v_x(j,i)+v_x(j,i+1)+v_x(j+1,i)+v_x(j+1,i+1))/4;
    end
end

% density
density_mean=Ptot./(R*T_S);
```

```
dRi=5.5; %radial grid spacing
radial_pos=radius(:,1)+dRi/2;

% mass averaged Ptot
for i=1:20
    for j=1:15
        Ptot_mean(j,i)=(Ptot(j,i)+Ptot(j,i+1)+Ptot(j+1,i)+Ptot(j+1,i+1))
/4;
    end
end

Ptot_sum=0;
m_dot_cell_tot=0;

for j=1:15
    for i=1:20
        dA=dRi*pi*1*(2*radius(j,i)+dRi)/360;
        m_dot_cell=dA*density_mean(j,i)*v_x_mean(j,i);
        Ptot_sum=Ptot_sum+Ptot_mean(j,i)*m_dot_cell;
        m_dot_cell_tot=m_dot_cell_tot+m_dot_cell;
end
Ptot_mmean(j)=Ptot_sum;
Ptot_mmean(j)=Ptot_mmean(j)/m_dot_cell_tot;
end

figure(1)
subplot(1,2,2)
plot(Ptot_mmean,radial_pos(2:16),'-o')
title('Mass averaged P_{tot}')
xlabel('P_{tot} [Pa]')
ylabel('radial position [mm]')

% mass averaged Pstat
for i=1:20
    for j=1:15
        Pstat_mean(j,i)=(Pstat(j,i)+Pstat(j,i+1)+Pstat(j+1,i)+Pstat(j+1,
i+1))/4;
    end
end
Pstat_sum=0;
m_dot_cell_tot=0;
for j=1:15
    for i=1:20
        dA=dRi*pi*1*(2*radius(j,i)+dRi)/360;
        m_dot_cell=dA*density_mean(j,i)*v_x_mean(j,i);
        Pstat_sum=Pstat_sum+Pstat_mean(j,i)*m_dot_cell;
        m_dot_cell_tot=m_dot_cell_tot+m_dot_cell;
    end
    Pstat_mmean(j)=Pstat_sum;
    Pstat_mmean(j)=Pstat_mmean(j)/m_dot_cell_tot;
end

figure(2)
subplot(1,2,2)
plot(Pstat_mmean,radial_pos(2:16),'-o')
title('Mass averaged P_{stat}')
xlabel('P_{stat} [Pa]')
ylabel('radial position [mm]')

% mass averaged Mach
for i=1:20
    for j=1:15
        Mach_mean(j,i)=(Mach(j,i)+Mach(j,i+1)+Mach(j+1,i)+Mach(j+1,i+1))
/4;
    end
end
```

```
Mach_sum=0;
m_dot_cell_tot=0;
for j=1:15
    for i=1:20
        dA=dRi*pi*1*(2*radius(j,i)+dRi)/360;
        m_dot_cell=dA*density_mean(j,i)*v_x_mean(j,i);
        Mach_sum=Mach_sum+Mach_mean(j,i)*m_dot_cell;
        m_dot_cell_tot=m_dot_cell_tot+m_dot_cell;
    end
    Mach_mmean(j)=Mach_sum;
    Mach_mmean(j)=Mach_mmean(j)/m_dot_cell_tot;
end

figure(3)
subplot(1,2,2)
plot(Mach_mmean,radial_pos(2:16),'-o')
title('Mass averaged Mach')
xlabel('Mach [-]')
ylabel('radial position [mm]')

% mass averaged Yawangle
for i=1:20
    for j=1:15
        Yawangle_mean(j,i)=(Yawangle(j,i)+Yawangle(j,i+1)+Yawangle(j+1,i)
+Yawangle(j+1,i+1))/4;
    end
end
Yawangle_sum=0;
m_dot_cell_tot=0;
for j=1:15
    for i=1:20
        dA=dRi*pi*1*(2*radius(j,i)+dRi)/360;
        m_dot_cell=dA*density_mean(j,i)*v_x_mean(j,i);
        Yawangle_sum=Yawangle_sum+Yawangle_mean(j,i)*m_dot_cell;
        m_dot_cell_tot=m_dot_cell_tot+m_dot_cell;
    end
    Yawangle_mmean(j)=Yawangle_sum;
    Yawangle_mmean(j)=Yawangle_mmean(j)/m_dot_cell_tot;
end

figure(4)
subplot(1,2,2)
plot(Yawangle_mmean,radial_pos(2:16),'-o')
title('Mass averaged Yaw angle \gamma')
xlabel('Yaw angle [rad]')
ylabel('radial position [mm]')

% mass averaged Pitch angle
for i=1:20
    for j=1:15
        Pitchangle_mean(j,i)=(Pitchangle(j,i)+Pitchangle(j,i+1)+Pitchangle
(j+1,i)+Pitchangle(j+1,i+1))/4;
    end
end
Pitchangle_sum=0;
m_dot_cell_tot=0;
for j=1:15
    for i=1:20
        dA=dRi*pi*1*(2*radius(j,i)+dRi)/360;
        m_dot_cell=dA*density_mean(j,i)*v_x_mean(j,i);
        Pitchangle_sum=Pitchangle_sum+Pitchangle_mean(j,i)*m_dot_cell;
        m_dot_cell_tot=m_dot_cell_tot+m_dot_cell;
    end
    Pitchangle_mmean(j)=Pitchangle_sum;
    Pitchangle_mmean(j)=Pitchangle_mmean(j)/m_dot_cell_tot;
end
```

```
figure(5)
subplot(1,2,2)
plot(Pitchangle_mmean,radial_pos(2:16),'-o')
title('Mass averaged Pitch \phi')
xlabel('Pitch [rad]')
ylabel('radial position [mm]')


% mass averaged v_x
for i=1:20
    for j=1:15
        v_x_mean(j,i)=(v_x(j,i)+v_x(j,i+1)+v_x(j+1,i)+v_x(j+1,i+1))/4;
    end
end
v_x_sum=0;
m_dot_cell_tot=0;
for j=1:15
    for i=1:20
        dA=dRi*pi*1*(2*radius(j,i)+dRi)/360;
        m_dot_cell=dA*density_mean(j,i)*v_mean(j,i);
        v_x_sum=v_x_sum+v_x_mean(j,i)*m_dot_cell;
        m_dot_cell_tot=m_dot_cell_tot+m_dot_cell;
    end
    v_x_mmean(j)=v_x_sum;
    v_x_mmean(j)=v_x_mmean(j)/m_dot_cell_tot;
end

figure(6)
subplot(1,2,2)
plot(v_x_mmean,radial_pos(2:16),'-o')
title('Mass averaged v_x')
xlabel('v_x [m/s]')
ylabel('radial position [mm]')

% mass averaged v_r
for i=1:20
    for j=1:15
        v_r_mean(j,i)=(v_r(j,i)+v_r(j,i+1)+v_r(j+1,i)+v_r(j+1,i+1))/4;
    end
end
v_r_sum=0;
m_dot_cell_tot=0;
for j=1:15
    for i=1:20
        dA=dRi*pi*1*(2*radius(j,i)+dRi)/360;
        m_dot_cell=dA*density_mean(j,i)*v_x_mean(j,i);
        v_r_sum=v_r_sum+v_r_mean(j,i)*m_dot_cell;
        m_dot_cell_tot=m_dot_cell_tot+m_dot_cell;
    end
    v_r_mmean(j)=v_r_sum;
    v_r_mmean(j)=v_r_mmean(j)/m_dot_cell_tot;
end

figure(7)
subplot(1,2,2)
plot(v_r_mmean,radial_pos(2:16),'-o')
title('Mass averaged v_r')
xlabel('v_r [m/s]')
ylabel('radial position [mm]')

% V_tetha
for i=1:20
    for j=1:15
        v_tetha_mean(j,i)=(v_tetha(j,i)+v_tetha(j,i+1)+v_tetha(j+1,i)
+v_tetha(j+1,i+1))/4;
```

```
    end
end
v_tetha_sum=0;
m_dot_cell_tot=0;
for j=1:15
    for i=1:20
        dA=dRi*pi*1*(2*radius(j,i)+dRi)/360;
        m_dot_cell=dA*density_mean(j,i)*v_x_mean(j,i);
        v_tetha_sum=v_tetha_sum+v_tetha_mean(j,i)*m_dot_cell;
        m_dot_cell_tot=m_dot_cell_tot+m_dot_cell;
    end
    v_tetha_mmean(j)=v_tetha_sum;
    v_tetha_mmean(j)=v_tetha_mmean(j)/m_dot_cell_tot;
end

figure(8)
subplot(1,2,2)
plot(v_tetha_mmean,radial_pos(2:16),'-o')
title('Mass averaged |v_{\theta}|')
xlabel('|v_{\theta}| [rad/s]')
ylabel('radial position [mm]')

% v_tot
for i=1:20
    for j=1:15
        v_tot_mean(j,i)=(v_tot(j,i)+v_tot(j,i+1)+v_tot(j+1,i)+v_tot(j+1,
i+1))/4;
    end
end
v_tot_sum=0;
m_dot_cell_tot=0;
for j=1:15
    for i=1:20
        dA=dRi*pi*1*(2*radius(j,i)+dRi)/360;
        m_dot_cell=dA*density_mean(j,i)*v_x_mean(j,i);
        v_tot_sum=v_tot_sum+v_tot_mean(j,i)*m_dot_cell;
        m_dot_cell_tot=m_dot_cell_tot+m_dot_cell;
    end
    v_tot_mmean(j)=v_tot_sum;
    v_tot_mmean(j)=v_tot_mmean(j)/m_dot_cell_tot;
end

figure(9)
subplot(1,2,2)
plot(v_tot_mmean,radial_pos(2:16),'-o')
title('Mass averaged v_{tot}')
xlabel('v_{tot} [m/s]')
ylabel('radial position [mm]')



format long
%Matrix with all data


span = 100*(radial_pos(2:16) - 183)/94; %span in porcentage
MEAN_DATA = [span radial_pos(2:16) Ptot_mmean' Pstat_mmean' Mach_mmean'
Yawangle_mmean' Pitchangle_mmean' v_x_mmean' v_r_mmean' v_tetha_mmean'];


   SPAN_DATA(1,1) = 90;
   SPAN_DATA(2,1) = 70;
   SPAN_DATA(3,1) = 50;
   SPAN_DATA(4,1) = 30;
   SPAN_DATA(5,1) = 10;
```

```
for i = 2:10



    SPAN_DATA(1,i) = MEAN_DATA(2,i) + (MEAN_DATA(1,i)-MEAN_DATA(2,i))*(90-
MEAN_DATA(2,1))/(MEAN_DATA(1,1)-MEAN_DATA(2,1));
    SPAN_DATA(2,i) = MEAN_DATA(5,i) + (MEAN_DATA(4,i)-MEAN_DATA(5,i))*(70-
MEAN_DATA(5,1))/(MEAN_DATA(4,1)-MEAN_DATA(5,1));
    SPAN_DATA(3,i) = MEAN_DATA(8,i) + (MEAN_DATA(7,i)-MEAN_DATA(8,i))*(50-
MEAN_DATA(8,1))/(MEAN_DATA(7,1)-MEAN_DATA(8,1));
    SPAN_DATA(4,i) = MEAN_DATA(12,i) + (MEAN_DATA(11,i)-MEAN_DATA(12,i))*
(30-MEAN_DATA(12,1))/(MEAN_DATA(11,1)-MEAN_DATA(12,1));
    SPAN_DATA(5,i) = MEAN_DATA(15,i) + (MEAN_DATA(14,i)-MEAN_DATA(15,i))*
(10-MEAN_DATA(15,1))/(MEAN_DATA(14,1)-MEAN_DATA(15,1));



end


SPAN_DATA;


%Blade angles
%Rotor velocity
N=5000; %Rounds per Minute
U=2*pi*N/60.*SPAN_DATA(:,2)*10^(-3);
%stator Blade entry angles
alpha2=[37.000; 39.500; 41.500; 45.000; 51.000];

%Behind stator
C3=sqrt(SPAN_DATA(:,8).^2+SPAN_DATA(:,10).^2);
alpha3=tan(SPAN_DATA(:,10)/SPAN_DATA(:,8));

%Behind rotor
C2=sqrt((SPAN_DATA(:,8).*tan(2*pi/360*alpha2)).^2+SPAN_DATA(:,8).^2);
beta2=360/(2*pi)*atan((U-SPAN_DATA(:,8).*tan(alpha2*2*pi/360))./SPAN_DATA
(:,8));
v2r=((U-SPAN_DATA(:,8).*tan(alpha2*2*pi/360)).^2+SPAN_DATA(:,8).^2).^
(0.5);

%in front of rotor
beta1=360/(2*pi)*atan(U./SPAN_DATA(:,8));
v1r=sqrt(SPAN_DATA(:,8).^2+U.^2);
```