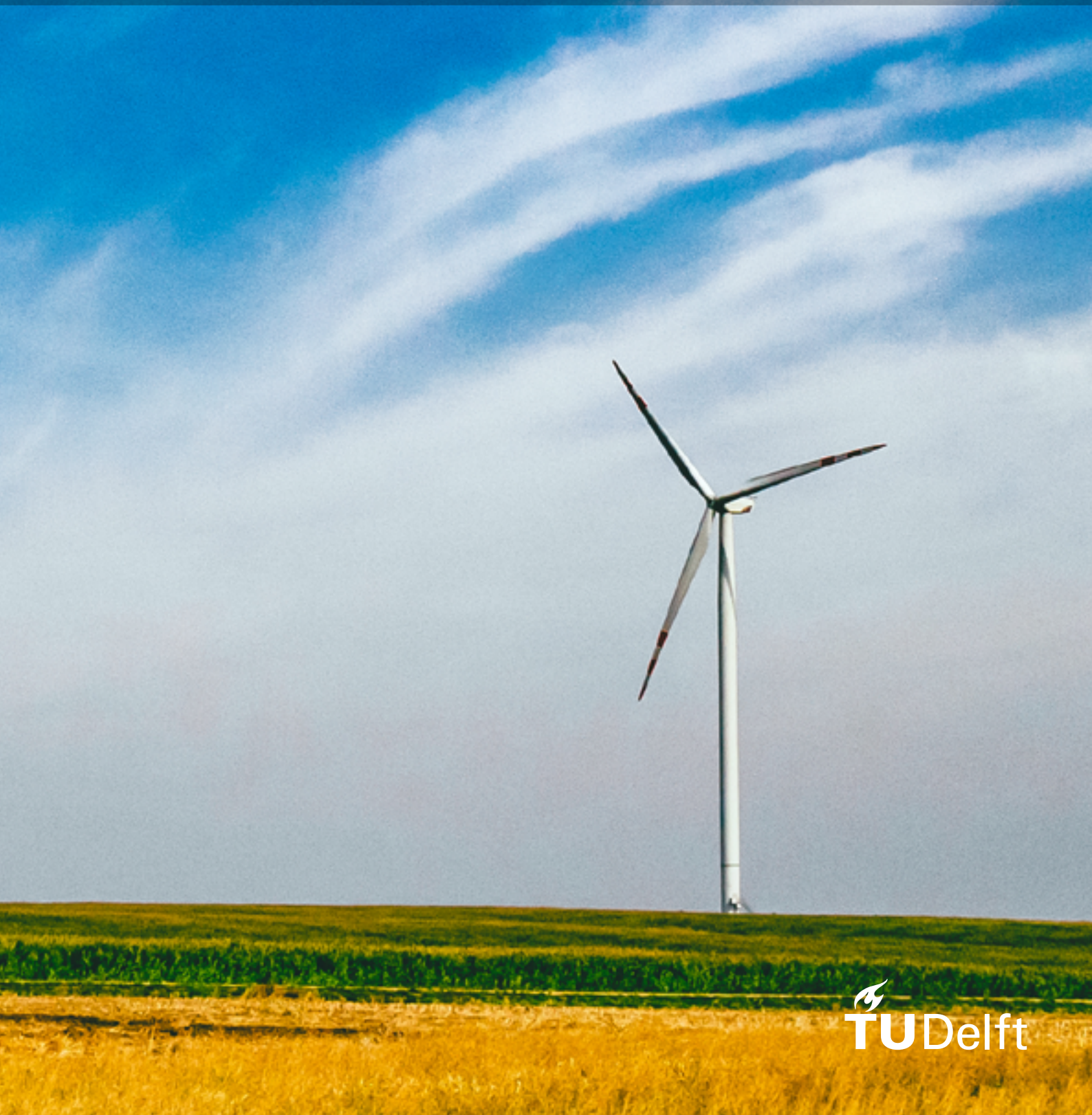
I-ACT Modular UAV

Literature Survey

April 28th, 2017



TU Delft

Delft University of Technology

[AE4180] Flow Measurement Techniques

Laboratory Exercise Report

PIV and HWA Results for a NACA-0012 Airfoil

Supervisors:
Dr. John Doe

Authors:
Ş. Kılkış 4192028

Abstract

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May 30, 2019

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List of Symbols

ABCD	Ayy Bee See Dee	
AHAHAH	Test Test Test	
Roman Symbols		
C_L	Lift Coefficient	–
V	Velocity	$\mathrm{kg\,m^{-1}}$
S	Wing Area	$\mathrm{m^2}$
Greek Symbols		
ρ	Density of Air	$\mathrm{kg\,m^{-3}}$

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1 Example LaTeX Elements

Şan Kılkış. This template has been developed for the [AE3200] Design Synthesis Exercise. `THIS TEMPLATE CANNOT BE USED WITHOUT EXPRESSED PERMISSION FROM:` Şan Kılkış and Munyung Kim

1.1 Tables & Figures

An example Table 1.1 and an example Figure 1.1 can be found in this section. When you label tables or figures, make sure to use 'tab:name' or 'fig:name', this is not necessary for syntax but makes organization and look-up of labels easier. For inserting 2+ figures in a row, look at the formatting of Figure Figure 1.2. Using the `cleveref` package negates the need for manually typing 'Table' or 'Figure'. The syntax is as follows, note that the 'tab' in 'tab:exampletable' is not necessary for `cref` and is purely for organizational reasons. However a ',' cannot be utilized as this is interpreted as a list.

```
\cref{tab:exampletable}
```

The Tables below use the package `tabularx` which adjusts column spacing automatically to fit the table within the margins of the page. The syntax is as follows where 'L' is for Left Aligned, 'C' for Centered, and 'R' is for Right Aligned:

```
\begin{tabularx}{\textwidth}{L C C C}
```

In order to keep up the same appearance for all tables use the commands `toprule`, `midrule`, `bottomrule`, and `hdashline` to create the horizontal lines. NO VERTICAL LINES ARE ALLOWED!

Table 1.1: Example Table

Component	**Mass [kg]**	**Location [m]**	**Location [% MAC]**
Wing	425.4	5.74	40.00
Main Landing Gear	243.1	5.82	45.00
Fuel System	80.74	5.91	50.00
Flight Control System	48.61	6.08	60.00
Hydraulics	4.660	6.08	60.00
Wing Group	**802.5**	**5.80**	**43.85**
Fuselage	265.2	5.74	40.00
Engine	409.4	1.64	-
Avionics	490.9	4.39	-
H. Tail	42.93	13.2	-
V. Tail	66.43	12.6	-
Nose Gear	54.58	2.50	-
Electrical	217.4	6.16	67.12
AC & Anti-Ice	215.7	6.16	67.12
Furnishings	241.5	6.16	67.12
Fuselage Group	**2004**	**5.01**	**-2.32**
OEW C.G.	**2806**	**5.24**	**10.88**

Table 1.2: Example Table II

m	$\Re\{\underline{\mathfrak{X}}(m)\}$	$-\Im\{\underline{\mathfrak{X}}(m)\}$	$\mathfrak{X}(m)$	$\frac{\mathfrak{X}(m)}{23}$	A_m	$\varphi(m)$ / °	φ_m / °
1	16.128	+8.872	16.128	1.402	1.373	-146.6	-137.6
2	3.442	-2.509	3.442	0.299	0.343	133.2	152.4
3	1.826	-0.363	1.826	0.159	0.119	168.5	-161.1
4	0.993	-0.429	0.993	0.086	0.08	25.6	90
5	1.29	+0.099	1.29	0.112	0.097	-175.6	-114.7
6	0.483	-0.183	0.483	0.042	0.063	22.3	122.5
7	0.766	-0.475	0.766	0.067	0.039	141.6	-122
8	0.624	+0.365	0.624	0.054	0.04	-35.7	90
9	0.641	-0.466	0.641	0.056	0.045	133.3	-106.3
10	0.45	+0.421	0.45	0.039	0.034	-69.4	110.9
11	0.598	-0.597	0.598	0.052	0.025	92.3	-109.3

Figure 1.1: TU Delft Logo Flame

(a) TU Delft Logo Flame (b) TU Delft Logo Flame

Figure 1.2: Two Figures Side-by-Side

1.2 References & Citations

The `biblatex` package is used for references with the default 'numeric' style for in-text citations and references [1]. The references sorting style is set to 'none' meaning that the references are sorted by the order in which they appear in text. A sample file `samplerefs.bib` is included to help when dealing with different types of publications.

```
\cite{citationtag}
```

1.3 Equations & Nomenclature

When typesetting equations, you need to use a nomenclature code when you introduce a variable for the FIRST time, such that the variable is listed on the list of symbols. An example is given below by Equation 1.1. With the current implementation, duplicate nomenclature items are not automatically removed.

$$L = \frac{1}{2}\rho V^2 S \cdot C_L \tag{1.1}$$

The the list of symbols for the above equation were generated with the code below:

```
\nomenclature[A]{ABCD}{Ayy Bee See Dee}
\nomenclature[B]{$C_L$}{Lift Coefficient \nomunit{-}}
\nomenclature[B, 01]{$V$}{Velocity \nomunit{\si{kg.m^{-1}}}}
\nomenclature[B, 02]{$S$}{Wing Area \nomunit{\si{m^{2}}}}
\nomenclature[G]{$\rho$}{Density of Air \nomunit{\si{kg.m^{-3}}}}
```

1.4 Units and Numbers

```
\SI{5}{\kilogram}
```

References

[1] Lots of Coffee and Caffiene. *LaTeX: A Lovely Typesetting Language*. No One Publishing House of Bravos, 2019.

A MATLAB Code

A.1 Main Script [main.m]

```
clear all;
close all;
clc;

gamma=1.4; %Ratio of Specific Heats (Air)

%% Importing Tables from Nozzle1.csv and Nozzle2.csv

global NoZ1 NoZ2

NoZ1.data=readtable('Nozzle1.csv'); %NoZ1 = Nozzle1
NoZ2.data=readtable('Nozzle2.csv'); %NoZ2 = Nozzle2

%% Importing Experimental Data

NoZ1.ExperimentSUP=readtable('2017-02-17_12-21-48.txt');
NoZ1.ExperimentSUB=readtable('2017-02-17_12-24-22.txt');
NoZ2.Experiment1=readtable('2017-02-17_12-37-39.txt');
NoZ2.Experiment2=readtable('2017-02-17_12-31-42.txt');
NoZ2.Experiment3=readtable('2017-02-17_12-34-20.txt');

%% Theoretical Supersonic Flow for First Nozzle [Choked Flow Conditions At=A*]

NoZ1.SUP.A=NoZ1.data.A;
NoZ1.SUP.MACH=zeros(length(NoZ1.SUP.A),1);
NoZ1.SUP.P=zeros(length(NoZ1.SUP.A),1);
for i=1:length(NoZ1.SUP.A);
    if i<6
        [NoZ1.SUP.MACH(i), ~, NoZ1.SUP.P(i), ~, ~]=flowisentropic(gamma, NoZ1.SUP.A(i), 'sub')
            ;
    else
        [NoZ1.SUP.MACH(i), ~, NoZ1.SUP.P(i), ~, ~]=flowisentropic(gamma, NoZ1.SUP.A(i), 'sup')
            ;
    end
end

%% Theoretical Subsonic Flow for First Nozzle [Non-Choked Flow Conditions At=/=A*]

PRatio=NoZ1.ExperimentSUB.P_Pt(1); % Measured Pressure Ratio at First Pressure Measurement

[~, ~, ~, ~, NoZ1.SUB.A_star]=flowisentropic(gamma, PRatio, 'pres');
NoZ1.SUB.A_correction=NoZ1.SUB.A_star*(1/NoZ1.data.A(1)); %A(x0)/A_star * A_t/A(x0) = A_t/
    A_star
NoZ1.SUB.A=NoZ1.SUB.A_correction.*NoZ1.data.A;

for i=1:length(NoZ1.SUB.A);
    [NoZ1.SUB.MACH(i), ~, NoZ1.SUB.P(i), ~, ~]=flowisentropic(gamma, NoZ1.SUB.A(i), 'sub');
end

%% Obtaining Experimental Mach Number using Isentropic Relations

NoZ1.SUP.MACH_EXP=zeros(length(NoZ1.ExperimentSUP.mm),1);
NoZ1.SUB.MACH_EXP=zeros(length(NoZ1.ExperimentSUP.mm),1);

for i=1:length(NoZ1.ExperimentSUP.mm)
        [NoZ1.SUP.MACH_EXP(i), ~, ~, ~, ~]=flowisentropic(gamma, NoZ1.ExperimentSUP.P_Pt(i), '
            pres');
        [NoZ1.SUB.MACH_EXP(i), ~, ~, ~, ~]=flowisentropic(gamma, NoZ1.ExperimentSUB.P_Pt(i), '
            pres');
end

%% Calculating Area Ratio at Shock Location

NoZ2.x_shock=[390 530 630];
[hk2,dh,h0]=meter2geo(15,10); %Input Experiment Meter Values Here (meter4,meter5)
A_ratio=(dh*NoZ2.x_shock(2:3)+h0)/hk2;
```

```
for i=1:length(A_ratio)
    [~, ~, NoZ2.SUB.Pe3(i), ~, ~]=flowisentropic(gamma, A_ratio(i), 'sub');
    [NoZ2.SUP.MACH_XSHOCK(i), ~, NoZ2.SUP.Pe6(i), ~, ~]=flowisentropic(gamma, A_ratio(i), 'sup
        ');
    [~, ~, NoZ2.SUP.Pe5(i), ~, ~, ~, ~]=flownormalshock(gamma, NoZ2.SUP.MACH_XSHOCK(i), 'mach'
        );
    NoZ2.SUP.Pe5(i)=NoZ2.SUP.Pe5(i)*NoZ2.SUP.Pe6(i);
end

%% Plotting Fiures

%Part I:

Margin=0.125; %Control Figure Margins
LabelSize=9; %Control Label Text Size
AR=[8 5]; %Aspect Ratio
NF=0.01; %Distance to Nudge Plot to Compensate for Axis Labels

figure('Name','MachNoZ1');
hold on; grid on; grid minor;
line([65 65],[0 NoZ1.SUP.MACH(5)],'Color','k','LineStyle','- -'); %Drawing a Vertical Line to
    Indicate Throat Sonic Value
line([0 65],[1 1],'Color','k','LineStyle','- -'); %Drawing a Horizontal Line to Indicate
    Throat Sonic Value
line([0 194.8],[2.1 2.1],'Color','k','LineStyle','- -'); %Drawing a Horizontal Line to
    Indicate Throat Sonic Value
text(65.5,0.75,'$\leftarrow x_t = 65 \left[ mm \right]$','Interpreter','LaTex','FontSize',8)
text(50,1.05,'M = 1','Interpreter','LaTex','FontSize',8)
text(120,2.15,['$M_{e} =$ ' num2str(NoZ1.SUP.MACH(26))],'Interpreter','LaTex','FontSize',8)
line1=plot(NoZ1.data.x,NoZ1.SUB.MACH,'LineWidth',1);
line2=plot(NoZ1.data.x,NoZ1.SUP.MACH,'LineWidth',1);
line3=plot(NoZ1.ExperimentSUB.mm,NoZ1.SUB.MACH_EXP,'Color',[0 174 255]/255,'marker','o','
    MarkerFaceColor','w','MarkerSize',3,'LineWidth',1);
line4=plot(NoZ1.ExperimentSUP.mm,NoZ1.SUP.MACH_EXP,'Color',[221 135 51]/255,'marker','o','
    MarkerFaceColor','w','MarkerSize',3,'LineWidth',1);
axis([44.8 194.8 0 2.5])
xlabel('Position [mm]','fontsize',12,'Interpreter','LaTex');
ylabel('Mach Number [-]','fontsize',12,'Interpreter','LaTex');
legend([line1,line3,line2,line4],{'Subsonic [Theory]','Subsonic [EXP1A]','Supersonic [Theory]'
    ,'Supersonic [EXP2A]'},'Location','East'); %Creating Legend
set(gca,... %Formatting Axis Text
    'XMinorTick','on',...
    'YMinorTick','on',...
    'FontSize',LabelSize/1.5,...
    'TickLabelInterpreter','LaTex',...
    'LabelFontSizeMultiplier',1.5,...
    'Position',[((Margin+NF)/2) ((0+((AR(1)/AR(2))*(Margin)))/2) (1-Margin) (1-((AR(1)/AR(2))*
        Margin))]);
set(gcf, 'InvertHardCopy', 'off');
set(gcf, 'PaperPosition', [0 0 AR(1) AR(2)]); %Position plot at left hand corner with width 6
    and height 5.
set(gcf, 'PaperSize', [AR(1) AR(2)]); %Set the paper to have width 6 and height 5.

figure('Name','PressureNoZ1');
hold on; grid on; grid minor;
line([65 65],[0 NoZ1.SUB.P(5)],'Color','k','LineStyle','- -'); %Drawing a Vertical Line to
    Indicate Throat Sonic Value
line([0 65],[0.528 0.528],'Color','k','LineStyle','- -'); %Drawing a Horizontal Line to
    Indicate Throat Sonic Value
text(65.5,0.1,'$\leftarrow x_t = 65 \left[ mm \right]$','Interpreter','LaTex','FontSize',8)
text(66,0.528,'$\leftarrow \frac{p}{p_t}=0.528$','Interpreter','LaTex','FontSize',8)
line1=plot(NoZ1.data.x,NoZ1.SUB.P,'LineWidth',1);
line2=plot(NoZ1.data.x,NoZ1.SUP.P,'LineWidth',1);
line3=plot(NoZ1.ExperimentSUB.mm,NoZ1.ExperimentSUB.P_Pt,'Color',[0 174 255]/255,'marker','o',
    'MarkerFaceColor','w','MarkerSize',3,'LineWidth',1);
line4=plot(NoZ1.ExperimentSUP.mm,NoZ1.ExperimentSUP.P_Pt,'Color',[221 135 51]/255,'marker','o'
    ,'MarkerFaceColor','w','MarkerSize',3,'LineWidth',1);
xlabel('Position [mm]','Interpreter','LaTex','Color','k');
ylabel('Pressure Ratio $\left[ \frac{p}{p_{t}} \right]$','Interpreter','LaTex','Color','k');
legend([line1,line3,line2,line4],{'Subsonic [Theory]','Subsonic [EXP1]','Supersonic [Theory]',
    'Supersonic [EXP2]'},'Location','East'); %Creating Legend
axis([44.8 194.8 0 1]) %Setting Axis Limits
```

```
set(gca,... %Formatting Axis Text
    'XMinorTick','on',...
    'YMinorTick','on',...
    'FontSize',LabelSize/1.5,...
    'TickLabelInterpreter','LaTex',...
    'LabelFontSizeMultiplier',1.5,...
    'Position',[((Margin+NF)/2) ((0+((AR(1)/AR(2))*(Margin)))/2) (1-Margin) (1-((AR(1)/AR(2))*
        Margin))]);
set(gcf, 'InvertHardCopy', 'off');
set(gcf, 'PaperPosition', [0 0 AR(1) AR(2)]); %Position plot at left hand corner with width 6
    and height 5.
set(gcf, 'PaperSize', [AR(1) AR(2)]); %Set the paper to have width 6 and height 5.

%Part II:

figure('Name','PressureNoZ2');
hold on; grid on; grid minor;
line1=plot(NoZ2.Experiment1.mm,NoZ2.Experiment1.P_Pt,'marker','o','MarkerFaceColor','w','
    MarkerSize',3,'LineWidth',1);
line2=plot(NoZ2.Experiment2.mm,NoZ2.Experiment2.P_Pt,'marker','o','MarkerFaceColor','w','
    MarkerSize',3,'LineWidth',1);
line3=plot(NoZ2.Experiment3.mm,NoZ2.Experiment3.P_Pt,'marker','o','MarkerFaceColor','w','
    MarkerSize',3,'LineWidth',1);
line4=line([NoZ2.x_shock(1) NoZ2.x_shock(1)],[0 1],'Color','k','LineStyle','-.');
line5=line([NoZ2.x_shock(2) NoZ2.x_shock(2)],[0 1],'Color','k','LineStyle','--');
line6=line([NoZ2.x_shock(3) NoZ2.x_shock(3)],[0 1],'Color','k');
point1=scatter(NoZ2.x_shock(2:3),NoZ2.SUB.Pe3,'*','MarkerEdgeColor',[0 0.60 0.50]);
point2=scatter(NoZ2.x_shock(2:3),NoZ2.SUP.Pe5,'*','MarkerEdgeColor',[0.80 0.40 0]);
point3=scatter(NoZ2.x_shock(2:3),NoZ2.SUP.Pe6,'*');
xlabel('Position [mm]','Interpreter','LaTex','Color','k');
ylabel('Pressure Ratio $\left[ \frac{p}{p_{t}} \right]$','Interpreter','LaTex','Color','k');
legend([line1,line2,line3,line4,line5,line6,point1,point2,point3],{'Experiment 3A','Experiment
     4A','Experiment 5A','Shock at Throat','Shock at $x=530$ [mm]','Shock at $x=630$ [mm]','
    Maximum Pressure Ratio [$p_{e3}/{p_t}$]','Pressure Ratio After Norm. Shock [$p_{e5}/{p_t}$
    ]','Minumum Pressure Ratio [$p_{e6}/{p_t}$]'},'Location','West','Interpreter','LaTex'); %
    Creating Legend
set(gca,... %Formatting Axis Text
    'XMinorTick','on',...
    'YMinorTick','on',...
    'FontSize',LabelSize/1.5,...
    'TickLabelInterpreter','LaTex',...
    'LabelFontSizeMultiplier',1.5,...
    'Position',[((Margin+NF)/2) ((0+((AR(1)/AR(2))*(Margin)))/2) (1-Margin) (1-((AR(1)/AR(2))*
        Margin))]);
set(gcf, 'InvertHardCopy', 'off');
set(gcf, 'PaperPosition', [0 0 AR(1) AR(2)]); %Position plot at left hand corner with width 6
    and height 5.
set(gcf, 'PaperSize', [AR(1) AR(2)]); %Set the paper to have width 6 and height 5.

clear vars Margin LabelSize AR NF

%% Saving/Overwriting Figures in the Images Folder as a .pdf

choice=questdlg('Would you like to close and save all figures to ../Figures?',...
    'Figure Save Dialog', ...
    'Yes','Just Save','Specify Directory','Specify Directory');
switch choice
    case 'Yes'
        if exist('Figures','dir')==0
        mkdir('Figures')
        end
        cd('Figures')
        b1=waitbar(0,'1','Name','Please Wait');
        H=gcf;
        i_prime=H.Number;
        for i=1:i_prime
            waitbar(i/i_prime,b1,sprintf('Saving Figure (%d/%d)',i,i_prime))
            saveas(i, get(i,'Name'), 'pdf')
        end
        cd('../')
        close all
        delete(b1)
        b2=msgbox('Operation Completed','Success');
```

```
    case 'Just Save'
        if exist('Figures','dir')==0
        mkdir('Figures')
        end
        cd('Figures')
        b1=waitbar(0,'1','Name','Please Wait');
        H=gcf;
        i_prime=H.Number;
        for i=1:i_prime
            waitbar(i/i_prime,b1,sprintf('Saving Figure (%d/%d)',i,i_prime))
            saveas(i, get(i,'Name'), 'pdf')
        end
        cd('../')
        delete(b1)
        b2=msgbox('Operation Completed','Success');
    case 'Specify Directory'
        old_dir=cd;
        new_dir=uigetdir('','Select Figure Saving Directory');
        cd(new_dir)
        b1=waitbar(0,'1','Name','Please Wait');
        H=gcf;
        i_prime=H.Number;
        for i=1:i_prime
            waitbar(i/i_prime,b1,sprintf('Saving Figure (%d/%d)',i,i_prime))
            saveas(i, get(i,'Name'), 'pdf')
        end
        cd(old_dir)
        close all
        delete(b1)
        b2=msgbox('Operation Completed','Success');
end
```

A.2 Table Look-Up Function [meter2geo.m]

```
function [hk2, dh, h0] = meter2geo(meter4, meter5)
%METER2GEO Utilizes provided Table 2 Data to read out the value of the 2nd
%throat height and parameters for the variable diffuser height function ( dh/dx & h0)

global NoZ2

hk2=0; dh=0; h0=0;

for i = 1:length(NoZ2.data.meter4)
    if NoZ2.data.meter4(i)==meter4 && NoZ2.data.meter5(i)==meter5
        hk2=NoZ2.data.hk2(i);
        dh=NoZ2.data.dh(i);
        h0=NoZ2.data.h0(i);
    end
end

if hk2==0 && dh==0 && h0==0
    disp('WARNING: No Valid Entry was Found in Look-up Table')
end
```