Charlie Nitschelm

4/7/19

ME 647

Engine Lab

Contents

Table of Figures 1

Optical Sensor Voltage, Crank Angle, Cylinder Volume, and Pressure 2

Pressure vs. Cylinder Volume for a Single Cycle 8

Pressure vs. Cylinder Volume for all Cycles 14

Average Work and Power / Cycle / Cylinder for Various Engine Speeds 20

Engine Parameters 20

Brake Torque and Power with Engine Speed 21

Brake Thermal Efficiency with Various Engine Speeds 22

Mass Flow Rate with Different Engine Speeds 23

Table of Figures

Figure 1 - Experimental Data for the Kohler Model CH20S SI Engine at 600RPM 2
Figure 2 - Experimental Data for the Kohler Model CH20S SI Engine at 700RPM 3
Figure 3 - Experimental Data for the Kohler Model CH20S SI Engine at 800RPM 4
Figure 4 - Experimental Data for the Kohler Model CH20S SI Engine at 900RPM 5
Figure 5 - Experimental Data for the Kohler Model CH20S SI Engine at 1000RPM 6
Figure 6 - Experimental Data for the Kohler Model CH20S SI Engine at 1100RPM 7
Figure 7 - Cylinder pressure vs. cylinder volume at 600 RPM for a single cycle 8
Figure 8 - Cylinder pressure vs. cylinder volume at 700 RPM for a single cycle 9
Figure 9 - Cylinder pressure vs. cylinder volume at 800 RPM for a single cycle 10
Figure 10 - Cylinder pressure vs. cylinder volume at 900 RPM for a single cycle 11
Figure 11 - Cylinder pressure vs. cylinder volume at 1000 RPM for a single cycle 12
Figure 12 - Cylinder pressure vs. cylinder volume at 1100 RPM for a single cycle 13
Figure 13 - Cylinder pressure vs. cylinder volume at 600 RPM for all cycles 14
Figure 14 - Cylinder pressure vs. cylinder volume at 700 RPM for all cycles 15
Figure 15 - Cylinder pressure vs. cylinder volume at 800 RPM for all cycles 16
Figure 16 - Cylinder pressure vs. cylinder volume at 900 RPM for all cycles 17
Figure 17 - Cylinder pressure vs. cylinder volume at 1000 RPM for all cycles 18
Figure 18 - Cylinder pressure vs. cylinder volume at 1100 RPM for all cycles 19
Figure 19 - Brake Torque and Power Values with different Rotational Engine Speeds 21
Figure 20 - The Brake Thermal Efficiency of the engine at different engine speeds 22
Figure 21 - Mass flow rate of the engine at different rotational speeds in kg/s 23
Figure 22 - Mass flow rate of the engine at different rotational speeds in kg/cycle/cylinder 24

Optical Sensor Voltage, Crank Angle, Cylinder Volume, and Pressure

The following figures detail the Crank Angle position, the cylindrical volume, and the pressure of the cylinder with respect to time for various rotational speeds of the Kohler Model CH20S SI Engine.

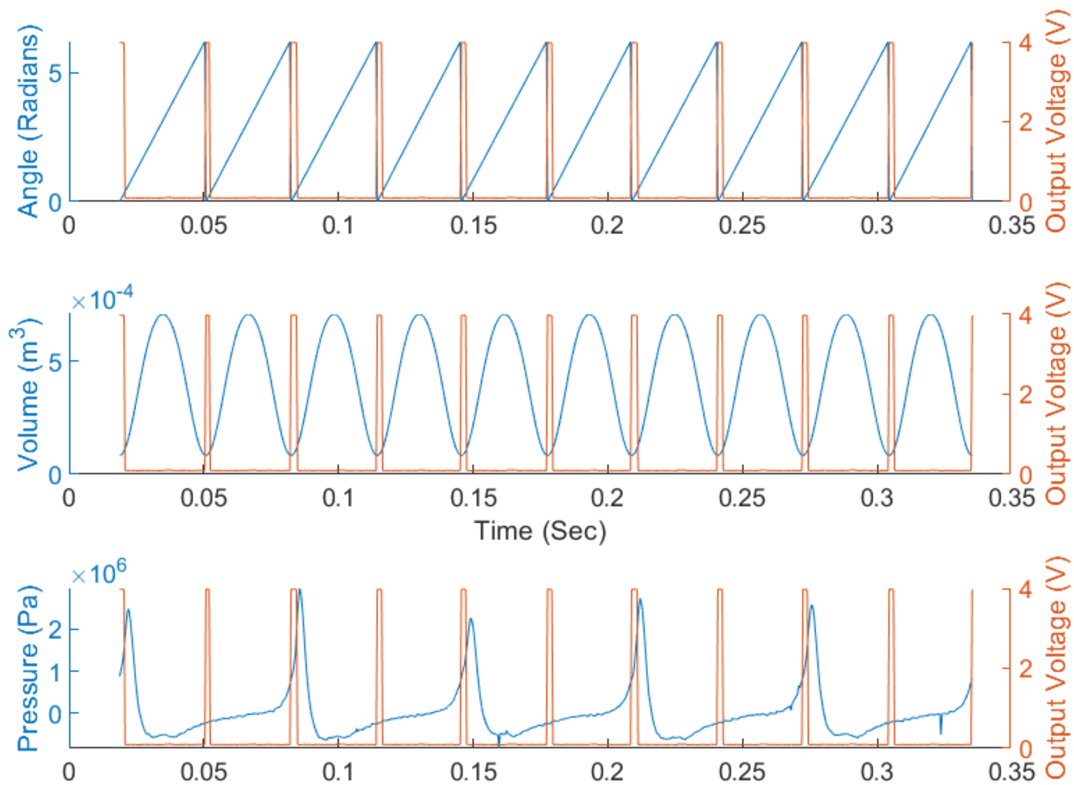

Figure 1 - Experimental Data for the Kohler Model CH20S SI Engine at 600RPM

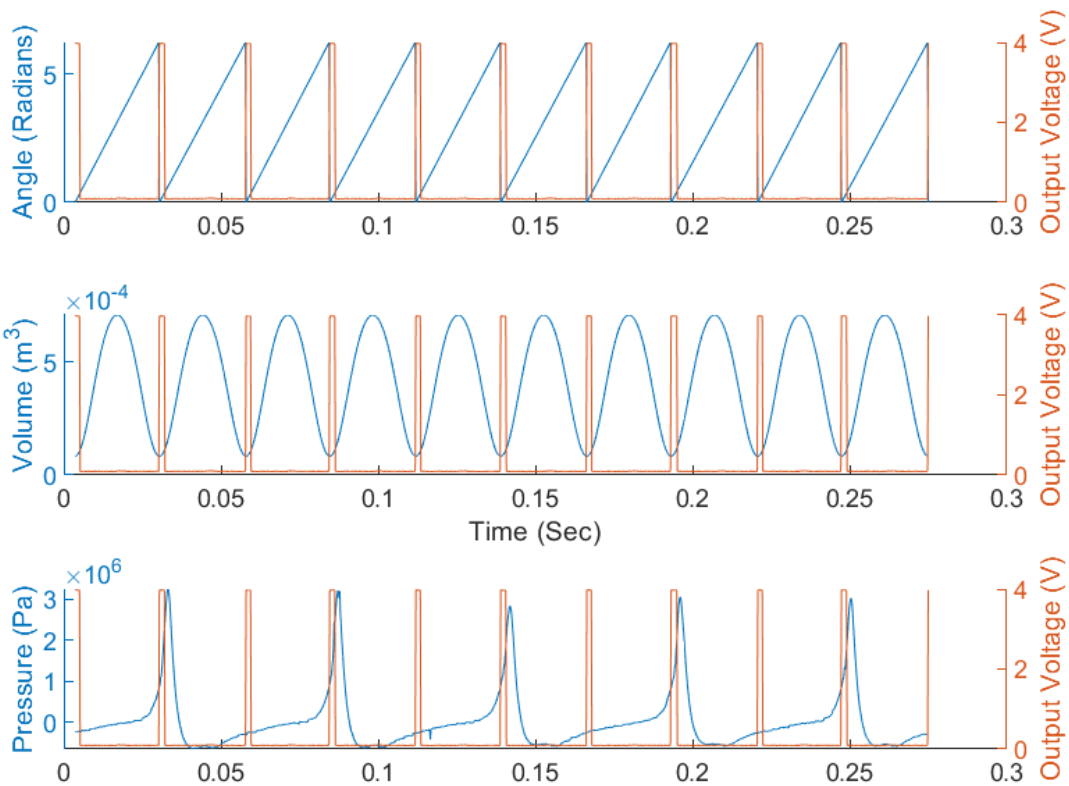

Figure 2 - Experimental Data for the Kohler Model CH20S SI Engine at 700RPM

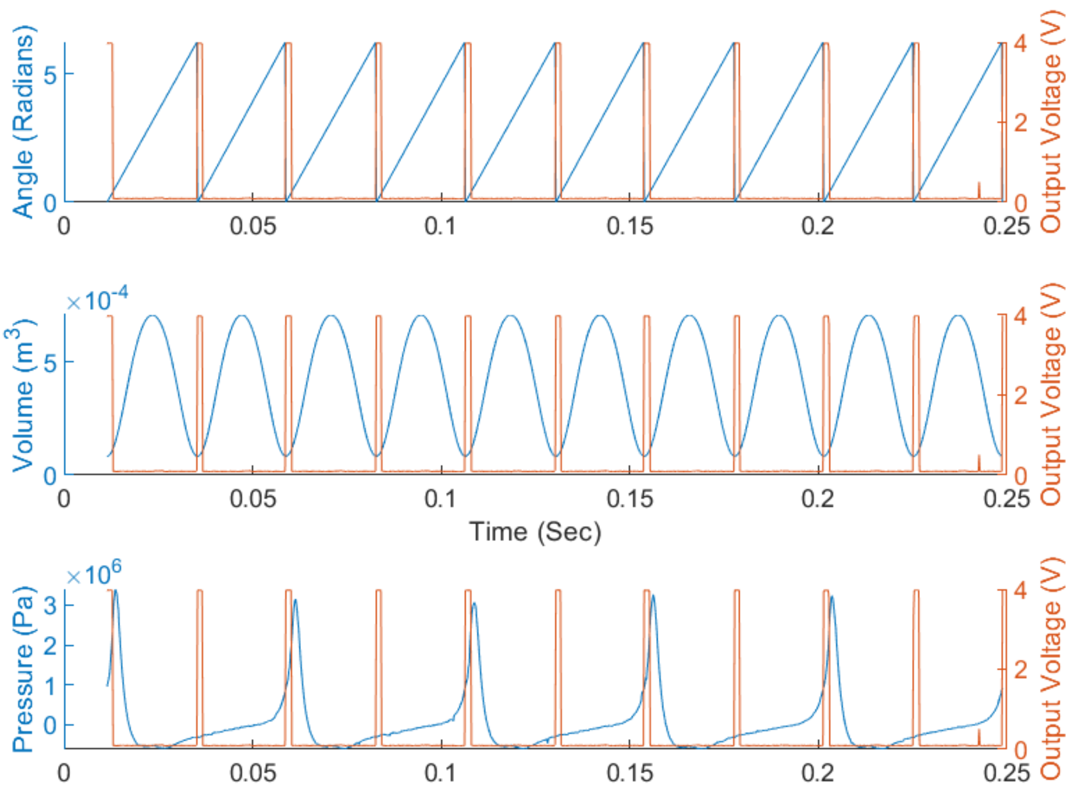

Figure 3 - Experimental Data for the Kohler Model CH20S SI Engine at 800RPM

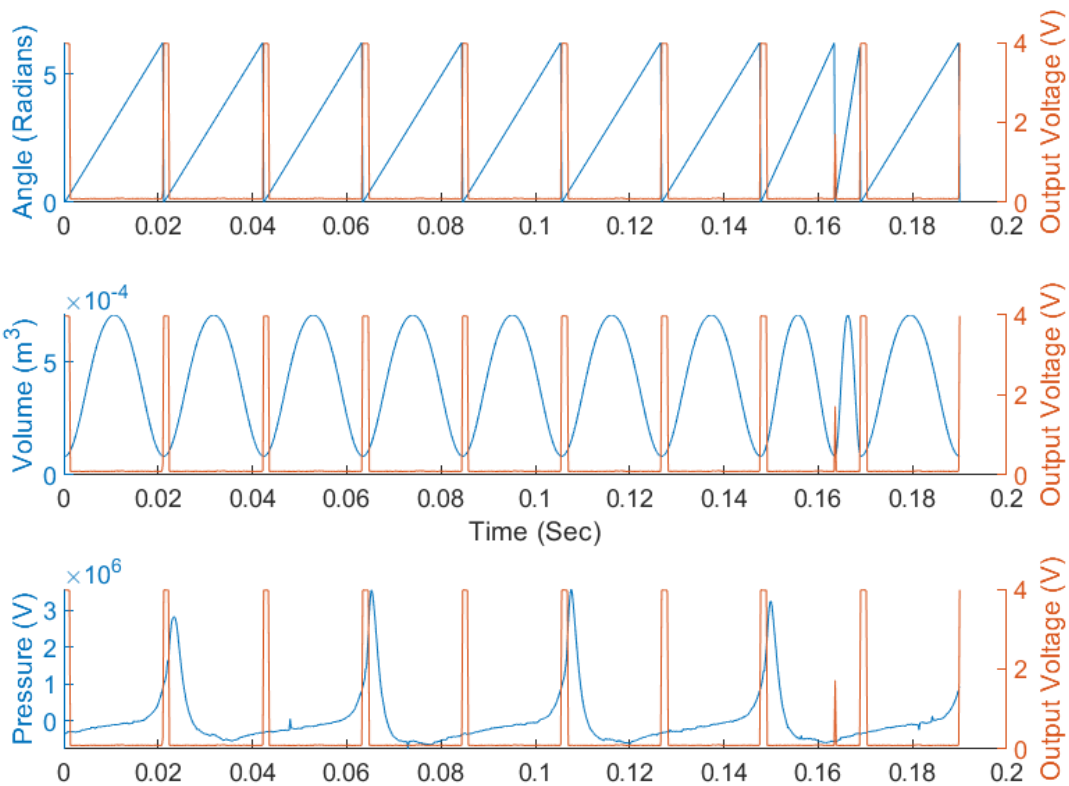

Figure 4 - Experimental Data for the Kohler Model CH20S SI Engine at 900RPM

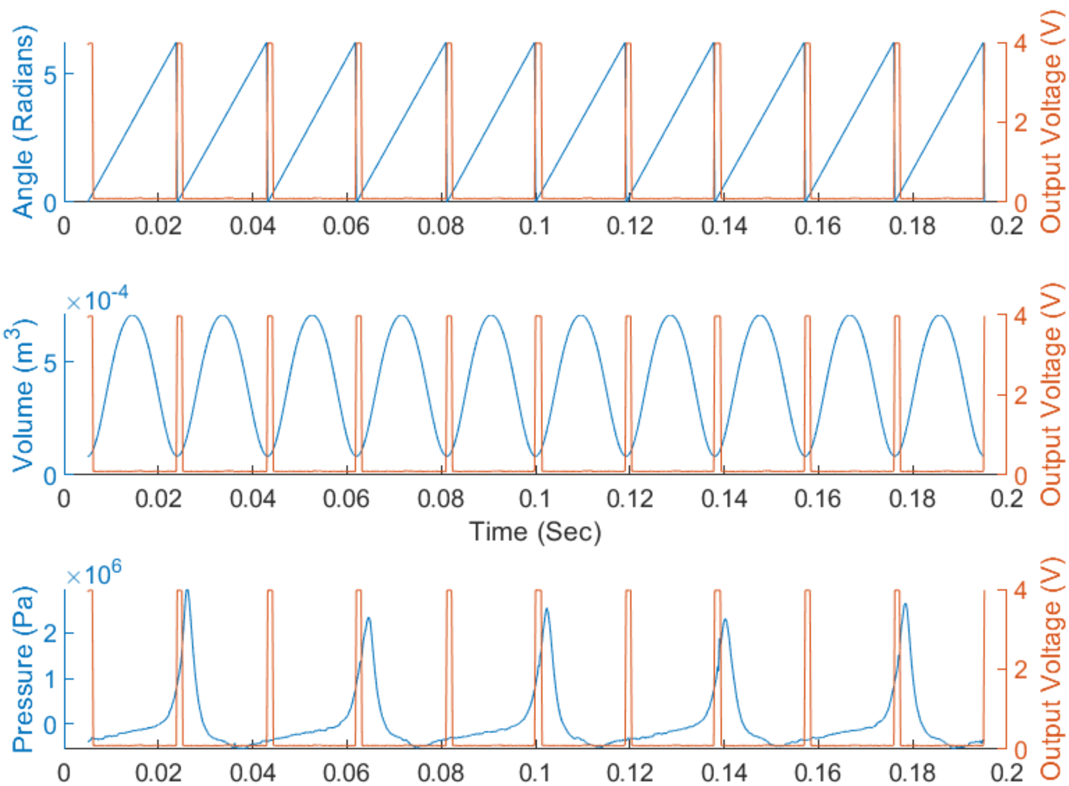

Figure 5 - Experimental Data for the Kohler Model CH20S SI Engine at 1000RPM

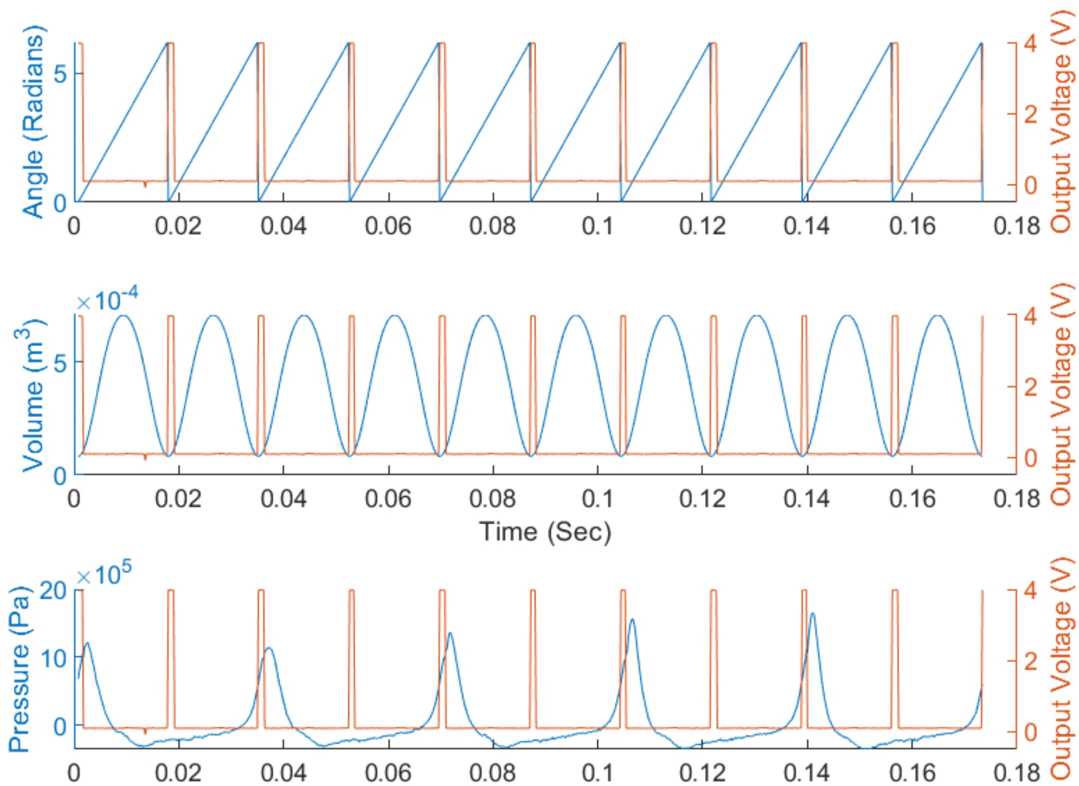

Figure 6 - Experimental Data for the Kohler Model CH20S SI Engine at 1100RPM

Pressure vs. Cylinder Volume for a Single Cycle

The following graphs detail a single cycle of the engine at various engine speeds.

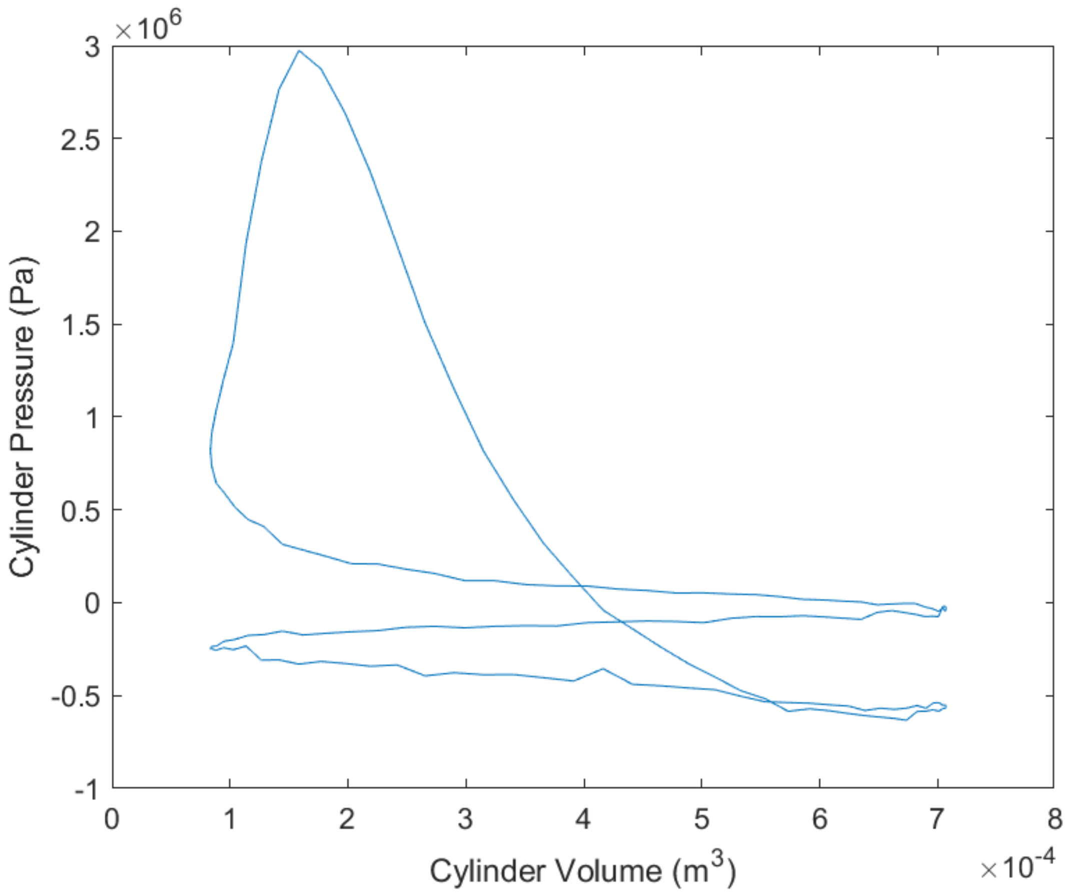

Figure 7 - Cylinder pressure vs. cylinder volume at 600 RPM for a single cycle

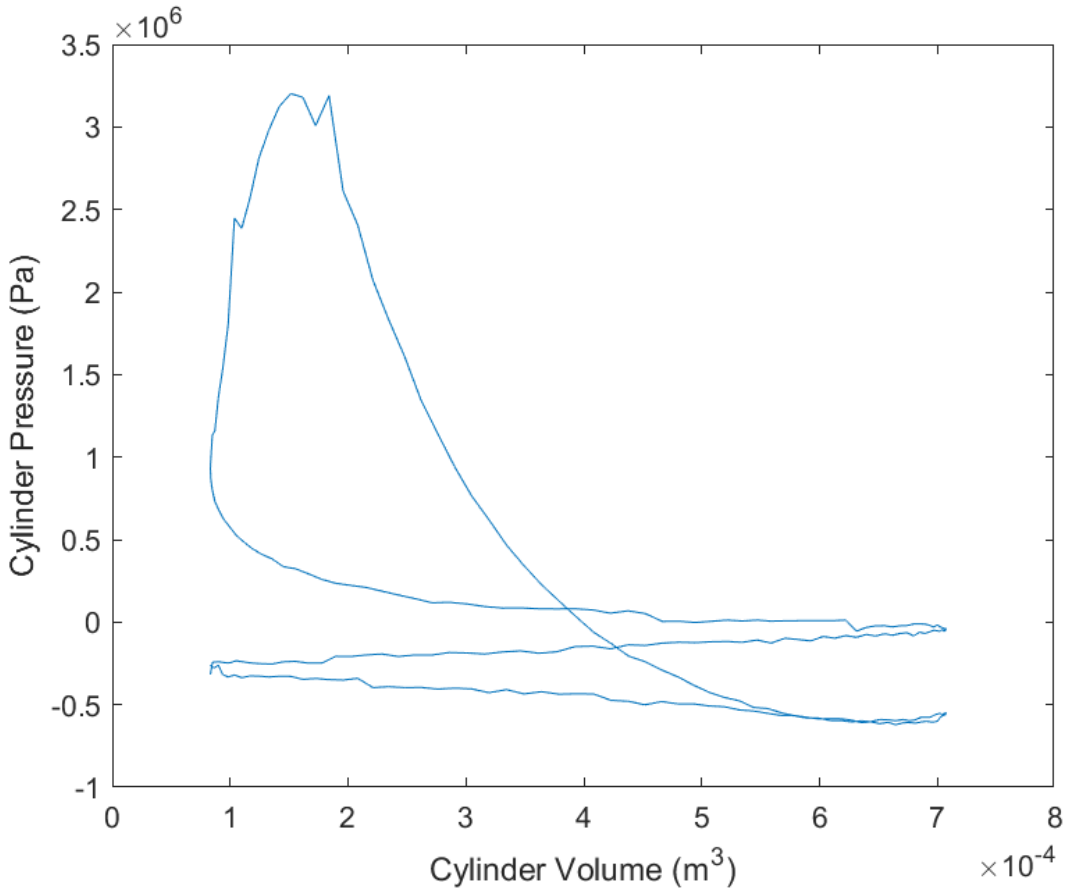

Figure 8 - Cylinder pressure vs. cylinder volume at 700 RPM for a single cycle

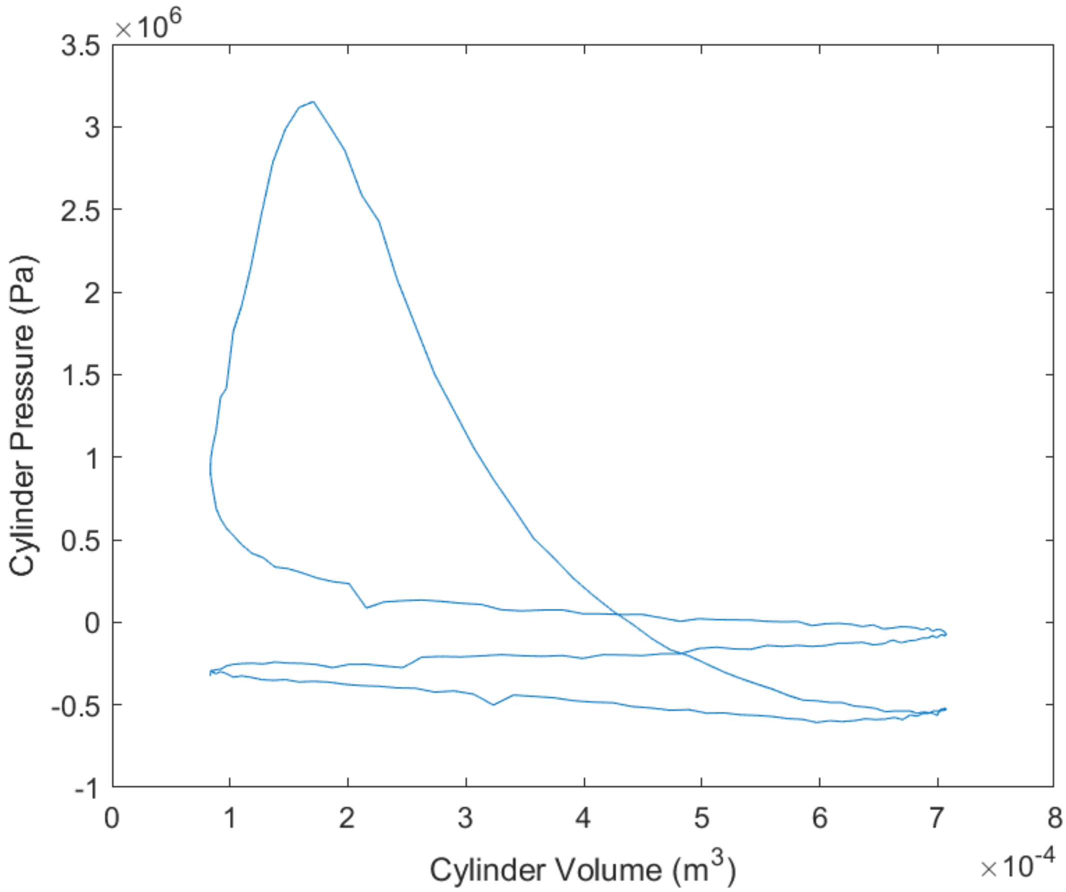

Figure 9 - Cylinder pressure vs. cylinder volume at 800 RPM for a single cycle

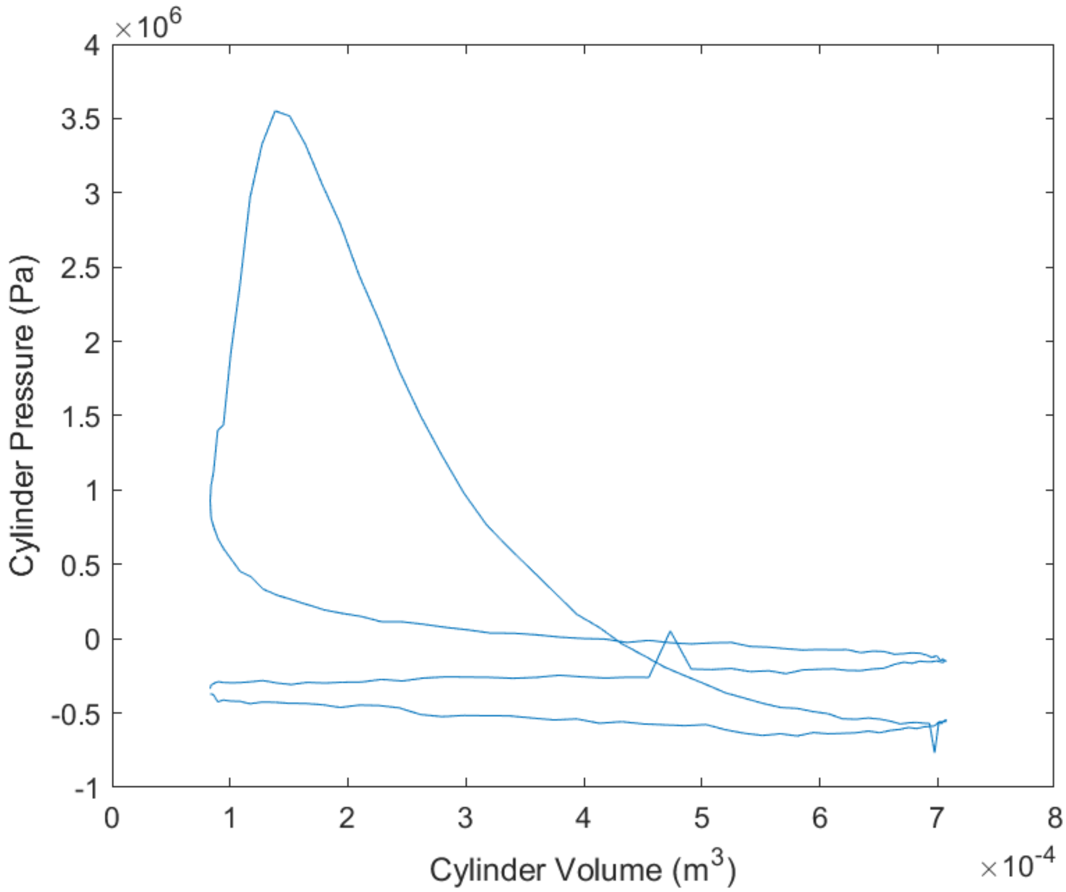

Figure 10 - Cylinder pressure vs. cylinder volume at 900 RPM for a single cycle

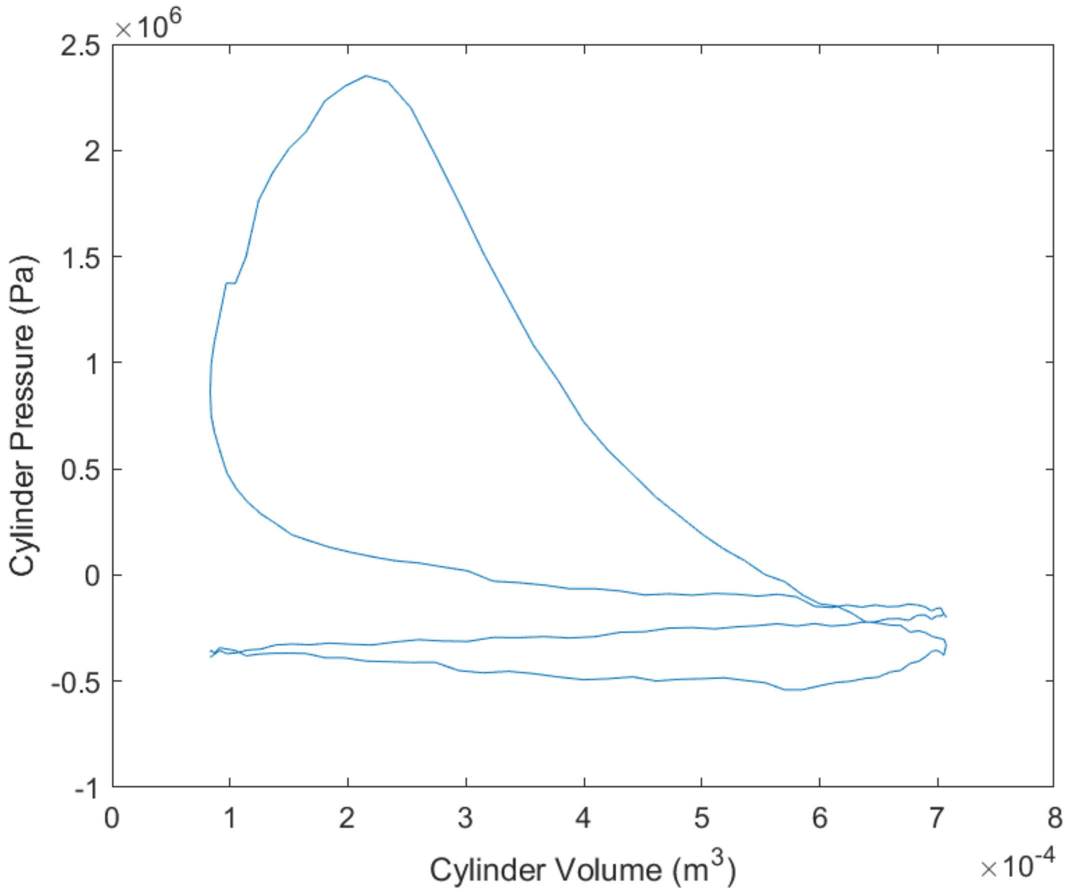

Figure 11 - Cylinder pressure vs. cylinder volume at 1000 RPM for a single cycle

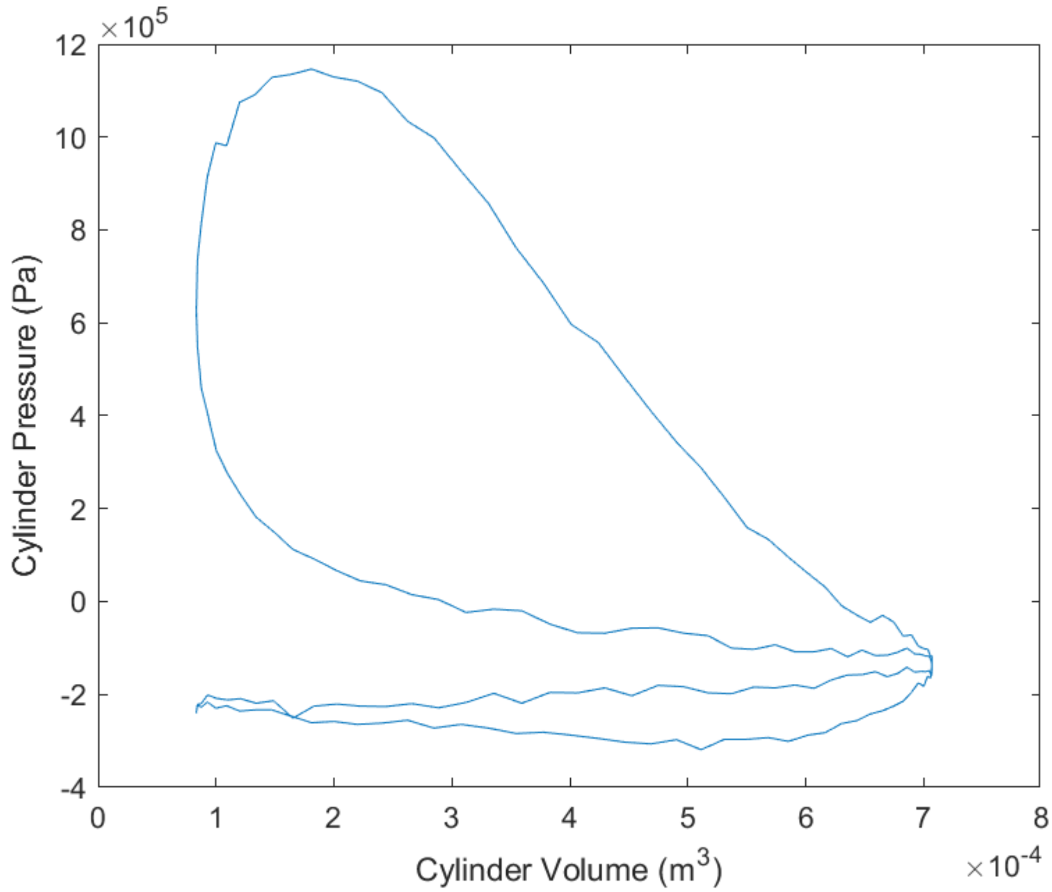

Figure 12 - Cylinder pressure vs. cylinder volume at 1100 RPM for a single cycle

Pressure vs. Cylinder Volume for all Cycles

The following graphs detail all cycles of the engine at various engine speeds.

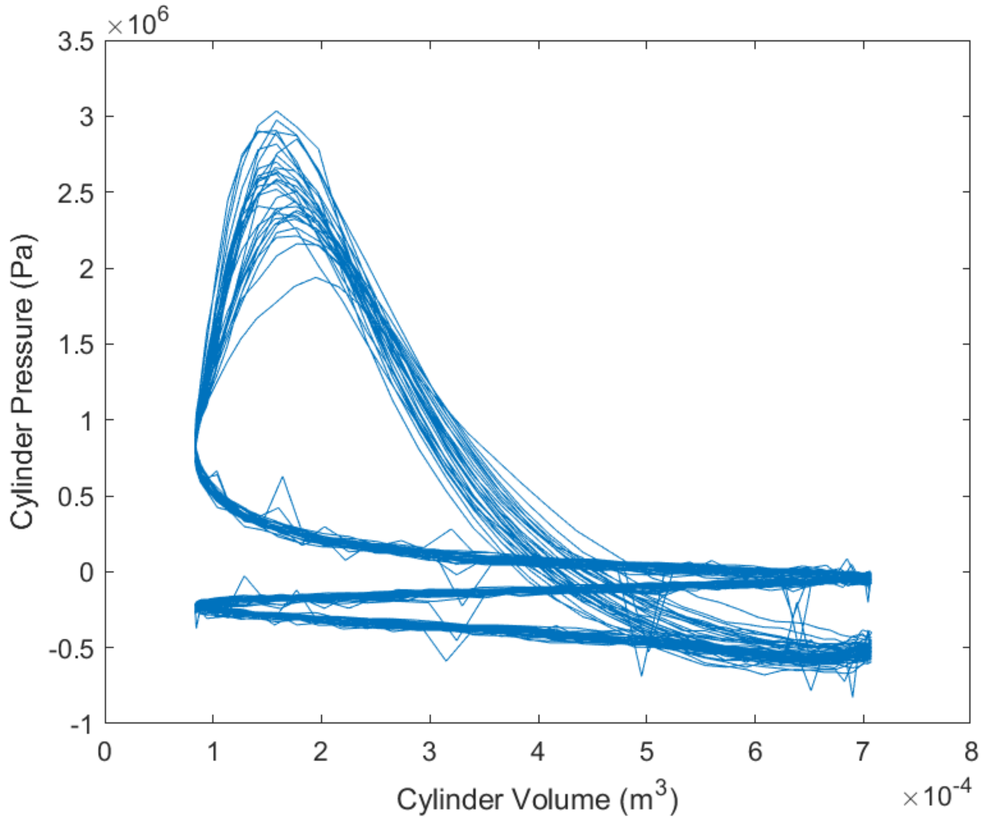

Figure 13 - Cylinder pressure vs. cylinder volume at 600 RPM for all cycles

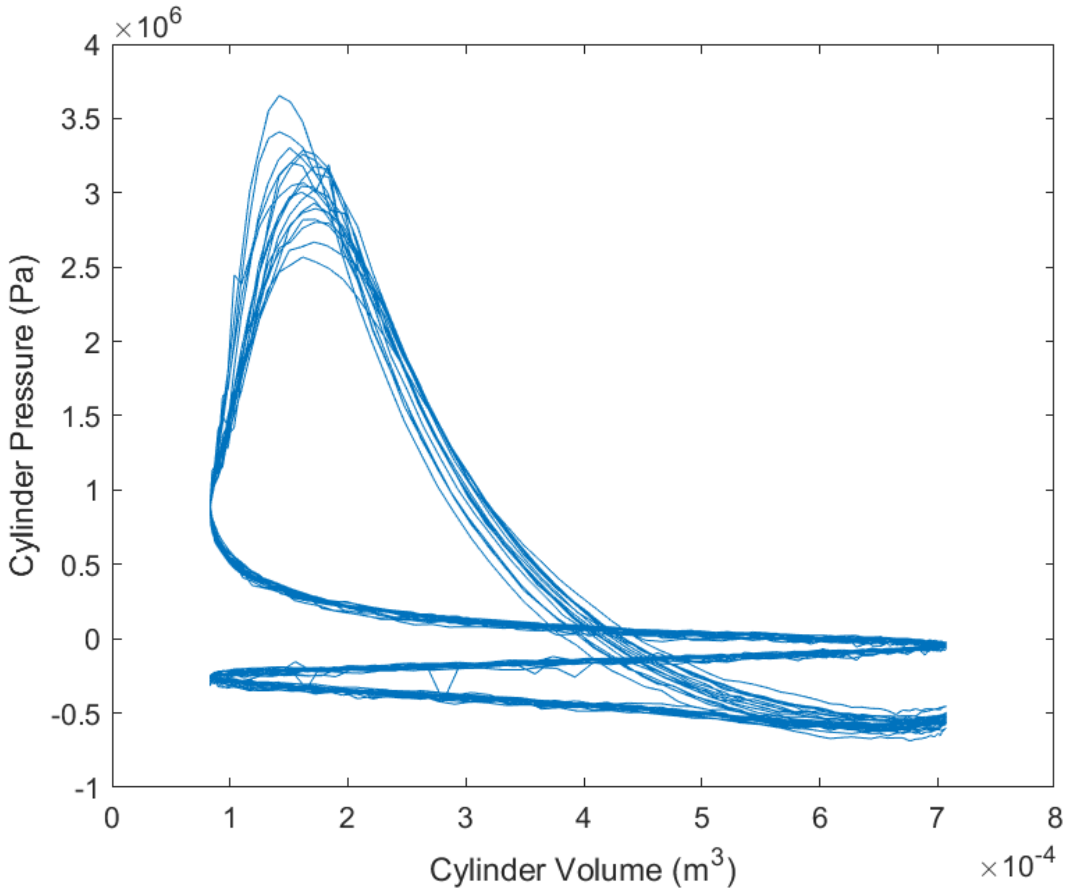

Figure 14 - Cylinder pressure vs. cylinder volume at 700 RPM for all cycles

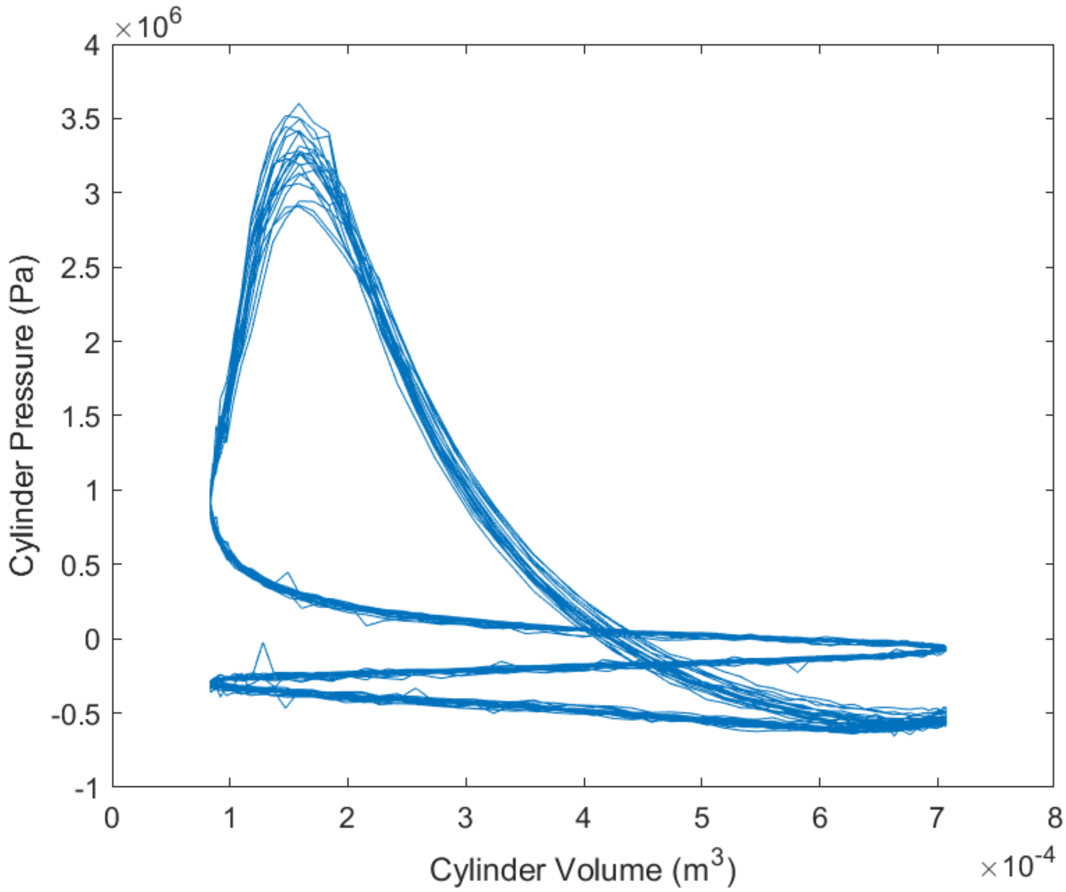

Figure 15 - Cylinder pressure vs. cylinder volume at 800 RPM for all cycles

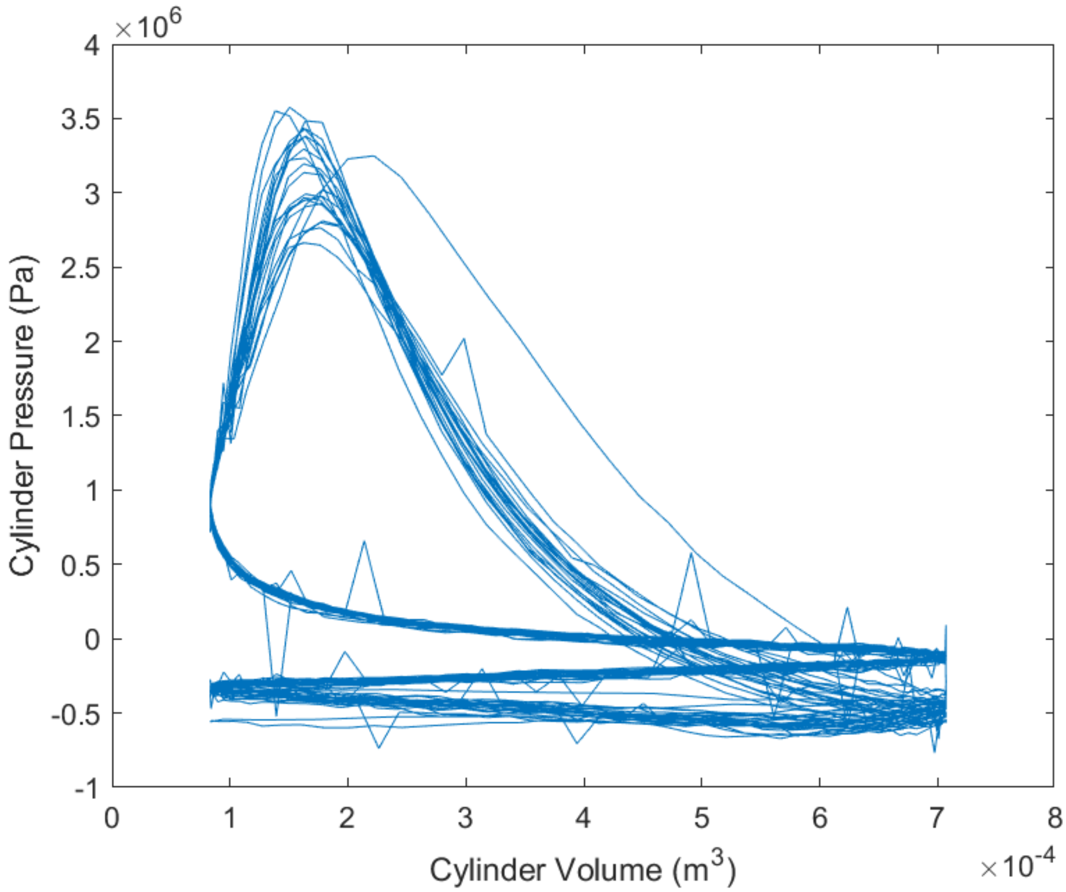

Figure 16 - Cylinder pressure vs. cylinder volume at 900 RPM for all cycles

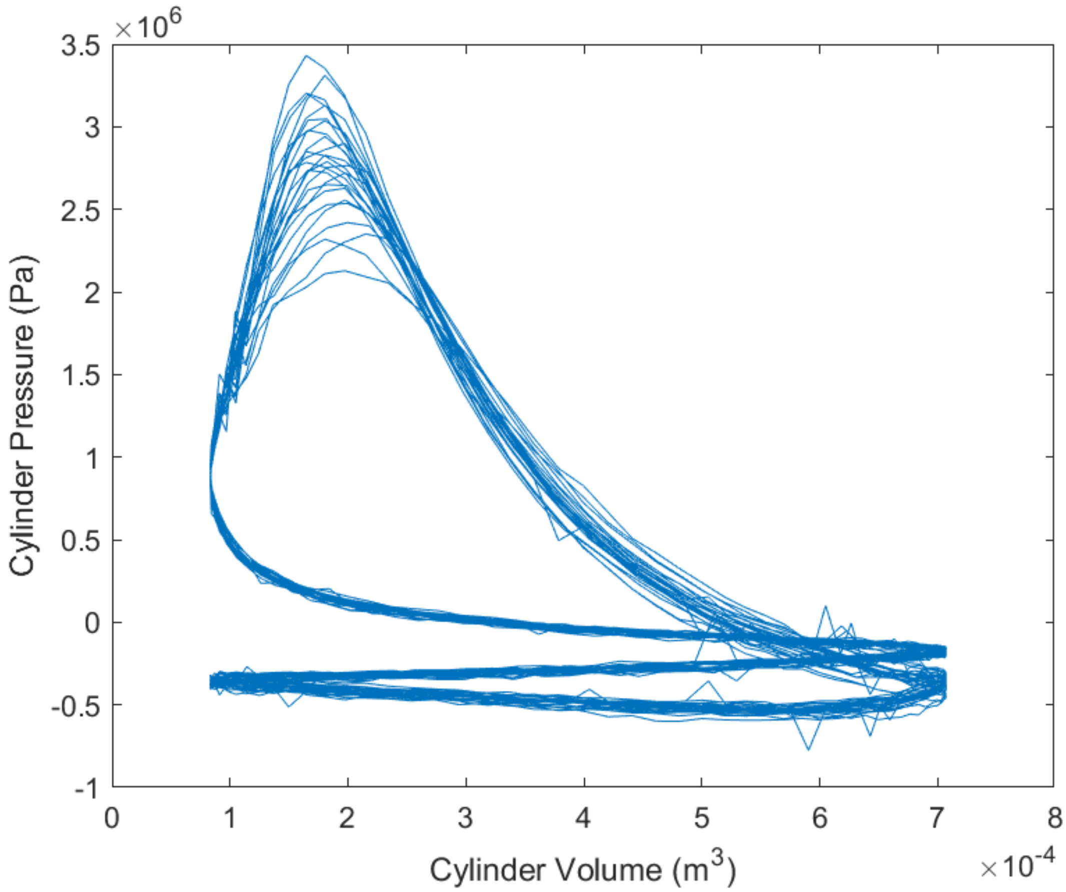

Figure 17 - Cylinder pressure vs. cylinder volume at 1000 RPM for all cycles

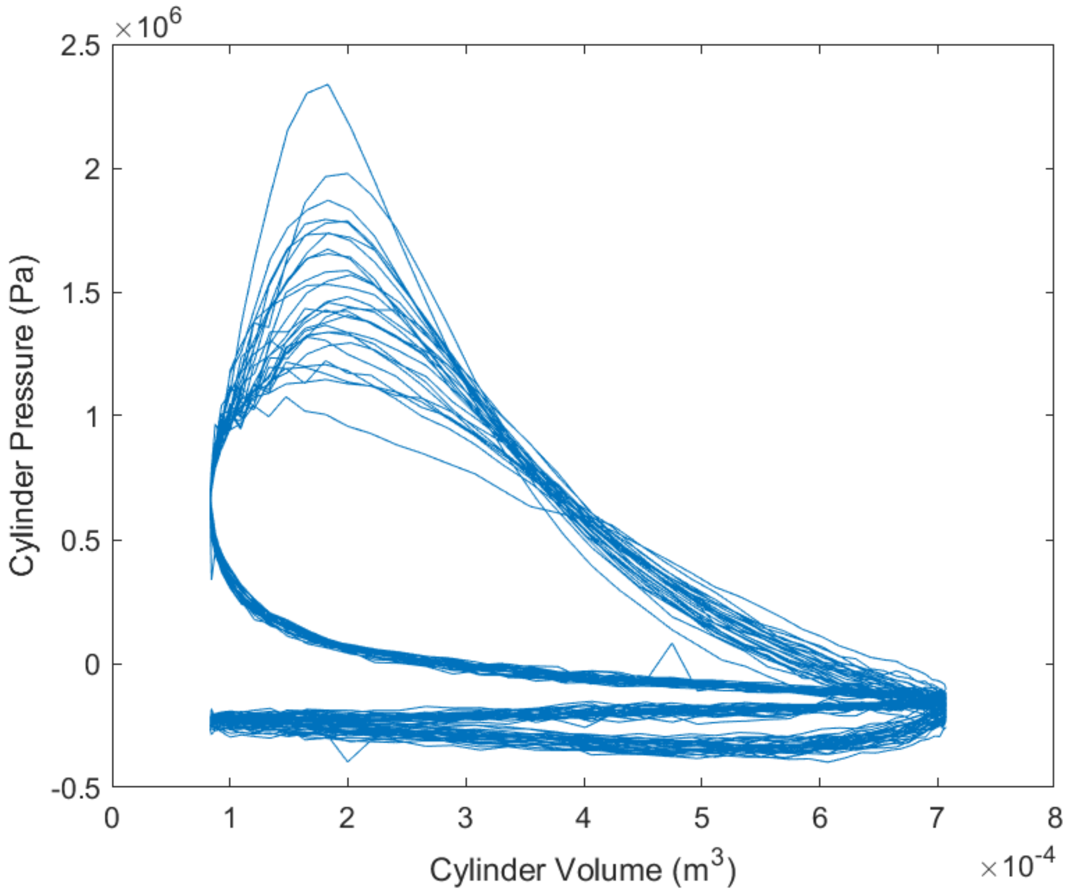

Figure 18 - Cylinder pressure vs. cylinder volume at 1100 RPM for all cycles

Average Work and Power / Cycle / Cylinder for Various Engine Speeds

The following table details the calculated average work and power at various engine speeds with the calculated standard deviation of the data obtained.

RPM (1/min)	Work (J)	Power (W)
600	233.1342	3681.948
700	253.8774	4677.063
800	274.2327	5775.736
900	286.7473	6780.336
1000	336.3609	8846.799
1100	230.9387	6686.308
Standard Deviation	39.60626	1806.906

Engine Parameters

RPM (1/min)	Mass Flow Rate (kg/cycle/cylinder)	Power (KW)	Torque (N-m)	Brake Efficiency ( )	Conversion Efficiency ( )
600	2.70E-05	3.68	73.8	0.124	0.629
700	2.84E-05	4.68	80.3	0.127	0.630
800	2.74E-05	5.78	86.8	0.144	0.629
900	2.62E-05	6.78	90.7	0.151	0.631
1000	2.52E-05	8.85	106.4	0.190	0.630
1100	1.70E-05	6.69	73.1	0.225	0.630

Brake Torque and Power with Engine Speed

The following graph plots the Brake Torque and Power of the engine as a function of the engine speed

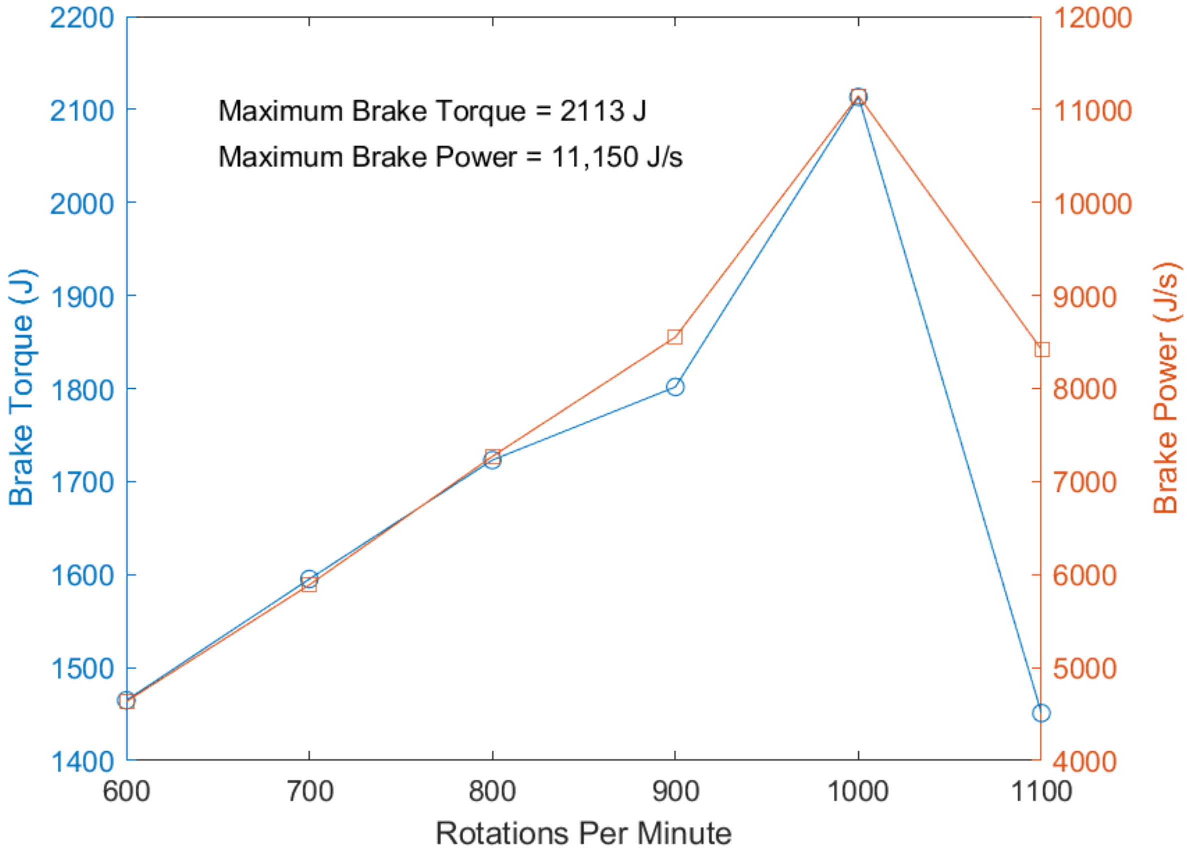

Figure 19 - Brake Torque and Power Values with different Rotational Engine Speeds

Brake Thermal Efficiency with Various Engine Speeds

The following graphs displays the relation between the break thermal efficiency at different engine speeds

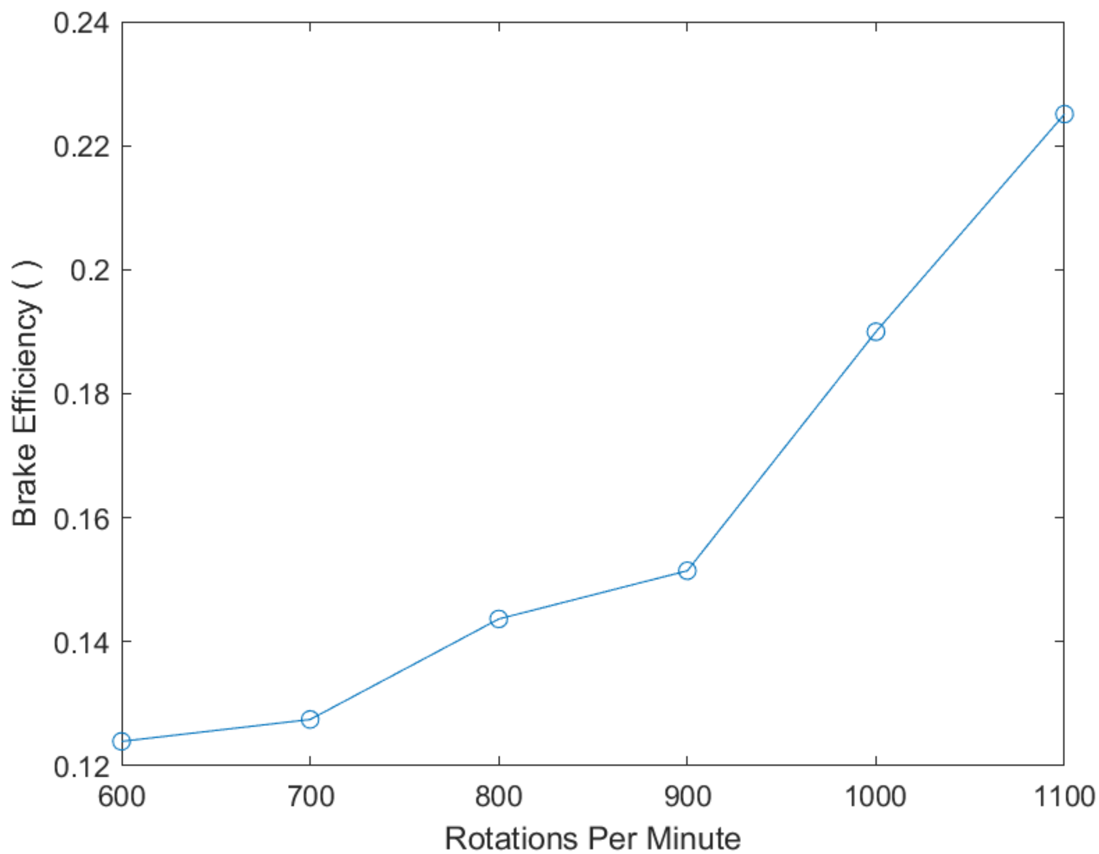

Figure 20 - The Brake Thermal Efficiency of the engine at different engine speeds

Mass Flow Rate with Different Engine Speeds

Figures 21 and 22 provide the difference in mass flow rate with different engine speeds in kg/s and kg/cycle/cylinder, respectively.

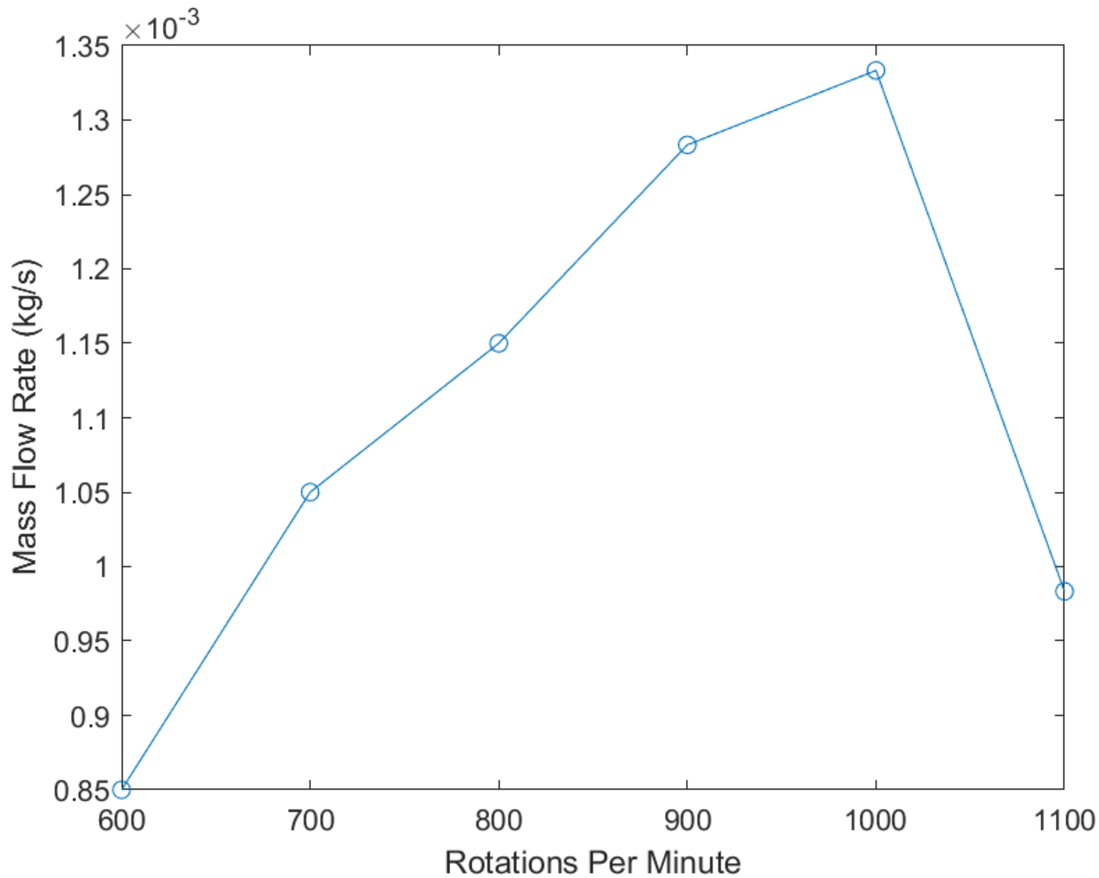

Figure 21 - Mass flow rate of the engine at different rotational speeds in kg/s

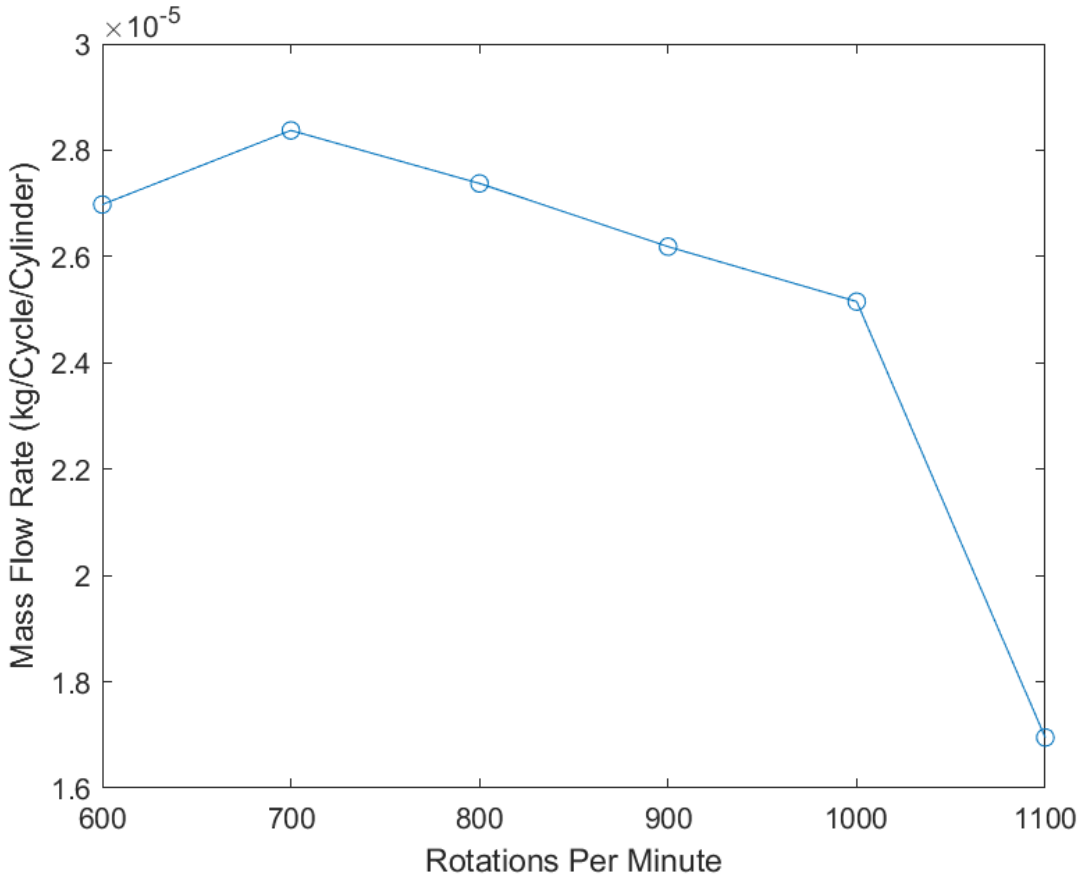

Figure 22 - Mass flow rate of the engine at different rotational speeds in kg/cycle/cylinder

Appendix

```
% Engine Lab
clear all
close all
```

Reading in Data

Reading in entire data set

```
Header=22;

RPM600  = importdata('600RPM.lvm' ,'\t',Header);
RPM700  = importdata('700RPM.lvm' ,'\t',Header);
RPM800  = importdata('800RPM.lvm' ,'\t',Header);
RPM900  = importdata('900RPM.lvm' ,'\t',Header);
RPM1000 = importdata('1000RPM.lvm','\t',Header);
RPM1100 = importdata('1100RPM.lvm','\t',Header);

% Separating entire data sets into vectors of Time and Voltage
RPM600_Volt  = RPM600.data(:,2); % Optical Sensor (V)
RPM700_Volt  = RPM700.data(:,2);
RPM800_Volt  = RPM800.data(:,2);
RPM900_Volt  = RPM900.data(:,2);
RPM1000_Volt = RPM1000.data(:,2);
RPM1100_Volt = RPM1100.data(:,2);

RPM600_Pres  = RPM600.data(:,3); % p(V)
RPM700_Pres  = RPM700.data(:,3);
RPM800_Pres  = RPM800.data(:,3);
RPM900_Pres  = RPM900.data(:,3);
RPM1000_Pres = RPM1000.data(:,3);
RPM1100_Pres = RPM1100.data(:,3);
```

Contants for the Engine

```
vp_conv  = 0.0104; % V/psi
CR       = 8.5; % Compression Ratio
Rod_L    = .116; % Meters
Stroke   = .067; % Meters
Vol_Disp = 624/(1e6); % Cubic Meters
Vol_Clea = Vol_Disp/(CR-1); % Cubic Meters
R        = 2*Rod_L/Stroke;
```

600 RPM

```
Power_600 = 10.3*745.7; % Watts
dm_600 = (13640-13589)/1000; % kilograms
```

```
RPM600P = (RPM600_Pres./vp_conv).*6894; % Pa
RPM600t = zeros(1,length(RPM600P));

for i = 1:length(RPM600t)
    RPM600t(i) = RPM600t(i) + (i-1)*.0004;
end
RPM600t = RPM600t';
sw = 0;
j = 1;
thresh = 1;
n = length(RPM600_Volt);

for i = 1:n
    if RPM600_Volt(i) - thresh > 0 && sw == 0
        sw = 1;
        pos_600(j) = i;
        j = j + 1;
    elseif RPM600_Volt(i) - thresh < 0 && sw == 1
        sw = 0;
    end
end

theta_600 = zeros(length(RPM600_Volt)-5,1);
for j = 1:length(pos_600)-1
    for i = pos_600(j):pos_600(j+1)
        theta_600(i) = 2*pi*(1 - ((RPM600t(pos_600(j+1)) -
RPM600t(i))/(RPM600t(pos_600(j+1)) - RPM600t(pos_600(j)))));
    end
end

Volume_600 = Vol_Clea.*(1+(.5.*(CR-1)).*(R+1-cos(theta_600)-sqrt(R.^2-
(sin(theta_600)).^2)));

% Figure for Part 1a

f1 = figure(1);
subplot(3,1,3)
hold on
yyaxis left
plot(RPM600t(pos_600(1):pos_600(11)),RPM600P(pos_600(1):pos_600(11)))
ylabel('Pressure (Pa)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM600t(pos_600(1):pos_600(11)),RPM600_Volt(pos_600(1):pos_600(11)))

subplot(3,1,1)
hold on
yyaxis left
plot(RPM600t(pos_600(1):pos_600(11)),theta_600(pos_600(1):pos_600(11)))
```

```
ylabel('Angle (Radians)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM600t(pos_600(1):pos_600(11)),RPM600_Volt(pos_600(1):pos_600(11)))

subplot(3,1,2)
hold on
yyaxis left
plot(RPM600t(pos_600(1):pos_600(11)),Volume_600(pos_600(1):pos_600(11)))
ylabel('Volume (m^3)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM600t(pos_600(1):pos_600(11)),RPM600_Volt(pos_600(1):pos_600(11)))
xlabel('Time (Sec)')

% Figure for part 1b
f2=figure(2);
plot(Volume_600(pos_600(3):pos_600(5)),RPM600P(pos_600(3):pos_600(5)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')

% Figure for part 1c

f3=figure(3);
plot(Volume_600(pos_600(3):pos_600(end)),RPM600P(pos_600(3):pos_600(end)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')

% Part 2
j=1;
W = zeros(10,1);
P = zeros(10,1);
for i = 1:2:19
    W(j) =
trapz(Volume_600(pos_600(i):pos_600(i+2)),RPM600P(pos_600(i):pos_600(i+2)))/2;
    P(j) = W(j)/(RPM600t(pos_600(i+2))-RPM600t(pos_600(i)));
    j=j+1;
end

Avg_W_600 = mean(W);
Avg_P_600 = mean(P);

MFR1 = dm_600/(60/RPM600t(end));
MFR = MFR1/(length(pos_600)/2);

MFR2_600 = dm_600/60;

MFR_Cyl_600 = MFR/2; % Flow rate of one cylinder per cycle
KW_600 = Avg_P_600/1000; % Power in KW
Torque_600 = Avg_W_600/3.16; % Engine Torque
```

```
Brake_Power_600 = 2*pi*(600/60)*Torque_600;
Brake_Eff_600 = Brake_Power_600/(MFR2_600*(44e6)); % Brake thermal eff
Conv_Eff_600  = Brake_Power_600/(Avg_P_600*2); % Mechanical conversion eff
```

700 RPM

```
Power_700 = 12.8*745.7; % Watts
dm_700 = (13729-13666)/1000; % kilograms

RPM700P = (RPM700_Pres./vp_conv).*6894; % Pa
RPM700t = zeros(1,length(RPM700P));

for i = 1:length(RPM700t)
    RPM700t(i) = RPM700t(i) + (i-1)*.0002;
end
RPM700t = RPM700t';
sw = 0;
j = 1;
thresh = 1;
n = length(RPM700_Volt);

for i = 1:n
    if RPM700_Volt(i) - thresh > 0 && sw == 0
        sw = 1;
        pos_700(j) = i;
        j = j + 1;
    elseif RPM700_Volt(i) - thresh < 0 && sw == 1
        sw = 0;
    end
end

theta_700 = zeros(length(RPM700_Volt)-5,1);
for j = 1:length(pos_700)-1
    for i = pos_700(j):pos_700(j+1)
        theta_700(i) = 2*pi*(1 - ((RPM700t(pos_700(j+1)) -
RPM700t(i))/(RPM700t(pos_700(j+1)) - RPM700t(pos_700(j)))));
    end
end

Volume_700 = Vol_Clea.*(1+(.5.*(CR-1)).*(R+1-cos(theta_700)-sqrt(R.^2-
(sin(theta_700)).^2)));

% Figure for Part 1a

f4=figure(4);
subplot(3,1,3)
hold on
yyaxis left
```

```
plot(RPM700t(pos_700(1):pos_700(11)),RPM700P(pos_700(1):pos_700(11)))
ylabel('Pressure (Pa)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM700t(pos_700(1):pos_700(11)),RPM700_Volt(pos_700(1):pos_700(11)))

subplot(3,1,1)
hold on
yyaxis left
plot(RPM700t(pos_700(1):pos_700(11)),theta_700(pos_700(1):pos_700(11)))
ylabel('Angle (Radians)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM700t(pos_700(1):pos_700(11)),RPM700_Volt(pos_700(1):pos_700(11)))

subplot(3,1,2)
hold on
yyaxis left
plot(RPM700t(pos_700(1):pos_700(11)),Volume_700(pos_700(1):pos_700(11)))
ylabel('Volume (m^3)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM700t(pos_700(1):pos_700(11)),RPM700_Volt(pos_700(1):pos_700(11)))
xlabel('Time (Sec)')

% Figure for part 1b
f18=figure(18);
plot(Volume_700(pos_700(3):pos_700(5)),RPM700P(pos_700(3):pos_700(5)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')

% Figure for part 1c

f5=figure(5);
plot(Volume_700(pos_700(3):pos_700(end)),RPM700P(pos_700(3):pos_700(end)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')

% Part 2
j=1;
W = zeros(10,1);
P = zeros(10,1);
for i = 1:2:19
    W(j) =
trapz(Volume_700(pos_700(i):pos_700(i+2)),RPM700P(pos_700(i):pos_700(i+2)))/2;
    P(j) = W(j)/(RPM700t(pos_700(i+2))-RPM700t(pos_700(i)));
    j=j+1;
end

Avg_W_700 = mean(W);
```

```
Avg_P_700 = mean(P);

MFR = (dm_700/(60/RPM700t(end)))/(length(pos_700)/2);

%MFR = ((dm_700/(60/RPM700t(end)))/(length(pos_700)/2));
MFR2_700 = dm_700/60;

MFR_Cyl_700 = MFR/2; % Flow rate of one cylinder per cycle
KW_700 = Avg_P_700/1000; % Power in KW
Torque_700 = Avg_W_700/3.16; % Engine Torque
Brake_Power_700 = 2*pi*(700/60)*Torque_700;
Brake_Eff_700 = Brake_Power_700/(MFR2_700*(44e6)); % Brake thermal eff
Conv_Eff_700  = Brake_Power_700/(Avg_P_700*2); % Mechanical conversion eff
```

800 RPM

```
Power_800 = 14.9*745.7; % Watts
dm_800 = (13829-13760)/1000; % kilograms

RPM800P = (RPM800_Pres./vp_conv).*6894; % Pa
RPM800t = zeros(1,length(RPM800P));

for i = 1:length(RPM800t)
    RPM800t(i) = RPM800t(i) + (i-1)*.0002;
end
RPM800t = RPM800t';
sw = 0;
j = 1;
thresh = 1;
n = length(RPM800_Volt);

for i = 1:n
    if RPM800_Volt(i) - thresh > 0 && sw == 0
        sw = 1;
        pos_800(j) = i;
        j = j + 1;
    elseif RPM800_Volt(i) - thresh < 0 && sw == 1
        sw = 0;
    end
end

theta_800 = zeros(length(RPM800_Volt)-5,1);
for j = 1:length(pos_800)-1
    for i = pos_800(j):pos_800(j+1)
        theta_800(i) = 2*pi*(1 - ((RPM800t(pos_800(j+1)) -
RPM800t(i))/(RPM800t(pos_800(j+1)) - RPM800t(pos_800(j)))));
    end
end
```

```
Volume_800 = Vol_Clea.*(1+(.5.*(CR-1)).*(R+1-cos(theta_800)-sqrt(R.^2-
(sin(theta_800)).^2)));

% Figure for Part 1a

f6=figure(6);
subplot(3,1,3)
hold on
yyaxis left
plot(RPM800t(pos_800(1):pos_800(11)),RPM800P(pos_800(1):pos_800(11)))
ylabel('Pressure (Pa)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM800t(pos_800(1):pos_800(11)),RPM800_Volt(pos_800(1):pos_800(11)))

subplot(3,1,1)
hold on
yyaxis left
plot(RPM800t(pos_800(1):pos_800(11)),theta_800(pos_800(1):pos_800(11)))
ylabel('Angle (Radians)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM800t(pos_800(1):pos_800(11)),RPM800_Volt(pos_800(1):pos_800(11)))

subplot(3,1,2)
hold on
yyaxis left
plot(RPM800t(pos_800(1):pos_800(11)),Volume_800(pos_800(1):pos_800(11)))
ylabel('Volume (m^3)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM800t(pos_800(1):pos_800(11)),RPM800_Volt(pos_800(1):pos_800(11)))
xlabel('Time (Sec)')

% Figure for part 1b
f19=figure(19);
plot(Volume_800(pos_800(3):pos_800(5)),RPM800P(pos_800(3):pos_800(5)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')

% Figure for part 1c
f7=figure(7);
plot(Volume_800(pos_800(3):pos_800(end)),RPM800P(pos_800(3):pos_800(end)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')

% Part 2
j=1;
W = zeros(10,1);
```

```
P = zeros(10,1);
for i = 1:2:19
    W(j) =
trapz(Volume_800(pos_800(i):pos_800(i+2)),RPM800P(pos_800(i):pos_800(i+2)))/2;
    P(j) = W(j)/(RPM800t(pos_800(i+2))-RPM800t(pos_800(i)));
    j=j+1;
end

Avg_W_800 = mean(W);
Avg_P_800 = mean(P);

MFR = (dm_800/(60/RPM800t(end)))/(length(pos_800)/2);

%MFR = ((dm_800/(60/RPM800t(end)))/(length(pos_800)/2));
MFR2_800 = dm_800/60;

MFR_Cyl_800 = MFR/2; % Flow rate of one cylinder per cycle
KW_800 = Avg_P_800/1000; % Power in KW
Torque_800 = Avg_W_800/3.16; % Engine Torque
Brake_Power_800 = 2*pi*(800/60)*Torque_800;
Brake_Eff_800 = Brake_Power_800/(MFR2_800*(44e6)); % Brake thermal eff
Conv_Eff_800  = Brake_Power_800/(Avg_P_800*2); % Mechanical conversion eff
```

900 RPM

```
Power_900 = 16.6*745.7; % Watts
dm_900 = (13941-13864)/1000; % kilograms

RPM900P = (RPM900_Pres./vp_conv).*6894; % Pa
RPM900t = zeros(1,length(RPM900P));

for i = 1:length(RPM900t)
    RPM900t(i) = RPM900t(i) + (i-1)*.0002;
end
RPM900t = RPM900t';
sw = 0;
j = 1;
thresh = 1;
n = length(RPM900_Volt);

for i = 1:n
    if RPM900_Volt(i) - thresh > 0 && sw == 0
        sw = 1;
        pos_900(j) = i;
        j = j + 1;
    elseif RPM900_Volt(i) - thresh < 0 && sw == 1
        sw = 0;
    end
```

```
end

theta_900 = zeros(length(RPM900_Volt)-5,1);
for j = 1:length(pos_900)-1
    for i = pos_900(j):pos_900(j+1)
        theta_900(i) = 2*pi*(1 - ((RPM900t(pos_900(j+1)) -
RPM900t(i))/(RPM900t(pos_900(j+1)) - RPM900t(pos_900(j)))));
    end
end

Volume_900 = Vol_Clea.*(1+(.5.*(CR-1)).*(R+1-cos(theta_900)-sqrt(R.^2-
(sin(theta_900)).^2)));

% Figure for Part 1a
f8=figure(8);
subplot(3,1,3)
hold on
yyaxis left
plot(RPM900t(pos_900(1):pos_900(11)),RPM900P(pos_900(1):pos_900(11)))
ylabel('Pressure (V)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM900t(pos_900(1):pos_900(11)),RPM900_Volt(pos_900(1):pos_900(11)))

subplot(3,1,1)
hold on
yyaxis left
plot(RPM900t(pos_900(1):pos_900(11)),theta_900(pos_900(1):pos_900(11)))
ylabel('Angle (Radians)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM900t(pos_900(1):pos_900(11)),RPM900_Volt(pos_900(1):pos_900(11)))

subplot(3,1,2)
hold on
yyaxis left
plot(RPM900t(pos_900(1):pos_900(11)),Volume_900(pos_900(1):pos_900(11)))
ylabel('Volume (m^3)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM900t(pos_900(1):pos_900(11)),RPM900_Volt(pos_900(1):pos_900(11)))
xlabel('Time (Sec)')


% Figure for part 1b
f20=figure(20);
plot(Volume_900(pos_900(3):pos_900(5)),RPM900P(pos_900(3):pos_900(5)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')
```

```
% Figure for part 1c
f9=figure(9);
plot(Volume_900(pos_900(3):pos_900(end)),RPM900P(pos_900(3):pos_900(end)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')

% Part 2
j=1;
W = zeros(10,1);
P = zeros(10,1);
for i = 1:2:19
    W(j) =
trapz(Volume_900(pos_900(i):pos_900(i+2)),RPM900P(pos_900(i):pos_900(i+2)))/2;
    P(j) = W(j)/(RPM900t(pos_900(i+2))-RPM900t(pos_900(i)));
    j=j+1;
end

Avg_W_900 = mean(W);
Avg_P_900 = mean(P);

MFR = (dm_900/(60/RPM900t(end)))/(length(pos_900)/2);

%MFR = ((dm_900/(60/RPM900t(end)))/(length(pos_900)/2));
MFR2_900 = dm_900/60;

MFR_Cyl_900 = MFR/2; % Flow rate of one cylinder per cycle
KW_900 = Avg_P_900/1000 ;% Power in KW
Torque_900 = Avg_W_900/3.16; % Engine Torque
Brake_Power_900 = 2*pi*(900/60)*Torque_900;
Brake_Eff_900 = Brake_Power_900/(MFR2_900*(44e6)); % Brake thermal eff
Conv_Eff_900  = Brake_Power_900/(Avg_P_900*2); % Mechanical conversion eff
```

1000 RPM

```
Power_1000 = 17.7*745.7; % Watts
dm_1000 = (14056-13976)/1000; % kilograms

RPM1000P = (RPM1000_Pres./vp_conv).*6894; % Pa
RPM1000t = zeros(1,length(RPM1000P));

for i = 1:length(RPM1000t)
    RPM1000t(i) = RPM1000t(i) + (i-1)*.0002;
end
RPM1000t = RPM1000t';
sw = 0;
j = 1;
thresh = 1;
n = length(RPM1000_Volt);
```

```
for i = 1:n
    if RPM1000_Volt(i) - thresh > 0 && sw == 0
        sw = 1;
        pos_1000(j) = i;
        j = j + 1;
    elseif RPM1000_Volt(i) - thresh < 0 && sw == 1
        sw = 0;
    end
end

theta_1000 = zeros(length(RPM1000_Volt)-5,1);
for j = 1:length(pos_1000)-1
    for i = pos_1000(j):pos_1000(j+1)
        theta_1000(i) = 2*pi*(1 - ((RPM1000t(pos_1000(j+1)) -
RPM1000t(i))/(RPM1000t(pos_1000(j+1)) - RPM1000t(pos_1000(j)))));
    end
end

Volume_1000 = Vol_Clea.*(1+(.5.*(CR-1)).*(R+1-cos(theta_1000)-sqrt(R.^2-
(sin(theta_1000)).^2)));

% Figure for Part 1a
f10=figure(10);
subplot(3,1,3)
hold on
yyaxis left
plot(RPM1000t(pos_1000(1):pos_1000(11)),RPM1000P(pos_1000(1):pos_1000(11)))
ylabel('Pressure (Pa)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM1000t(pos_1000(1):pos_1000(11)),RPM1000_Volt(pos_1000(1):pos_1000(11)))

subplot(3,1,1)
hold on
yyaxis left
plot(RPM1000t(pos_1000(1):pos_1000(11)),theta_1000(pos_1000(1):pos_1000(11)))
ylabel('Angle (Radians)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM1000t(pos_1000(1):pos_1000(11)),RPM1000_Volt(pos_1000(1):pos_1000(11)))

subplot(3,1,2)
hold on
yyaxis left
plot(RPM1000t(pos_1000(1):pos_1000(11)),Volume_1000(pos_1000(1):pos_1000(11)))
ylabel('Volume (m^3)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM1000t(pos_1000(1):pos_1000(11)),RPM1000_Volt(pos_1000(1):pos_1000(11)))
```

```
xlabel('Time (Sec)')

% Figure for part 1b
f21=figure(21);
plot(Volume_1000(pos_1000(3):pos_1000(5)),RPM1000P(pos_1000(3):pos_1000(5)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')

% Figure for part 1c
f11=figure(11);
plot(Volume_1000(pos_1000(3):pos_1000(end)),RPM1000P(pos_1000(3):pos_1000(end)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')

% Part 2
j=1;
W = zeros(10,1);
P = zeros(10,1);
for i = 1:2:19
    W(j) =
trapz(Volume_1000(pos_1000(i):pos_1000(i+2)),RPM1000P(pos_1000(i):pos_1000(i+2)))/2;
    P(j) = W(j)/(RPM1000t(pos_1000(i+2))-RPM1000t(pos_1000(i)));
    j=j+1;
end

Avg_W_1000 = mean(W);
Avg_P_1000 = mean(P);

MFR = (dm_1000/(60/RPM1000t(end)))/(length(pos_1000)/2);

%MFR = ((dm_1000/(60/RPM1000t(end)))/(length(pos_1000)/2));
MFR2_1000 = dm_1000/60;

MFR_Cyl_1000 = MFR/2; % Flow rate of one cylinder per cycle
KW_1000 = Avg_P_1000/1000; % Power in KW
Torque_1000 = Avg_W_1000/3.16; % Engine Torque
Brake_Power_1000 = 2*pi*(1000/60)*Torque_1000;
Brake_Eff_1000 = Brake_Power_1000/(MFR2_1000*(44e6)); % Brake thermal eff
Conv_Eff_1000  = Brake_Power_1000/(Avg_P_1000*2); % Mechanical conversion eff
```

1100 RPM

```
Power_1100 = 12*745.7; % Watts
dm_1100 = (14156-14097)/1000; % kilograms

RPM1100P = (RPM1100_Pres./vp_conv).*6894; % Pa
RPM1100t = zeros(1,length(RPM1100P));
```

```
for i = 1:length(RPM1100t)
    RPM1100t(i) = RPM1100t(i) + (i-1)*.0002;
end
RPM1100t = RPM1100t';
sw = 0;
j = 1;
thresh = 1;
n = length(RPM1100_Volt);

for i = 1:n
    if RPM1100_Volt(i) - thresh > 0 && sw == 0
        sw = 1;
        pos_1100(j) = i;
        j = j + 1;
    elseif RPM1100_Volt(i) - thresh < 0 && sw == 1
        sw = 0;
    end
end

theta_1100 = zeros(length(RPM1100_Volt)-5,1);
for j = 1:length(pos_1100)-1
    for i = pos_1100(j):pos_1100(j+1)
        theta_1100(i) = 2*pi*(1 - ((RPM1100t(pos_1100(j+1)) -
RPM1100t(i))/(RPM1100t(pos_1100(j+1)) - RPM1100t(pos_1100(j)))));
    end
end

Volume_1100 = Vol_Clea.*(1+(.5.*(CR-1)).*(R+1-cos(theta_1100)-sqrt(R.^2-
(sin(theta_1100)).^2)));

% Figure for Part 1a
f12=figure(12);
subplot(3,1,3)
hold on
yyaxis left
plot(RPM1100t(pos_1100(1):pos_1100(11)),RPM1100P(pos_1100(1):pos_1100(11)))
ylabel('Pressure (Pa)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM1100t(pos_1100(1):pos_1100(11)),RPM1100_Volt(pos_1100(1):pos_1100(11)))

subplot(3,1,1)
hold on
yyaxis left
plot(RPM1100t(pos_1100(1):pos_1100(11)),theta_1100(pos_1100(1):pos_1100(11)))
ylabel('Angle (Radians)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM1100t(pos_1100(1):pos_1100(11)),RPM1100_Volt(pos_1100(1):pos_1100(11)))
```

```
subplot(3,1,2)
hold on
yyaxis left
plot(RPM1100t(pos_1100(1):pos_1100(11)),Volume_1100(pos_1100(1):pos_1100(11)))
ylabel('Volume (m^3)')
yyaxis right
ylabel('Output Voltage (V)')
plot(RPM1100t(pos_1100(1):pos_1100(11)),RPM1100_Volt(pos_1100(1):pos_1100(11)))
xlabel('Time (Sec)')

% Figure for part 1b
f22=figure(22);
plot(Volume_1100(pos_1100(3):pos_1100(5)),RPM1100P(pos_1100(3):pos_1100(5)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')

% Figure for part 1c
f13=figure(13);
plot(Volume_1100(pos_1100(3):pos_1100(end)),RPM1100P(pos_1100(3):pos_1100(end)))
xlabel('Cylinder Volume (m^3)')
ylabel('Cylinder Pressure (Pa)')



% Part 2
j=1;
W = zeros(10,1);
P = zeros(10,1);
for i = 1:2:19
    W(j) =
trapz(Volume_1100(pos_1100(i):pos_1100(i+2)),RPM1100P(pos_1100(i):pos_1100(i+2)))/2;
    P(j) = W(j)/(RPM1100t(pos_1100(i+2))-RPM1100t(pos_1100(i)));
    j=j+1;
end

Avg_W_1100 = mean(W);
Avg_P_1100 = mean(P);

MFR = (dm_1100/(60/RPM1100t(end)))/(length(pos_1100)/2);

%MFR = ((dm_1100/(60/RPM1100t(end)))/(length(pos_1100)/2));
MFR2_1100 = dm_1100/60;

MFR_Cyl_1100 = MFR/2; % Flow rate of one cylinder per cycle
KW_1100 = Avg_P_1100/1000; % Power in KW
Torque_1100 = Avg_W_1100/3.16; % Engine Torque
Brake_Power_1100 = 2*pi*(1100/60)*Torque_1100;
Brake_Eff_1100 = Brake_Power_1100/(MFR2_600*(44e6)); % Brake thermal eff
Conv_Eff_1100  = Brake_Power_1100/(Avg_P_1100*2); % Mechanical conversion eff
```

Final Calculations and Tables

```
Work = [Avg_W_600;Avg_W_700;Avg_W_800;Avg_W_900;Avg_W_1000;Avg_W_1100];

Power = [Avg_P_600;Avg_P_700;Avg_P_800;Avg_P_900;Avg_P_1000;Avg_P_1100];

Std_Work = std(Work);

Std_Power = std(Power);



RPM = ["600";"700";"800";"900";"1000";"1100";"Standard Deviation"]; % rotations per
minute
Work = [Avg_W_600;Avg_W_700;Avg_W_800;Avg_W_900;Avg_W_1000;Avg_W_1100;Std_Work];
Power = [Avg_P_600;Avg_P_700;Avg_P_800;Avg_P_900;Avg_P_1000;Avg_P_1100;Std_Power];

T1 = table(RPM,Work,Power);


RPM = ["600";"700";"800";"900";"1000";"1100"]; % rotations per minute
MFR = [MFR_Cyl_600;MFR_Cyl_700;MFR_Cyl_800;MFR_Cyl_900;MFR_Cyl_1000;MFR_Cyl_1100]; %
Mass flow rate kg/s
Power = [KW_600;KW_700;KW_800;KW_900;KW_1000;KW_1100]; % power in KW
Torque = [Torque_600;Torque_700;Torque_800;Torque_900;Torque_1000;Torque_1100]; % N-m
Brake_Efficiency =
[Brake_Eff_600;Brake_Eff_700;Brake_Eff_800;Brake_Eff_900;Brake_Eff_1000;Brake_Eff_1100
];
Conversion_Efficieny =
[Conv_Eff_600;Conv_Eff_700;Conv_Eff_800;Conv_Eff_900;Conv_Eff_1000;Conv_Eff_1100];

T2 = table(RPM,MFR,Power,Torque,Brake_Efficiency,Conversion_Efficieny);
```

Plotting End Results

```
Work = [Avg_W_600;Avg_W_700;Avg_W_800;Avg_W_900;Avg_W_1000;Avg_W_1100];

RPM = [600;700;800;900;1000;1100]; % rotations per minute
BrakeTorque = 2*pi.*Work;

Torque = [Torque_600,Torque_700,Torque_800,Torque_900,Torque_1000,Torque_1100];

for i = 1:length(Torque)
    BrakePower(i) = 2*pi.*(RPM(i)/60).*Torque(i);
end

f14=figure(14);
yyaxis left
plot(RPM,BrakeTorque,'-o')
```

```
ylabel('Brake Torque (J)')
hold on
yyaxis right
plot(RPM,BrakePower,'-s')
ylabel('Brake Power (J/s)')
xlabel('Rotations Per Minute')
text(650,11000,'Maximum Brake Torque = 2113 J')
text(650,10500,'Maximum Brake Power = 11,150 J/s')

f15=figure(15);
plot(RPM,Brake_Efficiency,'-o')
xlabel('Rotations Per Minute')
ylabel('Brake Efficiency ( )')

f16 = figure(16);
plot(RPM,MFR,'-o')
xlabel('Rotations Per Minute')
ylabel('Mass Flow Rate (kg/Cycle/Cylinder)')

MFR2 = [MFR2_600,MFR2_700,MFR2_800,MFR2_900,MFR2_1000,MFR2_1100];
f17 = figure(17);
plot(RPM,MFR2,'-o')
xlabel('Rotations Per Minute')
ylabel('Mass Flow Rate (kg/s)')
```

Saving Figures

```
saveas(f1, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\subplot600.png','png');
saveas(f2, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\onecycle600.png','png');
saveas(f3, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\allcycle600.png','png');

saveas(f4, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\subplot700.png','png');
saveas(f5, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\allcycle700.png','png');

saveas(f6, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\subplot800.png','png');
saveas(f7, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\allcycle800.png','png');

saveas(f8, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\subplot900.png','png');
saveas(f9, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\allcycle900.png','png');
```

```
saveas(f10, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\subplot1000.png','png');
saveas(f11, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\allcycle1000.png','png');

saveas(f12, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\subplot1100.png','png');
saveas(f13, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\allcycle1100.png','png');

saveas(f14, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\braketorquepower.png','png');
saveas(f15, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\thermaleff.png','png');

saveas(f16, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\mfr.png','png');
saveas(f17, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\mfgkgs.png','png');

saveas(f18, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\onecycle700.png','png');
saveas(f19, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\onecycle800.png','png');
saveas(f20, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\onecycle900.png','png');
saveas(f21, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\onecycle1000.png','png');
saveas(f22, 'C:\Users\User\Desktop\Charlie\Classes\Junior Year\Spring 2019\J-Lab\Lab
5\Figures\onecycle1100.png','png');
```