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ME 647

Engine Lab

Contents

[Table of Figures 1](#_Toc5550418)

[Optical Sensor Voltage, Crank Angle, Cylinder Volume, and Pressure 2](#_Toc5550419)

[Pressure vs. Cylinder Volume for a Single Cycle 8](#_Toc5550420)

[Pressure vs. Cylinder Volume for all Cycles 14](#_Toc5550421)

[Average Work and Power / Cycle / Cylinder for Various Engine Speeds 20](#_Toc5550422)

[Engine Parameters 20](#_Toc5550423)

[Brake Torque and Power with Engine Speed 21](#_Toc5550424)

[Brake Thermal Efficiency with Various Engine Speeds 22](#_Toc5550425)

[Mass Flow Rate with Different Engine Speeds 23](#_Toc5550426)

# Table of Figures

[Figure 1 - Experimental Data for the Kohler Model CH20S SI Engine at 600RPM 2](#_Toc5550386)

[Figure 2 - Experimental Data for the Kohler Model CH20S SI Engine at 700RPM 3](#_Toc5550387)

[Figure 3 - Experimental Data for the Kohler Model CH20S SI Engine at 800RPM 4](#_Toc5550388)

[Figure 4 - Experimental Data for the Kohler Model CH20S SI Engine at 900RPM 5](#_Toc5550389)

[Figure 5 - Experimental Data for the Kohler Model CH20S SI Engine at 1000RPM 6](#_Toc5550390)

[Figure 6 - Experimental Data for the Kohler Model CH20S SI Engine at 1100RPM 7](#_Toc5550391)

[Figure 7 - Cylinder pressure vs. cylinder volume at 600 RPM for a single cycle 8](#_Toc5550392)

[Figure 8 - Cylinder pressure vs. cylinder volume at 700 RPM for a single cycle 9](#_Toc5550393)

[Figure 9 - Cylinder pressure vs. cylinder volume at 800 RPM for a single cycle 10](#_Toc5550394)

[Figure 10 - Cylinder pressure vs. cylinder volume at 900 RPM for a single cycle 11](#_Toc5550395)

[Figure 11 - Cylinder pressure vs. cylinder volume at 1000 RPM for a single cycle 12](#_Toc5550396)

[Figure 12 - Cylinder pressure vs. cylinder volume at 1100 RPM for a single cycle 13](#_Toc5550397)

[Figure 13 - Cylinder pressure vs. cylinder volume at 600 RPM for all cycles 14](#_Toc5550398)

[Figure 14 - Cylinder pressure vs. cylinder volume at 700 RPM for all cycles 15](#_Toc5550399)

[Figure 15 - Cylinder pressure vs. cylinder volume at 800 RPM for all cycles 16](#_Toc5550400)

[Figure 16 - Cylinder pressure vs. cylinder volume at 900 RPM for all cycles 17](#_Toc5550401)

[Figure 17 - Cylinder pressure vs. cylinder volume at 1000 RPM for all cycles 18](#_Toc5550402)

[Figure 18 - Cylinder pressure vs. cylinder volume at 1100 RPM for all cycles 19](#_Toc5550403)

[Figure 19 - Brake Torque and Power Values with different Rotational Engine Speeds 21](#_Toc5550404)

[Figure 20 - The Brake Thermal Efficiency of the engine at different engine speeds 22](#_Toc5550405)

[Figure 21 - Mass flow rate of the engine at different rotational speeds in kg/s 23](#_Toc5550406)

[Figure 22 - Mass flow rate of the engine at different rotational speeds in kg/cycle/cylinder 24](#_Toc5550407)

# 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.

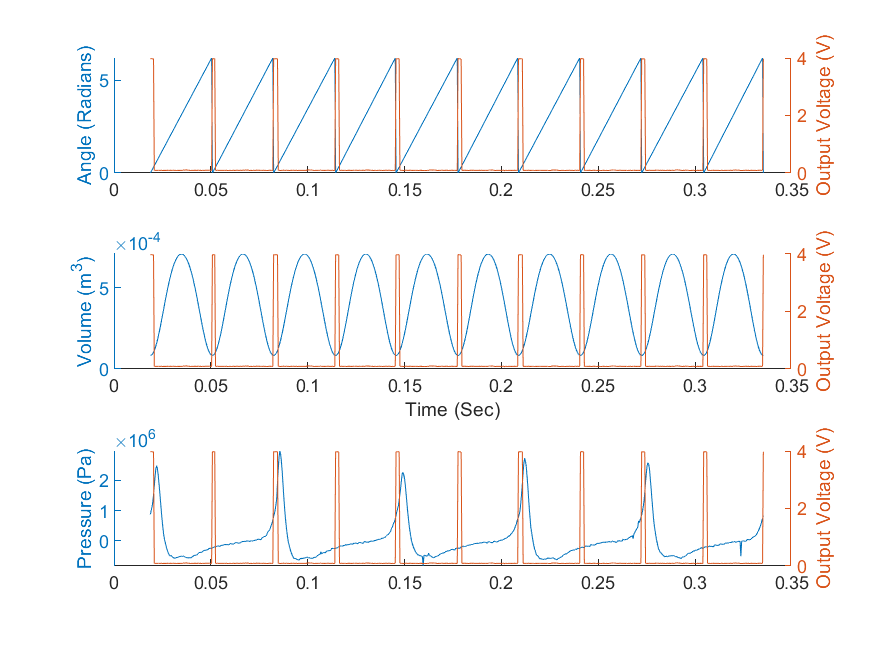


Figure 1 - Experimental Data for the Kohler Model CH20S SI Engine at 600RPM

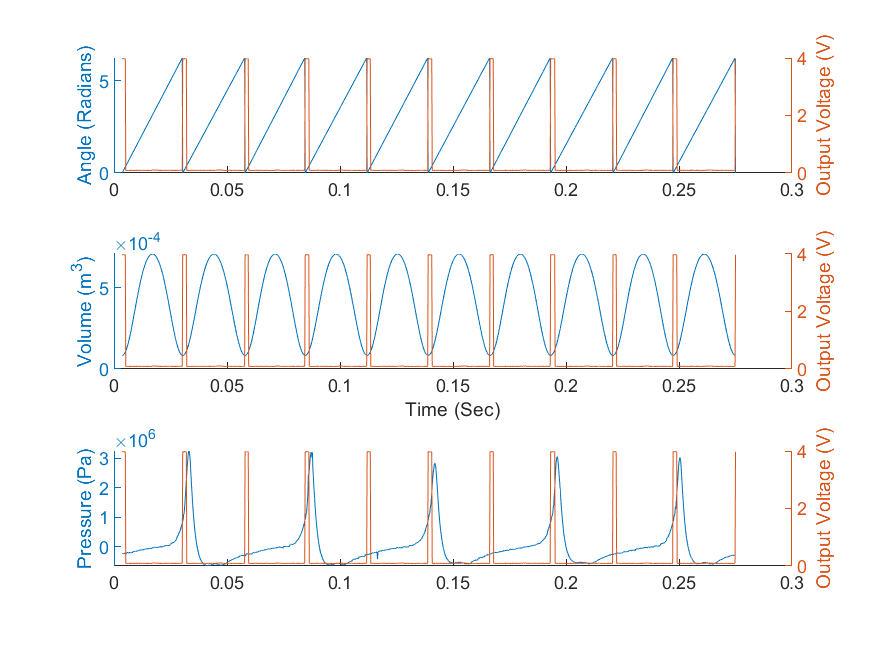


Figure 2 - Experimental Data for the Kohler Model CH20S SI Engine at 700RPM

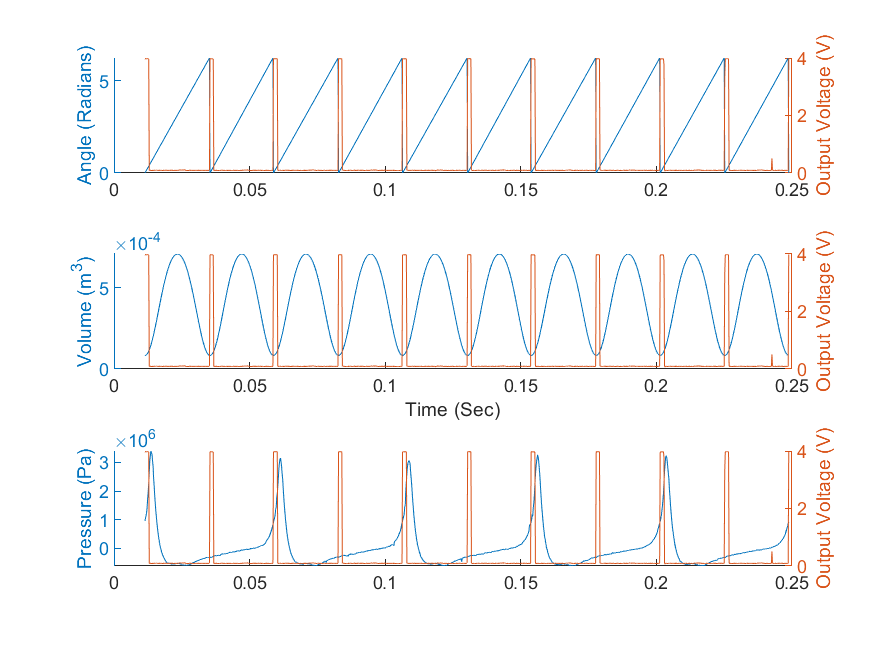


Figure 3 - Experimental Data for the Kohler Model CH20S SI Engine at 800RPM

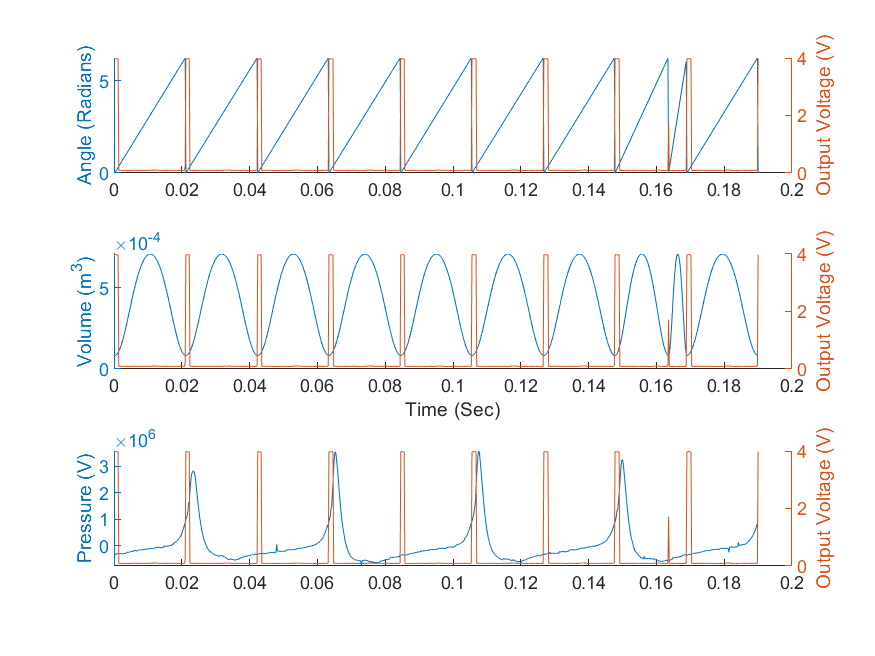


Figure 4 - Experimental Data for the Kohler Model CH20S SI Engine at 900RPM

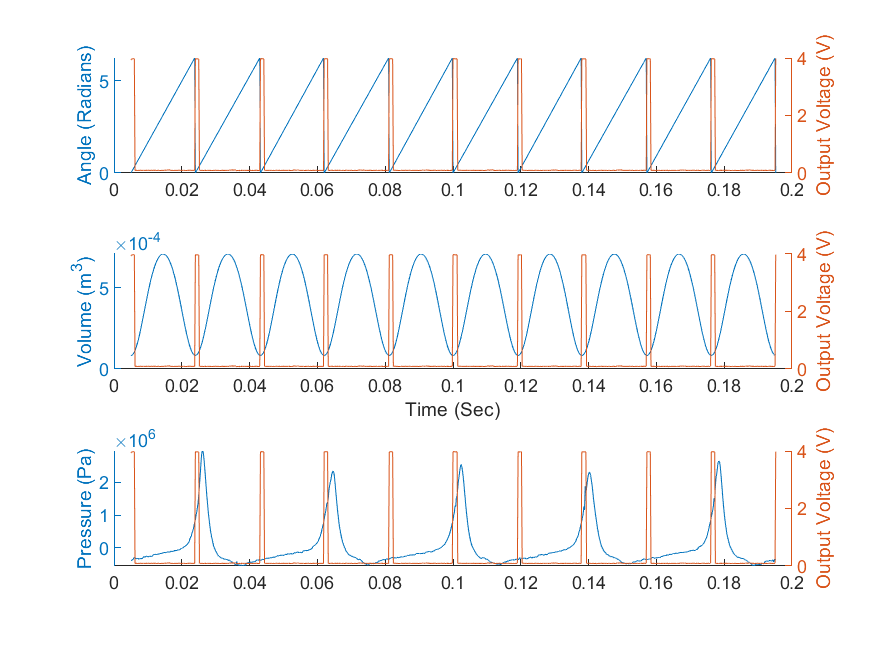


Figure 5 - Experimental Data for the Kohler Model CH20S SI Engine at 1000RPM

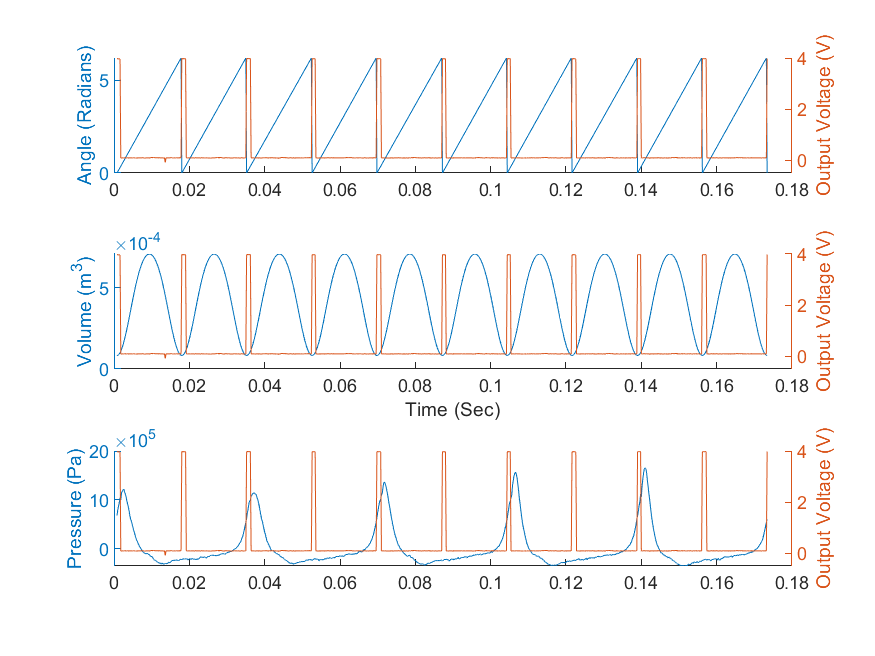


Figure 6 - Experimental Data for the Kohler Model CH20S SI Engine at 1100RPM

# Pressure vs. Cylinder Volume for a Single Cycle

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

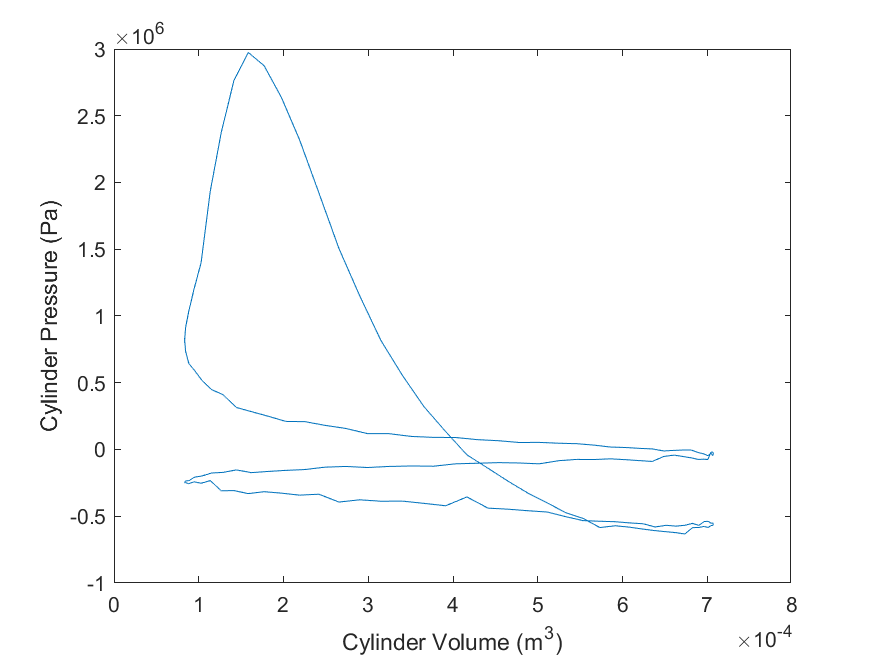


Figure 7 - Cylinder pressure vs. cylinder volume at 600 RPM for a single cycle

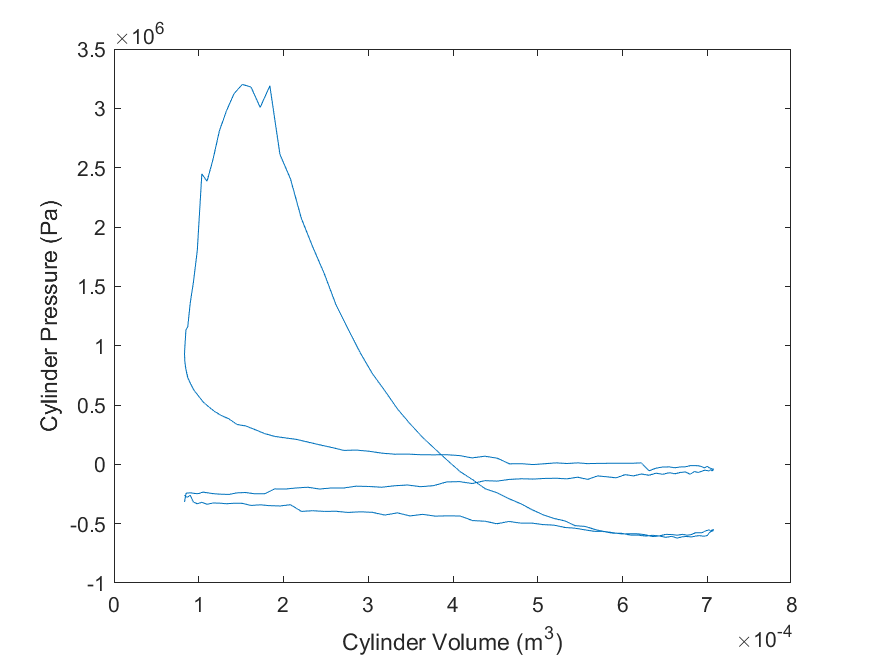


Figure 8 - Cylinder pressure vs. cylinder volume at 700 RPM for a single cycle

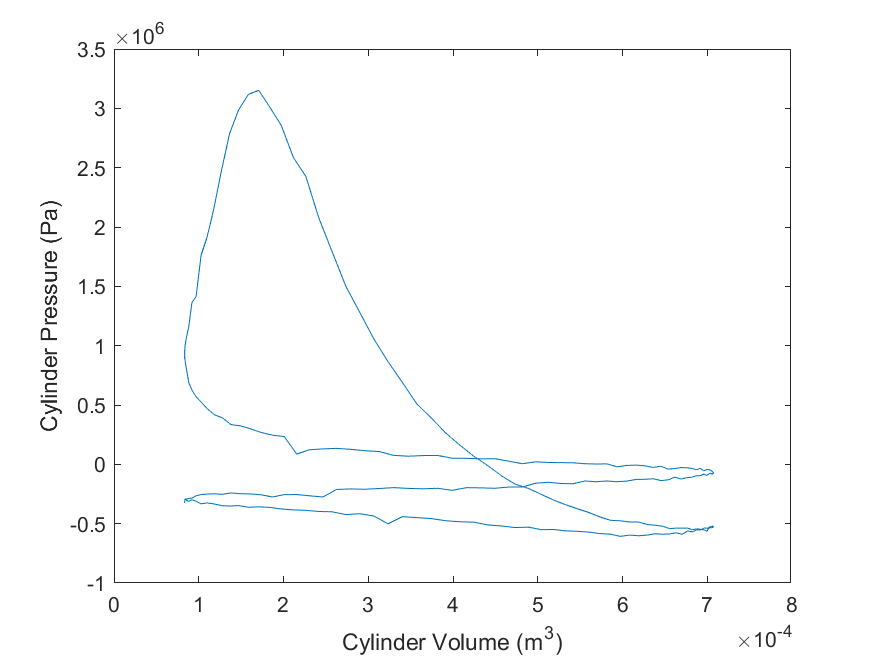


Figure 9 - Cylinder pressure vs. cylinder volume at 800 RPM for a single cycle

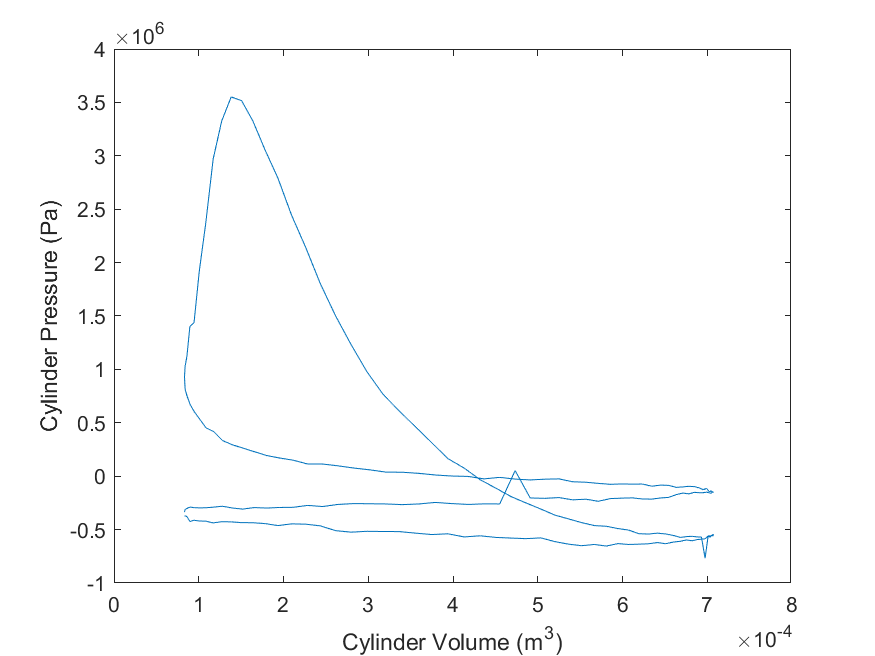


Figure 10 - Cylinder pressure vs. cylinder volume at 900 RPM for a single cycle

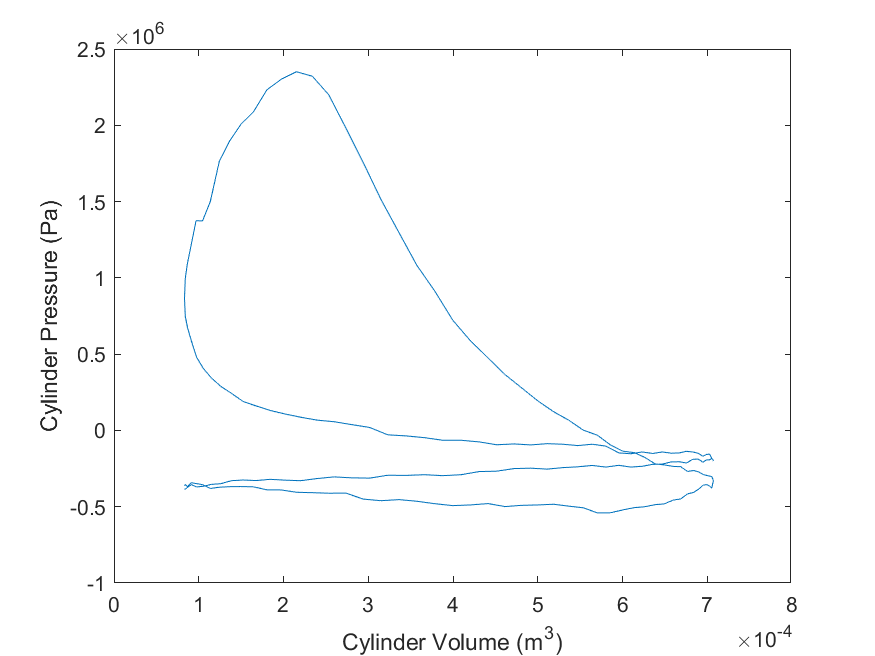


Figure 11 - Cylinder pressure vs. cylinder volume at 1000 RPM for a single cycle

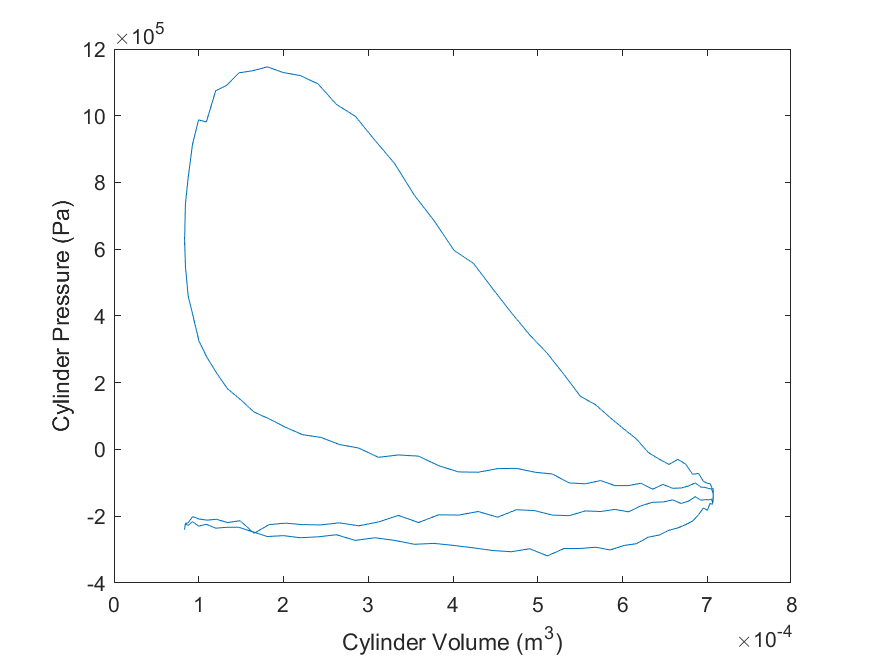


Figure 12 - Cylinder pressure vs. cylinder volume at 1100 RPM for a single cycle

# Pressure vs. Cylinder Volume for all Cycles

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

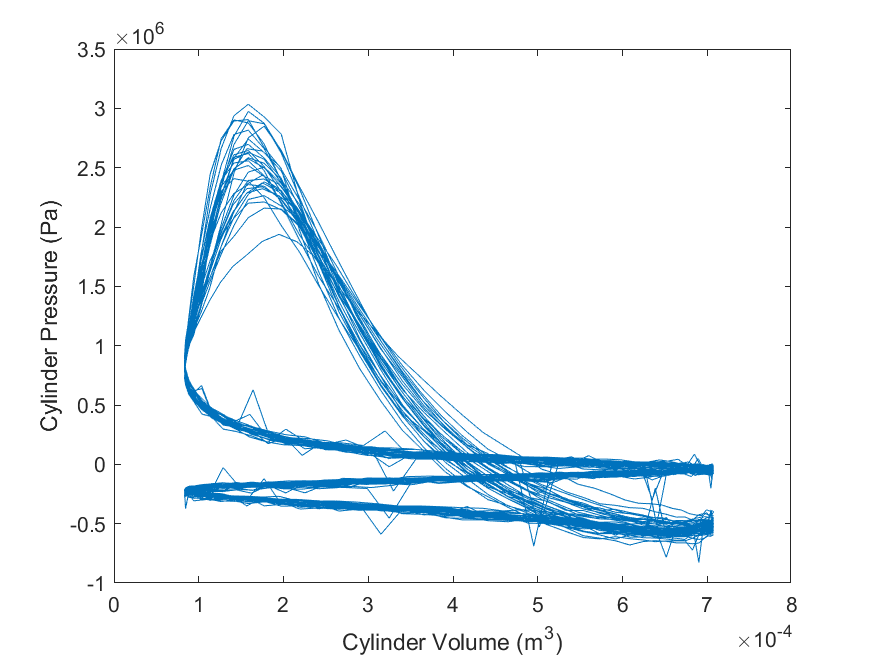


Figure 13 - Cylinder pressure vs. cylinder volume at 600 RPM for all cycles

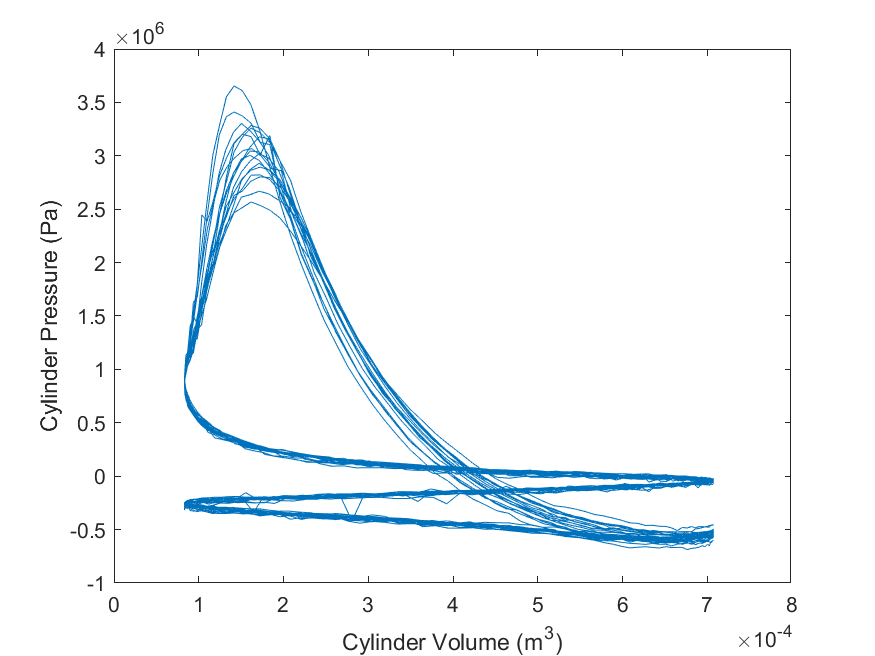


Figure 14 - Cylinder pressure vs. cylinder volume at 700 RPM for all cycles

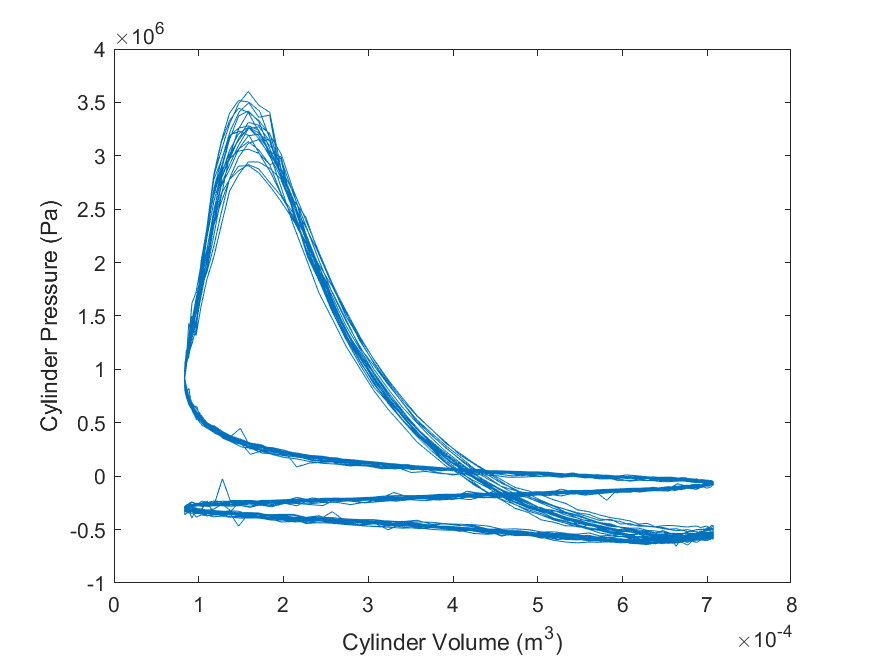


Figure 15 - Cylinder pressure vs. cylinder volume at 800 RPM for all cycles

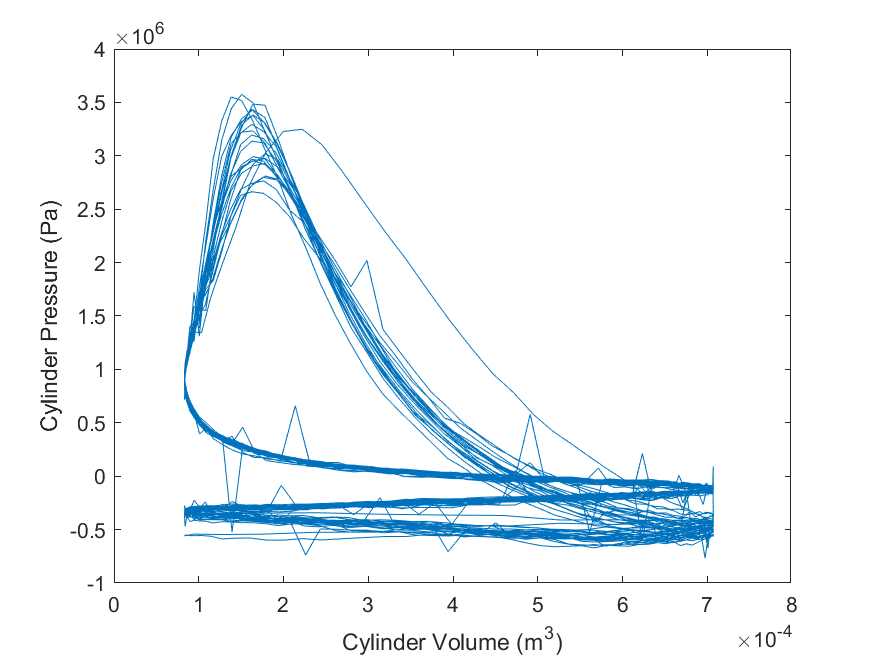


Figure 16 - Cylinder pressure vs. cylinder volume at 900 RPM for all cycles

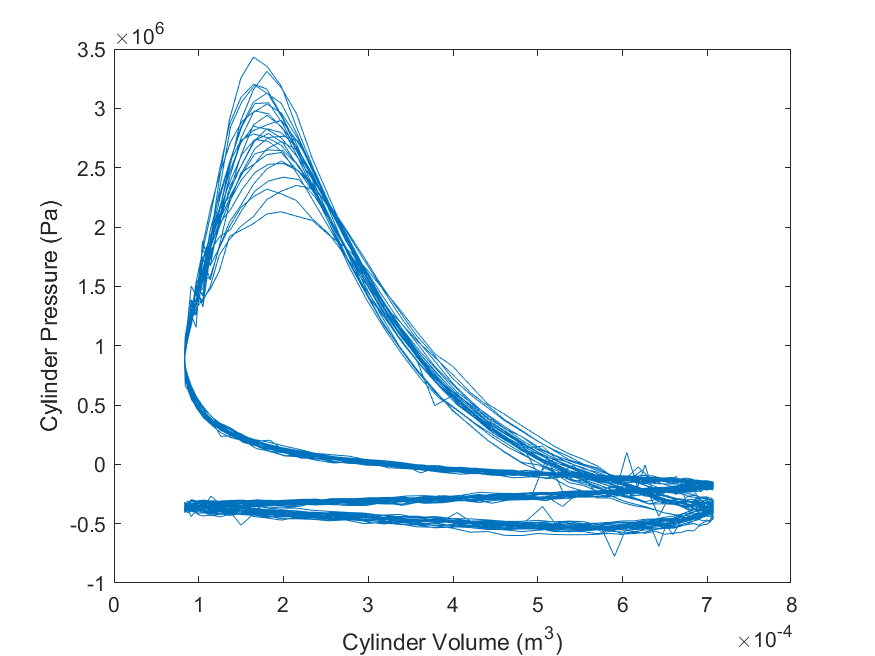


Figure 17 - Cylinder pressure vs. cylinder volume at 1000 RPM for all cycles

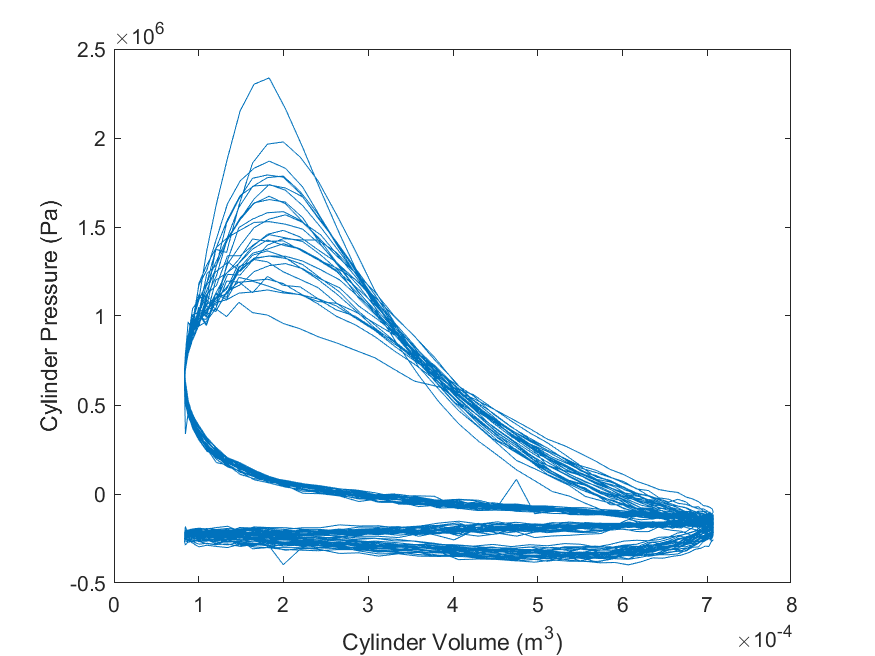


Figure 18 - Cylinder pressure vs. cylinder volume at 1100 RPM for all cycles

# 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

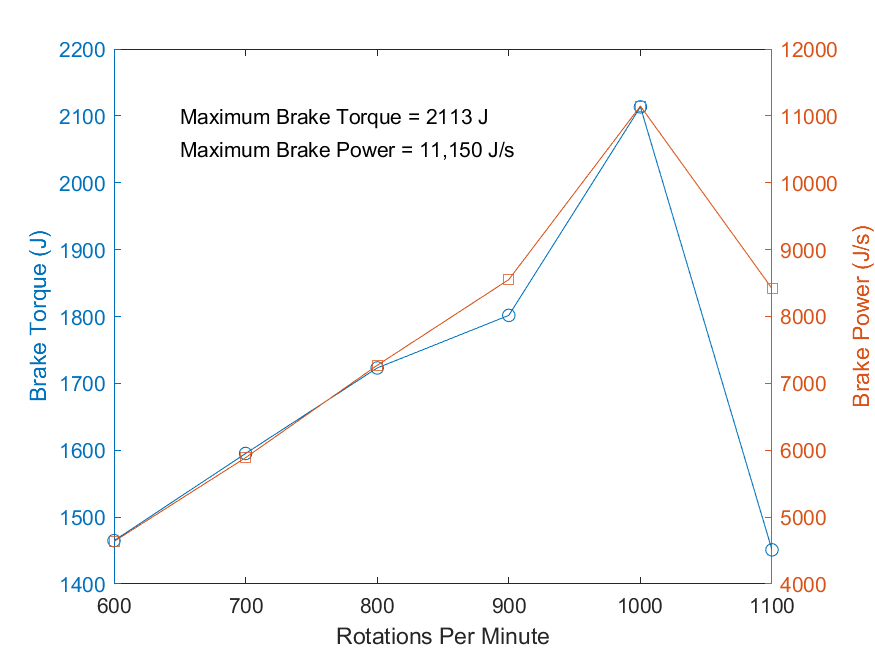


Figure 19 - Brake Torque and Power Values with different Rotational Engine Speeds

# Brake Thermal Efficiency with Various Engine Speeds

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

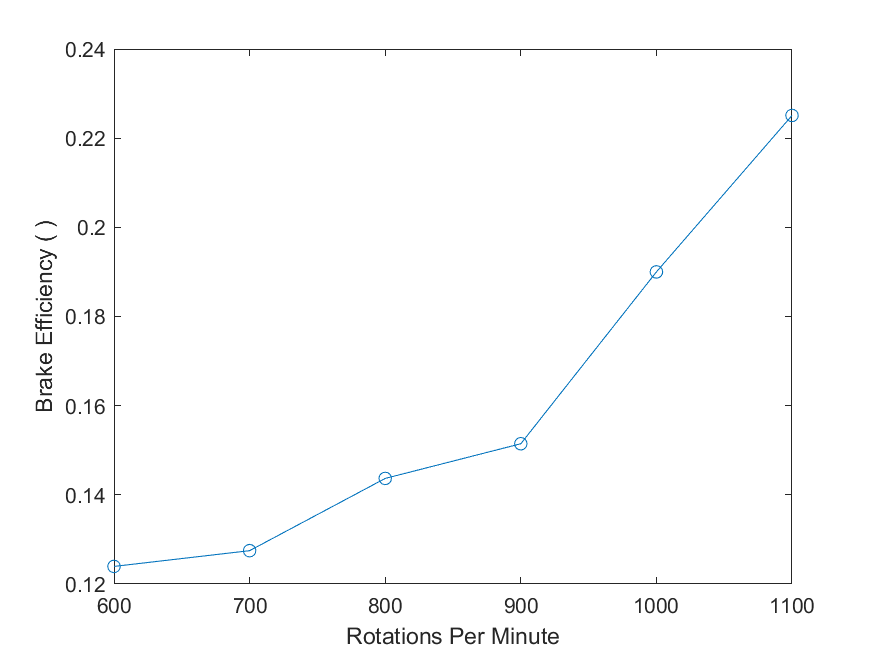


Figure 20 - The Brake Thermal Efficiency of the engine at different engine speeds

# 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.

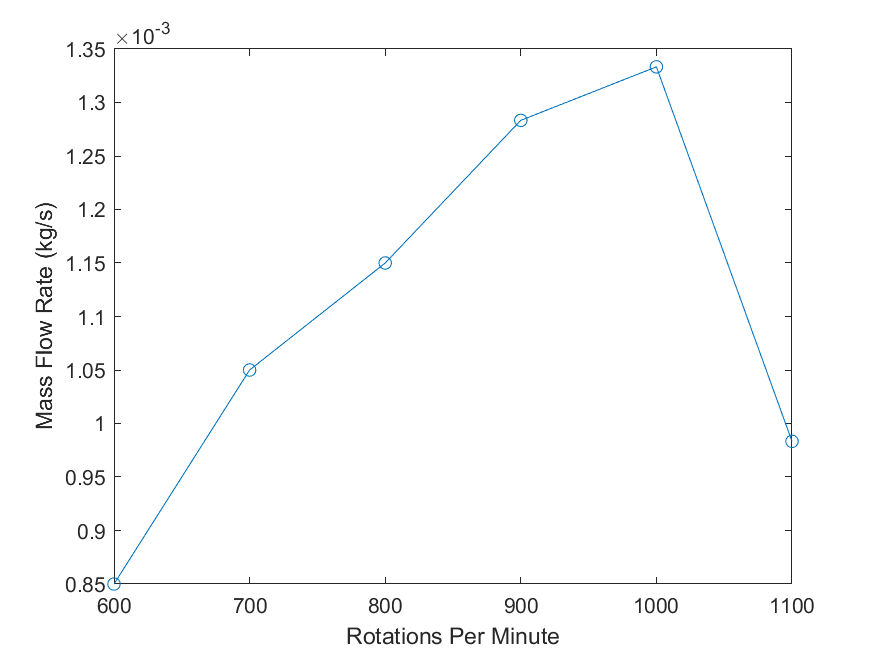


Figure 21 - Mass flow rate of the engine at different rotational speeds in kg/s

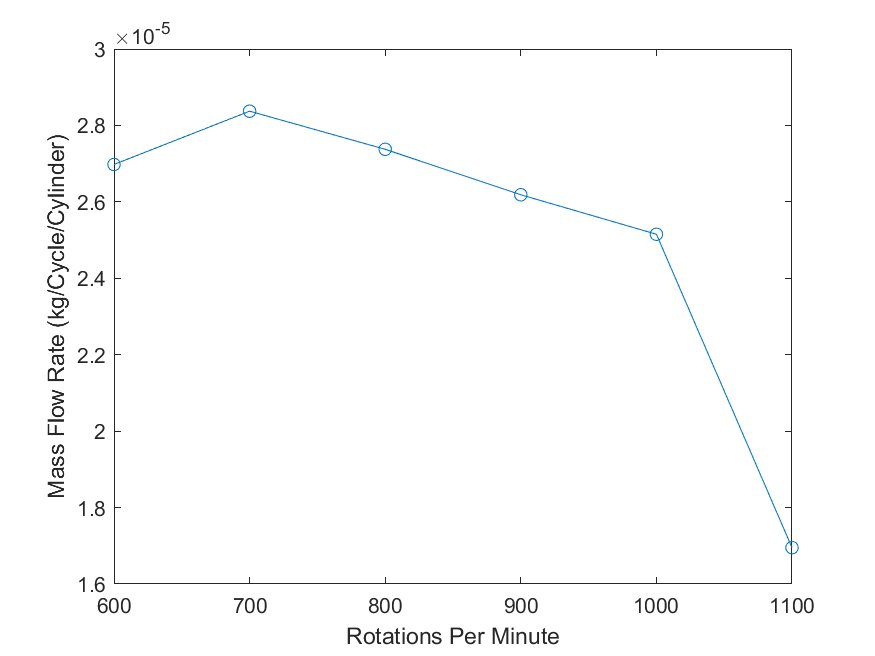


Figure 22 - Mass flow rate of the engine at different rotational speeds in kg/cycle/cylinder

# 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');