**EGB322 Thermodynamics**

**Engine Performance Analysis.**

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## 1.0 Introduction

Engine performance is vital in design and development of Internal Combustion Engines [1]. Engine performance is an indication of success of the engine to perform its delegated task and its ability to convert the chemical energy associated with fuel into useful mechanical work [1]. Engine performance contains several parameters which are but not limited to brake power, torque, brake mean pressure, specific fuel consumption and brake thermal efficiency [1]. There is an extensive array of methods to test engine performance parameters, and a solid background of literature and systematic studies relating to engine performance. Dynamometers are commonly used to determine engine power, associated torque and BMEP [1]. While fuel and air consumption required for efficiency parameters are measured with precise volumetric flow meters [2]. Moreover, dynamic data like combustion, fuel injection pressure and/or crank angle can be measured with adapters made and instrumented to measure specific spots inside the cylinder head [3].

## 2.0 Test-engine and instrumentation

The experimental tests were performed on a six-cylinder diesel engine. The details and specifications of the engine and the testing instrumentation are seen below in table 1. Being used within the data analysis and presentation applied to specifically calculate parameters and values for this diesel engine.

| Engine and Experiment Specification | Instrumentation |
|---|---|
| 102 mm bore x 120 mm stroke | Dynamometer: engine Torque and RPM meters (Water brake dynamometer) |
| 6 in line Cylinders | Fuel flow rate meter |
| 4 Stroke | Air flow rate meter |
| 17.3:1 compression ratio | Cooling water flow rate meter and water temperature thermometers |
| Capacity=5.9L | Exhaust gas calorimeter |
| Maximum Torque = 820/1500(Nm/RPM) | In-cylinder P-V data logger: pressure transducer and crank angle sensor |
| Maximum power = 162/2500(KW/RPM) | |
| Aspiration Turbo-charged & after cooled | |

**Table 1-Experiment Specifications**

The experiment can be divided into three unique sections. Firstly, the experiment measured the engine performance across increasing RPMS from 1300-2400 under half and full load conditions. Specifically determining performance parameters: output torque, brake power, brake mean effective pressure, specific fuel consumption, volumetric efficiency, and thermal efficiency. Secondly, the experiment displays the pressure and volume changes within a full piston cycle at 100% load for both 1300 and 2400 RPM. Thirdly, the experiment measures the energy balance at full load for 1300 and 2400 RPM.

## 3.0 Test data

| | |
|---|---|
| Diesel Density | .86Kg/L |
| Specific heat Air | 1KJ/KGK |
| Diesel Heat Value | 43.2MJ |

**Table 2-Test Data(NOTE THE TEST DATA I USED IN THE ANALYSIS IS IN THE ANALYSIS AND MATLAB CODE)**

## 4.0 Data analysis

### 4.1 PART I-Engine performance at various RPM at 50% and 100% load.

| RPM | Output Torque (NM) | Brake Power (KW) | BMEP KPa | Specific Fuel Consumption (g/KW hr) | Air-Fuel ratio | Volumetric Efficiency (%) | Thermal Efficiency (%) |
|---|---|---|---|---|---|---|---|
| **1300** | 405.0664 | 55.7587 | 862.7483 | 221.7470 | 12.4862 | 56.8117 | 37.5803 |
| **1400** | 410.1495 | 60.2810 | 873.5555 | 217.2803 | 13.2656 | 59.3716 | 38.3529 |
| **1500** | 420.7578 | 66.3168 | 896.1692 | 221.8312 | 13.7160 | 64.3519 | 37.5661 |
| **1600** | 425.1286 | 71.4571 | 905.4785 | 219.3155 | 14.2931 | 66.9729 | 37.9970 |
| **1800** | 394.1775 | 74.4615 | 839.5561 | 221.2682 | 16.0823 | 70.4216 | 37.6617 |
| **2000** | 373.0882 | 78.2451 | 794.6381 | 226.4814 | 17.7316 | 75.1598 | 36.7948 |
| **2200** | 337.6935 | 77.2451 | 718.2512 | 232.5765 | 19.7580 | 77.9046 | 35.8305 |
| **2400** | 302.9250 | 76.2250 | 645.1979 | 222.0374 | 21.6481 | 73.0313 | 37.5312 |

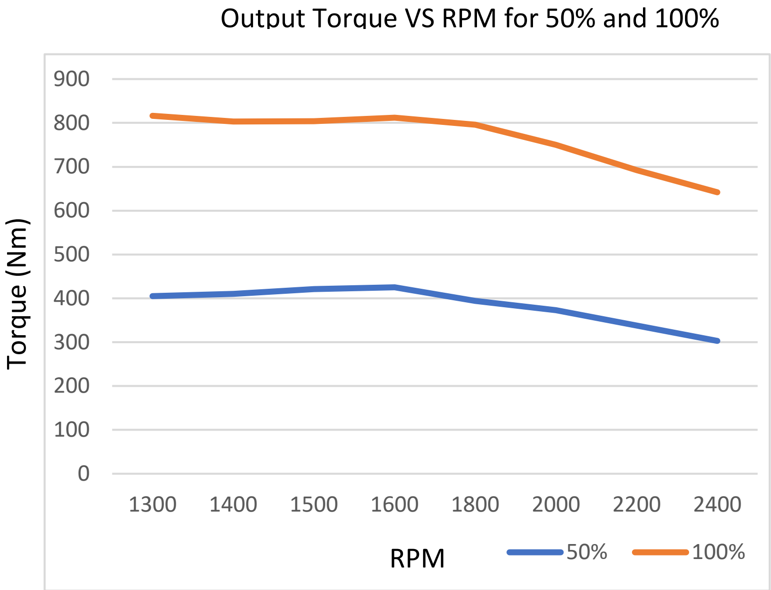
**Table 3- 50% Load**

| RPM | Output Torque (NM) | Brake Power (KW) | BMEP (MPa) | Specific Fuel Consumption (g/KW hr) | Air-Fuel ratio | Volumetric Efficiency (%) | Thermal Efficiency (%) |
|---|---|---|---|---|---|---|---|
| **1300** | 816.2483 | 112.3811 | 1.7385 | 216.6988 | 7.9971 | 71.6665 | 38.4558 |
| **1400** | 802.8803 | 118.0726 | 1.7100 | 221.8469 | 9.0972 | 81.4252 | 37.5634 |
| **1500** | 803.5833 | 126.8106 | 1.7115 | 227.6516 | 9.8704 | 90.8756 | 36.6056 |
| **1600** | 812.1118 | 136.5528 | 1.7297 | 224.7073 | 10.4580 | 95.9435 | 37.0861 |
| **1800** | 795.9282 | 150.4258 | 1.6952 | 217.4852 | 11.9133 | 103.5828 | 38.3168 |
| **2000** | 749.7911 | 157.2342 | 1.5970 | 221.4773 | 12.3746 | 103.0748 | 37.6261 |
| **2200** | 692.0057 | 159.7989 | 1.4739 | 223.4565 | 13.0194 | 101.0905 | 37.2929 |
| **2400** | 641.8889 | 161.4596 | 1.3672 | 206.3290 | 14.5291 | 96.4778 | 40.3886 |

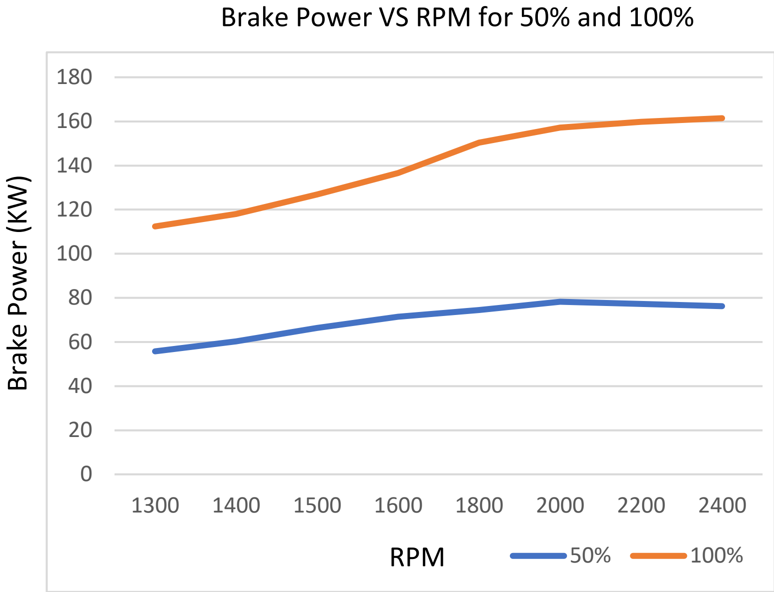
**Table 4-100% Load**

**Example of the calculations and process is shown in Appendix A for 50% Load and Appendix B for 100% Load. The MATLAB was used to automate the data process making it more efficient and accurate. The calculations are within the code. Which were then plotted using Excel.**

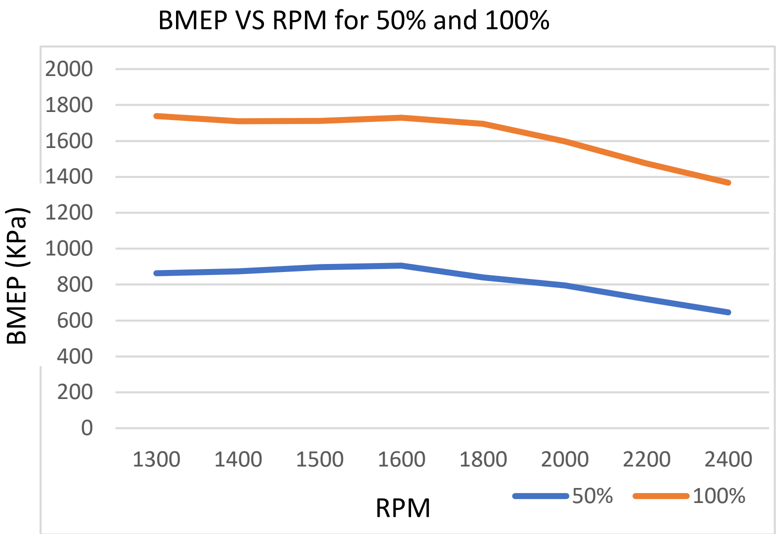
#### 4.1.1 Plots



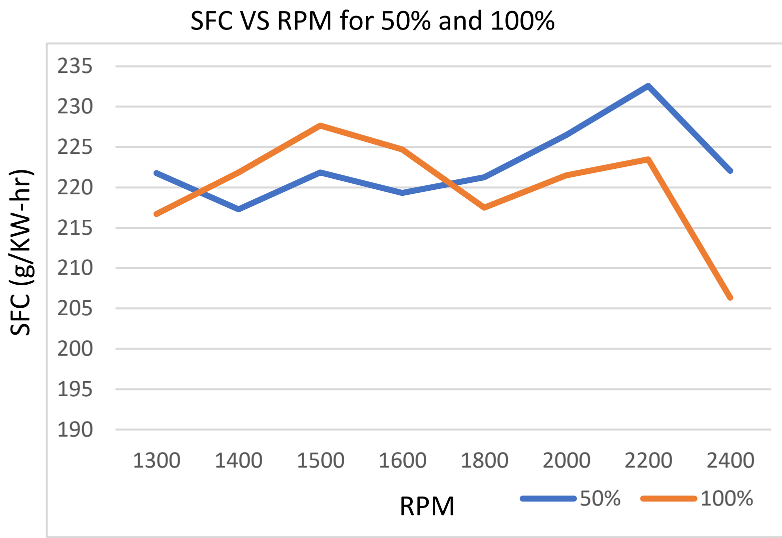

Plot 1



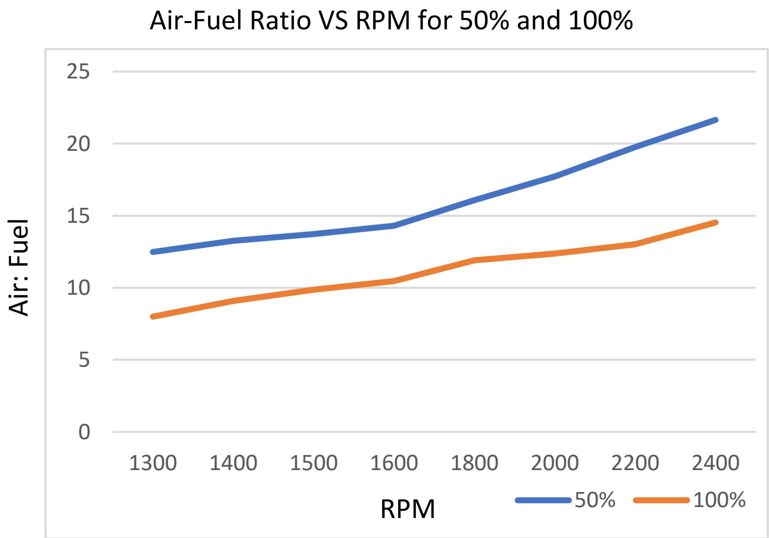

Plot 2



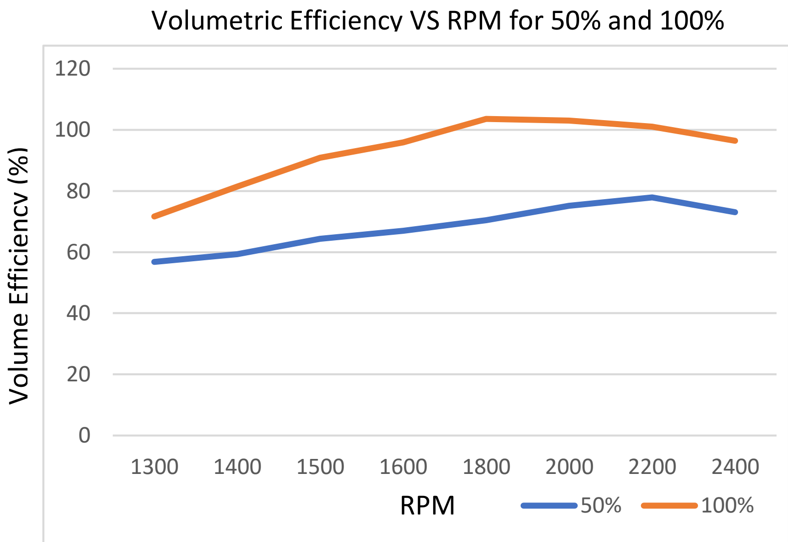

Plot 3



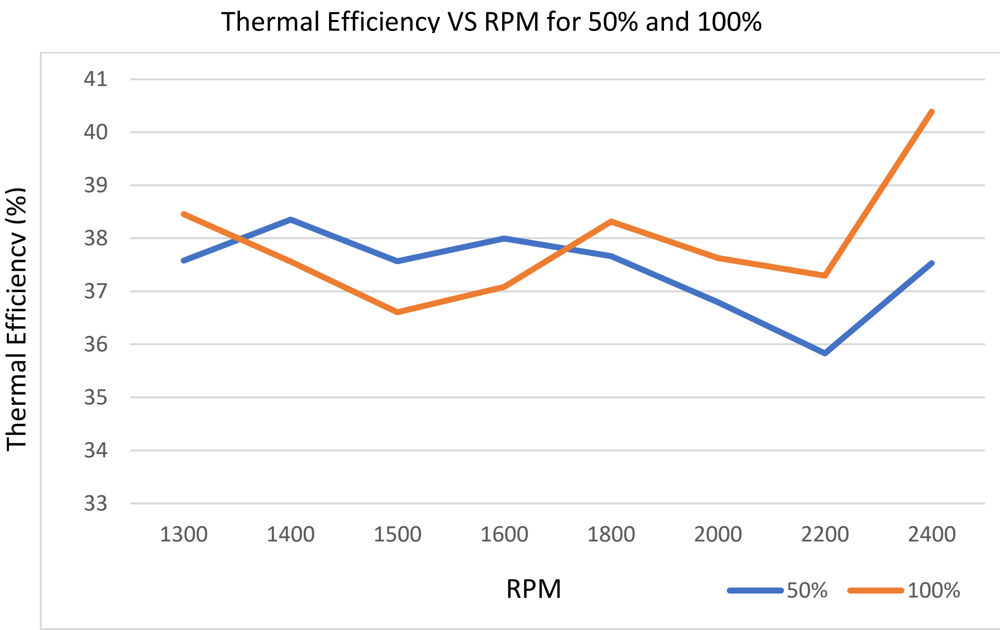

Plot 4




Plot 5

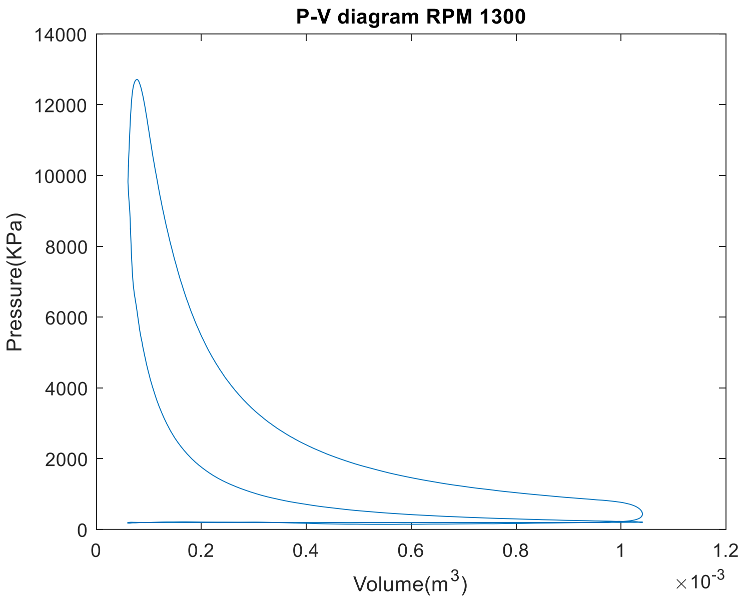



Plot 6

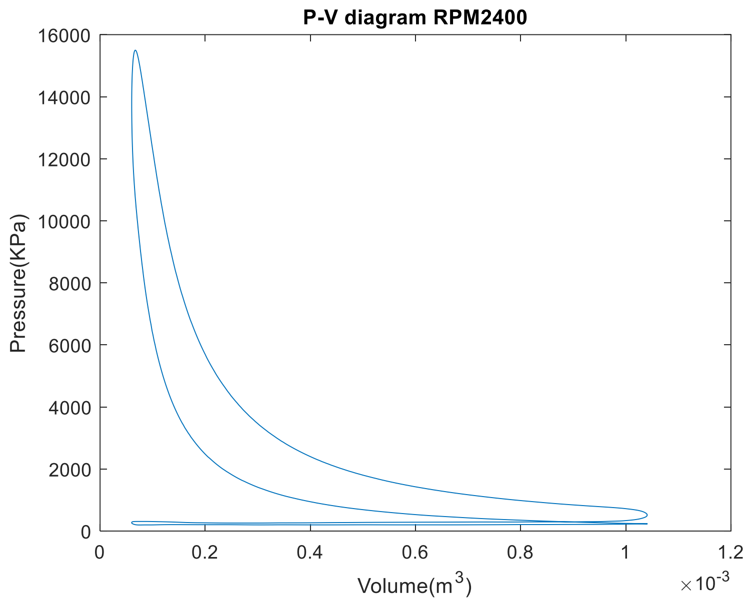



Plot 7

### 4.2 PART II- P-V diagram analysis at full load at 1300 and 2400 RPM




Plot 8




Plot 9

MATLAB code is seen in Appendix C & D.

**Indicated Power, Mechanical Efficiency and IMEP Calculations**

The indicated power can be approximated using the trapezoidal rule. Also, MATLAB can be used to determine the area under the curve, however, ignores the fact that the smaller area, B under the main area would require work.

| **1300 RPM** | **2400 RPM** |
|---|---|
| Indicated Work = 1.8349KJ | Indicated Work =1.5077KJ |
| **Indicated Power**<br>**Indicated work*Number of cylinders*Cycles/second** | |
| $\boldsymbol{Cycles/s = \frac{\left(\frac{1300}{60}\right) revs/s}{2\ strokes}}$<br>$= \mathbf{65/6}$ Cycles/s<br>$= \mathbf{1.8349}\boldsymbol{KJ} \times \mathbf{65}$<br>$= \mathbf{119.269}$ | $Cycles/s = \frac{\left(\frac{2400}{60}\right) revs/s}{2\ strokes}$<br>$= 20$ Cycles/s<br>$= 1.5077KJ \times 65$<br>$= 180.924KW$ |
| $\mathbf{IMEP = \ Wnet, cylinder, cycle\ /Vd}$<br>$\mathbf{Vd = .0059}\boldsymbol{m^3}$ | |
| $\boldsymbol{IMEP} = \frac{\mathbf{1.8349}}{\mathbf{.0059}}$<br>$= \mathbf{311}\boldsymbol{KPa}$ | $IMEP = \frac{1.5077}{.0059}$<br>$= 255.542KPa$ |
| **Mechanical Efficiency**<br>**N=Power output/Power input** | |
| $\boldsymbol{n} = \left(\frac{\mathbf{76.2250}}{\mathbf{119.269}}\right) \times \mathbf{100}$<br>$\boldsymbol{n} = \mathbf{63.9102}\%$ | $n = \left(\frac{161.4596}{180.924}\right) \times 100$<br>$n = 89.2417\%$ |

**Polytropic Coefficients Calculations**

| **Power stroke**<br>$\boldsymbol{P_3V_3^n = \ P_4V_4^n}$<br>$\mathbf{ln}\frac{\boldsymbol{P_3}}{\boldsymbol{P_4}} = \ \boldsymbol{n}\,\mathbf{ln}\frac{\boldsymbol{V_4}}{\boldsymbol{V_3}}$ | |
|---|---|
| $\boldsymbol{P_3} = \mathbf{12700}\boldsymbol{KPa}, \boldsymbol{V_3} = \mathbf{7.878 \times 10^{-5}}\boldsymbol{m^3}$<br>$\boldsymbol{P_4} = \mathbf{462.1}\boldsymbol{KPa}\ , \boldsymbol{V_4} = \mathbf{.00104}\boldsymbol{m^3}$<br>$\mathbf{ln}\frac{\mathbf{12700}}{\mathbf{462.1}} = \boldsymbol{n}\,\mathbf{ln}\frac{\mathbf{.00104}}{\mathbf{7.878 \times 10^{-5}}}$<br>$\boldsymbol{n} = \mathbf{1.2842}$ | $P_3 = 15460KPa, V_3 = 6.894 \times 10^{-5}m^3$<br>$P_4 = 582.7KPa\ , V_4 = .001038m^3$<br>$\ln\frac{15460}{582.7} = n\ln\frac{.001038}{6.894 \times 10^{-5}}$<br>$n = 1.2106$ |
| **Compression Stroke**<br>$\boldsymbol{P_1V_1^n = \ P_2V_2^n}$<br>$\mathbf{ln}\frac{\boldsymbol{P_1}}{\boldsymbol{P_2}} = \ \boldsymbol{n}\,\mathbf{ln}\frac{\boldsymbol{V_2}}{\boldsymbol{V_1}}$ | |
| $\boldsymbol{P_1} = \mathbf{201.5}\boldsymbol{KPa}\ , \boldsymbol{V_1} = \mathbf{.00104}\boldsymbol{m^3}$<br>$\boldsymbol{P_2} = \mathbf{9835}\boldsymbol{KPa}, \boldsymbol{V_2} = \mathbf{6.016 \times 10^{-5}}\boldsymbol{m^3}$<br>$\mathbf{ln}\frac{\mathbf{201.5}}{\mathbf{9835}} = \boldsymbol{n}\,\mathbf{ln}\frac{\mathbf{6.016 \times 10^{-5}}}{\mathbf{.00104}}$<br>$\boldsymbol{n} = \mathbf{1.3642}$ | $P_1 = 232.2KPa, V_1 = .001041m^3$<br>$P_2 = 14130KPa, V_2 = 6.028 \times 10^{-5}m^3$<br>$\ln\frac{232.2}{14130} = n\ln\frac{6.028 \times 10^{-5}}{.001041}$<br>$n = 1.4421$ |

**Cut-off and Heat Input Calculations**

| Cut-off ratio $\boldsymbol{r = \frac{V_3}{V_2}}$ | |
|---|---|
| $\boldsymbol{r = \frac{V_3}{V_2}}$ $\boldsymbol{r = \frac{7.878 \times 10^{-5}}{6.016 \times 10^{-5}}}$ $\boldsymbol{r = 1.31}$ | $r = \frac{V_3}{V_2}$ $r = \frac{6.894 \times 10^{-5}}{6.028 \times 10^{-5}}$ $r = 1.14$ |

- Use the Compression polytropic equation to calculate the pressure at TDC (where V = clearance volume)

▪ Re-plot the original experimental P-V diagram, and plot the diesel cycle as calculated above on the

same graph (polytropic compression, constant pressure heat addition, polytropic expansion, constant volume cooling at BDC).

▪ Calculate the heat input, and express this as a percentage of the available heat from the fuel flow (per

cylinder per cycle).

## 4.3 PART III- Energy Balance at full load at 1300 and 2400 RPM

| Fuel Rate | Water Out | Water In | Calorimeter Out | Calorimeter In | Calorimeter Flow | Coolant Flow | Exh. Temp In | Exh. Temp Out | Air Flow |
|---|---|---|---|---|---|---|---|---|---|
| .4720 | 89.1119 | 80.4315 | 28.9941 | 19.2210 | 66.1011 | 141.2101 | 454.3811 | 91.6329 | .0660 |

**Table 5- Averaged Values 1300 RPM**

| Fuel Rate | Water Out | Water In | Calorimeter Out | Calorimeter In | Calorimeter Flow | Coolant Flow | Exh. Temp In | Exh. Temp Out | Air Flow |
|---|---|---|---|---|---|---|---|---|---|
| .5452 | 89.2756 | 83.2551 | 32.9303 | 23.9930 | 67.0483 | 221.7132 | 313.4460 | 180.7770 | .1232 |

**Table 6- Averaged Values 2400 RPM**

MATLAB used to generate table 5 is seen in Appendix E & F for table 6.

1)Calculate the energy flow into the engine from the fuel flow rate.

$$\dot{Q} = q_{fuel}\dot{m}_{fuel}$$

$$q_{fuel} = 43.2MJ$$

Density of Diesel = .86 kg/l

| **1300** | **2400** |
|---|---|
| $\dot{m}_{fuel} = .4720LPM = .007867L/s$<br>$.007867L/s \times .86kg/l$<br>$= .006766kg/s$<br>$\dot{Q} = 43200000 \times .006766$<br>$= 292.291KW$ | $\dot{m}_{fuel} = .5452LPM = .009087l/s$<br>$.009087 \times .86kg/l$<br>$= .007815kg/s$<br>$\dot{Q} = 43200000 \times .007815$<br>$= 337.608KW$ |

2) Calculate the cooling water heat removal from the engine.

$$\dot{Q} = \dot{m}_{water}C_{P,water}(T_{in,water} - T_{out,water})$$

$$C_P = 4200J/KgK$$

| **1300** | **2400** |
|---|---|
| $\dot{m} = 141.4101LPM = 2.3568L/s$<br>$= 2.3568kg/s$<br>$\dot{Q} = 2.3568 \times 4200(80.4315 - 89.1119)$<br>$= -85923.5W$ | $\dot{m} = 221.7132LPM = 3.6952L/s$<br>$= 3.6952kg/s$<br>$\dot{Q} = 3.6952 \times 4200(83.2551 - 89.2756)$<br>$= -93437.2W$ |

3) Calculate the exhaust flow energy out of the engine.

$$\dot{Q} = \dot{m}_{exhaust}C_{P,exhaust}(T_{in,cal} - T_{out,cal})$$

The exhaust is made of an unknown mixture. To simplify the specific heat of air will be used at standard conditions.

$$C_P = 1000J/KgK$$

| 1300 | 2400 |
|---|---|
| $\dot{m}_{exhaust} = \dot{m}_{fuel} + \dot{m}_{air}$<br>$\dot{m}_{fuel} = .006766kg/s$<br>$\dot{m}_{air} = .0660kg/s$<br>$\dot{m}_{exhaust} = .0728kg/s$<br>$\dot{Q} = .0728 \times 1000(19.2210 - 28.9941)$<br>$\dot{Q} = -711.482W$ | $\dot{m}_{exhaust} = \dot{m}_{fuel} + \dot{m}_{air}$<br>$\dot{m}_{fuel} = .007815kg/s$<br>$\dot{m}_{air} = .1232kg/s$<br>$\dot{m}_{exhaust} = .1310kg/s$<br>$\dot{Q} = .1310 \times 1000(23.9930 - 32.9303)$<br>$\dot{Q} = -1170.79W$ |

| Fuel Energy | Brake Power | Exhaust heat | Cooling | Unaccounted heat losses |
|---|---|---|---|---|
| $\mathbf{292.291\mathit{KW}}$ | 112.3811KW | 711.482W | 85923.5W | 93.2749KW |
| $\mathbf{337.608\mathit{KW}}$ | 161.4596KW | 1170.79W | 93437.2W | 81.5404KW |

Table 7- Energy Consumption PIE CHART

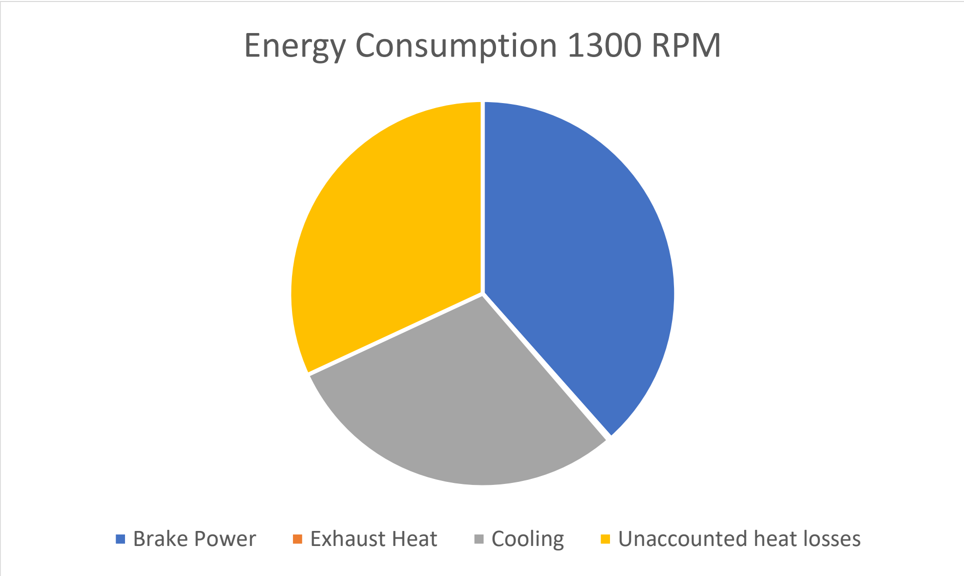



**Figure 1-Energy Consumption 1300RPM**

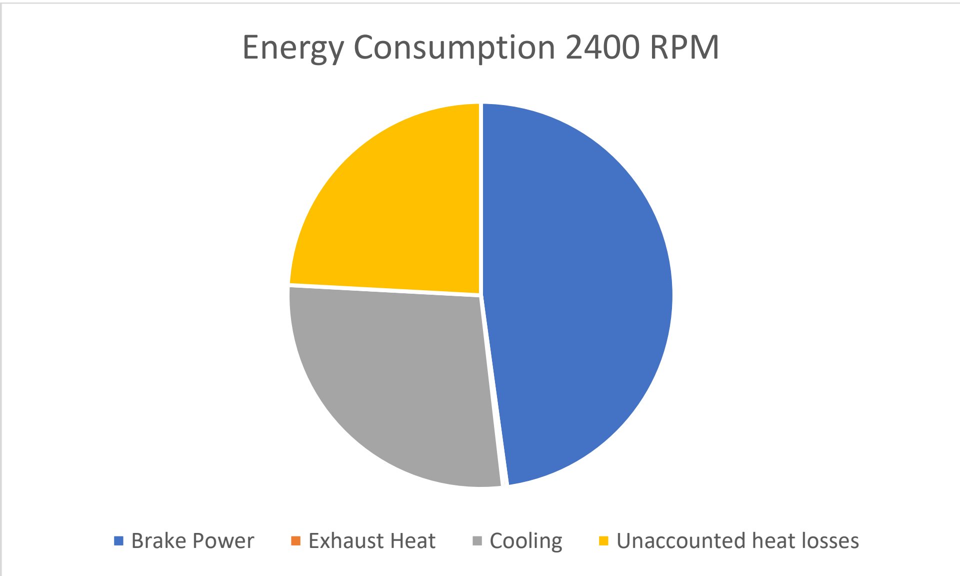



**Figure 2-Energy Consumption 2400RPM**

## 5.0 Discussion and conclusions

The results shown in the data analysis and presentation used MATLAB to condense the large data sheets to average values and calculate the required variables. Part I measured the engine performance with increasing RPM at both half and full load engine conditions. The results were collected in table 3 and 4 and are illustrated in plots 1-7.

Plot 1 shows a distinct correlation between RPM and output torque. Increasing engine RPM substantially decreases torque for both loads and highlights that higher loads produce greater torque. This torque is related to plot 2 being used to calculate the brake power which displays a strong correlation, increasing Brake power with RPM and higher engine loads. Thus, the engine produces the greatest power at higher RPM and loads. Plots 3 illustrates that Brake Mean Effective Pressure decreases with increasing RPM which is amplified with higher engine loads. Essentially decreasing the required average pressure imposed to drive the power stroke which is related with increased brake power supporting plot 2 [4]. Plot 4 shows limited effects between SFC and RPM. The 50% load presents an upward trend until the last RPM increment increasing fuel consumption with increasing RPM. However, the 100% load is ununified and shows no distinct relation. Also, both engine loads are seen to have similar results. In theory the SFC should increase with RPM and engine loads due to increased pumping work, friction, and heat transfer [5]. Plot 5 displays the relation between Air-fuel ratio and RPM. Air-fuel ratio increases with RPM. However, higher loads are seen to have lower than expected air-fuel ratios making them run richer. Richer fuel ratios have greater energy content which can produce more power with lower efficiency [5]. Plot 6 shows that volumetric efficiency increases with RPM. While plot 7 display an erratic relationship with thermal efficiency and RPM. The 50% load decreases and the 100% load increases with RPMs. In theory, thermal efficiency should decrease with increasing RPM similarly to increased fuel consumption [5]. Overall, the engine performance concluded the effects increasing RPM with half and full load conditions. Most importantly increasing power, BMEP and volumetric efficiency, while worsening fuel consumption and thermal efficiency.

Similar published performance testings mostly support the experiments findings. A study on internal combustion engines 'PERFORMANCE OF BIODIESEL COMPARED TO CONVENTIONAL DIESEL FUEL IN STATIONARY INTERNAL COMBUSTION ENGINES' measures similar parameters with increasing RPMs [5]. Which supports the analysed output torque, brake power and BMEP. However, it does not support the SFC and thermal efficiency which are erratic and clearly wrong.

Another study 'Engine performance and emission of compression ignition engine fuelled with emulsified biodiesel-water' shows the effects of increasing engine load measuring fewer shared parameters [6]. It supports the seen brake power and states that SFC should be lower for higher loads.

Part II data was used to plot the P-V diagram of the piston under full load at 1300 and 2400 RPM to enhance and compare the engine performance parameters. The indicated work derived from the P-V diagram seen in plot 7 and 8 highlights that at 2400 RPM less work is produced per cycle than at 1300 RPM. However, at 2400 RPM more indicated power generated due to its higher speed producing 180KW compared to 120KW. Which supports Part I showing that higher RPMs produce greater power. Also, the calculated indicated mean effective pressure is lower for 2400RPM corroborating with Part I. Moreover, the calculated mechanical efficiency shows similarity with the volumetric efficiency seen in plot 6.

Part III calculates the energy balance of the system finding the energy flow of the fuel and the removed energy represented in removed heat from water, exhaust and other losses. The pie chart shows that consumption of the available energy in the system calculated by the energy content of fuel. Most importantly shows that majority of its energy is utilised as power and also displays that the higher RPM produces a greater amount of useful power.

The heat balance seen within figure 1 for 1300 RPM and figure 2 for 2400 RPM is supported by the study ‘Performance Analysis of Exhaust Gas Calorimeter for Diesel Engine’ showing a similar proportion of energy consumption [7].

## 6.0 References


[1] Kaisan, U. M., & Pam, Y.G. (2013). Determination of Engine Performance Parameters of a Stationary Single Cylinder Compression Ignition Engine Run on Biodiesel from Wild Grape Seeds/Diesel Blends. Journal of Energy, Environment & Carbon Credits, (2249 – 8621), 15-21. Retrieved from https://www.researchgate.net/publication/265162521_Determination_of_Engine_Performance_Parameters_of_a_Stationary_Single_Cylinder_Compression_Ignition_Engine_Run_on_Biodiesel_from_Wild_Grape_SeedsDiesel_Blends

[2] Khalid, A., Jaat, N., Sapit, A., Razali, A., Manshoor, b., Zaman, I., & Adbullah, A.A. (2015). PERFORMANCE AND EMISSIONS CHARACTERISTICS OF CRUDE JATROPHA OIL BIODIESEL BLENDS IN A DIESEL ENGINE. International Journal of Automotive and Mechanical Engineering (IJAME), 11(229-8649),2447-2457. Retrieved from http://dx.doi.org/10.15282/ijame.11.2015.25.0206

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[6] Maawa, N.W., Mamat, R., Nakafi, G., Ali, M.O., & Aziz, A. (2015). Engine performance and emission of compression ignition engine fuelled with emulsified biodiesel-water. IOP Conf. Series: Materials Science and Engineering 100 (012061). Retrieved from doi:10.1088/1757-899X/100/1/012061

[7] Patel, M.H., Gosai, C.D., & Modi, J.A. (2014). Performance Analysis of Exhaust Gas Calorimeter for Diesel Engine. International Journal of Engineering Development and Research, 2(2), 2492-2501. Retrieved from https://www.researchgate.net/publication/281115913_Performance_Analysis_of_Exhaust_Gas_Calorimeter_for_Diesel_Engine

# 7.0 Appendix

**Appendix A-50% Load**

**I used MATLAB to develop a code to gather the data more accurately and easily. The code seen below shows the steps I took to conclude each variable seen in the 50% load table. This made collecting the data easier as I could adapt the code to whatever RPM and Load.**

```
T = readmatrix('EGB322Diesel.xls');%Imported the diesel engine data set
into Matlab
ind1=T(:,6) ==50;%Applied a condition to coloumn 6 to equal 50%/Half Load
ind2 =T(:,6)==100;%Applied a condition to coloumn 6 to equal 100%/Full Load
T1=T(ind1,:);%Creates a new matrix which displays all data that are at
50%/Half load
ind3=T1(:,3)<1320;%A condition to coloumn 3 to be less than 1320
RPM1300=T1(ind3,:);%Creates a new matrix which displays all data less than
1320 to represent 1300RPM data
Torque1300=mean(RPM1300(:,4));%Found torque using mean in coloumn 4
BP1300=mean(RPM1300(:,5));%Found Brake Power using mean in coloumn 5
BMEP1300=(((2*pi*Torque1300*2)/.0059))/1000;%Found BMEP using the formula:
Torque X 2pi X Number of strokes / Volume displacement
FR1300=mean(RPM1300(:,7));%Found mean Fuel Rate in L/Min
MF1300=(FR1300/60)*.86;%Converted it to Litres per second and times it by
the density of the fuel to get fuel mass flow in kg/s
BSFC1300=(MF1300*1000*3600)/BP1300;%Calculated BSFC by converting Fuel mass
flow to grams/hour and dividing it by Brake power
AF1300=mean(RPM1300(:,14));%Found the mean Air mass flow which was already
in kg/s
AR1300=AF1300/MF1300;%Calculated Air ratio by dividing Air mass flow by
Fuel mass flow
Nv1300=(2*AF1300)/(1.181*.0059*(1300/60))*100;%Calculated volumetric
efficiency by the formula: (Number of strokes X Air mass flow)/(Air density
X Volume displacement X Revs/sec)
Nt1300=83.3333/(BSFC1300)*100;%Calculated the thermal efficiency through
Nt=1/(SFC*Qhv) where Qhv=43.2MJ/Kg
%% RPM 1400
ind4=T1(:,3)<1420;
RPMA=T1(ind4,:);
ind5=RPMA(:,3)>1399;
RPM1400=RPMA(ind5,:);
Torque1400=mean(RPM1400(:,4));
BP1400=mean(RPM1400(:,5));
BMEP1400=(((2*pi*Torque1400*2)/.0059))/1000;
FR1400=mean(RPM1400(:,7));
MF1400=(FR1400/60)*.86;
BSFC1400=(MF1400*1000*3600)/BP1400;
AF1400=mean(RPM1400(:,14));
AR1400=AF1400/MF1400;
Nv1400=(2*AF1400)/(1.181*.0059*(1400/60))*100;
Nt1400=83.3333/(BSFC1400)*100;
%% RPM 1500
ind6=T1(:,3)<1520;
RPMB=T1(ind6,:);
ind7=RPMB(:,3)>1499;
RPM1500=RPMB(ind7,:);
Torque1500=mean(RPM1500(:,4));
BP1500=mean(RPM1500(:,5));
BMEP1500=(((2*pi*Torque1500*2)/.0059))/1000;
FR1500=mean(RPM1500(:,7));
MF1500=(FR1500/60)*.86;
```

```
BSFC1500=(MF1500*1000*3600)/BP1500;
AF1500=mean(RPM1500(:,14));
AR1500=AF1500/MF1500;
Nv1500=(2*AF1500)/(1.181*.0059*(1500/60))*100;
Nt1500=83.3333/(BSFC1500)*100;
%%RPM 1600
ind8=T1(:,3)<1620;
RPMC=T1(ind8,:);
ind9=RPMC(:,3)>1599;
RPM1600=RPMC(ind9,:);
Torque1600=mean(RPM1600(:,4));
BP1600=mean(RPM1600(:,5));
BMEP1600=(((2*pi*Torque1600*2)/.0059))/1000;
FR1600=mean(RPM1600(:,7));
MF1600=(FR1600/60)*.86;
BSFC1600=(MF1600*1000*3600)/BP1600;
AF1600=mean(RPM1600(:,14));
AR1600=AF1600/MF1600;
Nv1600=(2*AF1600)/(1.181*.0059*(1600/60))*100;
Nt1600=83.3333/(BSFC1600)*100;
%%RPM 1800
ind10=T1(:,3)<1820;
RPMD=T1(ind10,:);
ind11=RPMD(:,3)>1799;
RPM1800=RPMD(ind11,:);
Torque1800=mean(RPM1800(:,4));
BP1800=mean(RPM1800(:,5));
BMEP1800=(((2*pi*Torque1800*2)/.0059))/1000;
FR1800=mean(RPM1800(:,7));
MF1800=(FR1800/60)*.86;
BSFC1800=(MF1800*1000*3600)/BP1800;
AF1800=mean(RPM1800(:,14));
AR1800=AF1800/MF1800;
Nv1800=(2*AF1800)/(1.181*.0059*(1800/60))*100;
Nt1800=83.3333/(BSFC1800)*100;
%%RPM 2000
ind12=T1(:,3)<2020;
RPME=T1(ind12,:);
ind13=RPME(:,3)>1999;
RPM2000=RPME(ind13,:);
Torque2000=mean(RPM2000(:,4));
BP2000=mean(RPM2000(:,5));
BMEP2000=(((2*pi*Torque2000*2)/.0059))/1000;
FR2000=mean(RPM2000(:,7));
MF2000=(FR2000/60)*.86;
BSFC2000=(MF2000*1000*3600)/BP2000;
AF2000=mean(RPM2000(:,14));
AR2000=AF2000/MF2000;
Nv2000=(2*AF2000)/(1.181*.0059*(2000/60))*100;
Nt2000=83.3333/(BSFC2000)*100;
%%RPM 2200
ind14=T1(:,3)<2220;
RPMF=T1(ind14,:);
ind15=RPMF(:,3)>2199;
RPM2200=RPMF(ind15,:);
Torque2200=mean(RPM2200(:,4));
BP2200=mean(RPM2200(:,5));
BMEP2200=(((2*pi*Torque2200*2)/.0059))/1000;
FR2200=mean(RPM2200(:,7));
MF2200=(FR2200/60)*.86;
BSFC2200=(MF2200*1000*3600)/BP2200;
```

```
AF2200=mean(RPM2200(:,14));
AR2200=AF2200/MF2200;
Nv2200=(2*AF2200)/(1.181*.0059*(2200/60))*100;
Nt2200=83.3333/(BSFC2200)*100;
%%RPM 2400
ind16=T1(:,3)<2420;
RPMG=T1(ind16,:);
ind17=RPMG(:,3)>2399;
RPM2400=RPMG(ind17,:);
Torque2400=mean(RPM2400(:,4));
BP2400=mean(RPM2400(:,5));
BMEP2400=(((2*pi*Torque2400*2)/.0059))/1000;
FR2400=mean(RPM2400(:,7));
MF2400=(FR2400/60)*.86;
BSFC2400=(MF2400*1000*3600)/BP2400;
AF2400=mean(RPM2400(:,14));
AR2400=AF2400/MF2400;
Nv2400=(2*AF2400)/(1.181*.0059*(2400/60))*100;
Nt2400=83.3333/(BSFC2400)*100;
```

**Appendix B-100% Load Code**

```
T = readmatrix('EGB322Diesel.xls');%Imported the diesel engine data set
into Matlab
ind1=T(:,6) ==50;%Applied a condition to coloumn 6 to equal 50%/Half Load
ind2 =T(:,6)==100;%Applied a condition to coloumn 6 to equal 100%/Full Load
T2=T(ind2,:);%Creates a new matrix which displays all data that are at
50%/Half load
ind3=T2(:,3)<1320;%A condition to coloumn 3 to be less than 1320
RPM1300=T2(ind3,:);%Creates a new matrix which displays all data less than
1320 to represent 1300RPM data
Torque1300=mean(RPM1300(:,4));%Found torque using mean in coloumn 4
BP1300=mean(RPM1300(:,5));%Found Brake Power using mean in coloumn 5
BMEP1300=(((2*pi*Torque1300*2)/.0059))/1000;%Found BMEP using the formula:
Torque X 2pi X Number of strokes / Volume displacement
FR1300=mean(RPM1300(:,7));%Found mean Fuel Rate in L/Min
MF1300=(FR1300/60)*.86;%Converted it to Litres per second and times it by
the density of the fuel to get fuel mass flow in kg/s
BSFC1300=(MF1300*1000*3600)/BP1300;%Calculated BSFC by converting Fuel mass
flow to grams/hour and dividing it by Brake power
AF1300=mean(RPM1300(:,14));%Found the mean Air mass flow which was already
in kg/s
AR1300=AF1300/MF1300;%Calculated Air ratio by dividing Air mass flow by
Fuel mass flow
Nv1300=(2*AF1300)/(1.181*.0059*(1300/60))*100;%Calculated volumetric
efficiency by the formula: (Number of strokes X Air mass flow)/(Air density
X Volume displacement X Revs/sec)
Nt1300=83.3333/(BSFC1300)*100;%Calculated the thermal efficiency through
Nt=1/(SFC*Qhv) where Qhv=43.2MJ/Kg
%% RPM 1400
ind4=T2(:,3)<1420;
RPMA=T2(ind4,:);
ind5=RPMA(:,3)>1399;
RPM1400=RPMA(ind5,:);
Torque1400=mean(RPM1400(:,4));
BP1400=mean(RPM1400(:,5));
BMEP1400=(((2*pi*Torque1400*2)/.0059))/1000;
FR1400=mean(RPM1400(:,7));
MF1400=(FR1400/60)*.86;
BSFC1400=(MF1400*1000*3600)/BP1400;
AF1400=mean(RPM1400(:,14));
AR1400=AF1400/MF1400;
Nv1400=(2*AF1400)/(1.181*.0059*(1400/60))*100;
Nt1400=83.3333/(BSFC1400)*100;
%% RPM 1500
ind6=T2(:,3)<1520;
RPMB=T2(ind6,:);
ind7=RPMB(:,3)>1499;
RPM1500=RPMB(ind7,:);
Torque1500=mean(RPM1500(:,4));
BP1500=mean(RPM1500(:,5));
BMEP1500=(((2*pi*Torque1500*2)/.0059))/1000;
FR1500=mean(RPM1500(:,7));
MF1500=(FR1500/60)*.86;
BSFC1500=(MF1500*1000*3600)/BP1500;
AF1500=mean(RPM1500(:,14));
AR1500=AF1500/MF1500;
Nv1500=(2*AF1500)/(1.181*.0059*(1500/60))*100;
Nt1500=83.3333/(BSFC1500)*100;
%%RPM 1600
ind8=T2(:,3)<1620;
RPMC=T2(ind8,:);
ind9=RPMC(:,3)>1599;
```

```
RPM1600=RPMC(ind9,:);
Torque1600=mean(RPM1600(:,4));
BP1600=mean(RPM1600(:,5));
BMEP1600=(((2*pi*Torque1600*2)/.0059))/1000;
FR1600=mean(RPM1600(:,7));
MF1600=(FR1600/60)*.86;
BSFC1600=(MF1600*1000*3600)/BP1600;
AF1600=mean(RPM1600(:,14));
AR1600=AF1600/MF1600;
Nv1600=(2*AF1600)/(1.181*.0059*(1600/60))*100;
Nt1600=83.3333/(BSFC1600)*100;
%%RPM 1800
ind10=T2(:,3)<1820;
RPMD=T2(ind10,:);
ind11=RPMD(:,3)>1799;
RPM1800=RPMD(ind11,:);
Torque1800=mean(RPM1800(:,4));
BP1800=mean(RPM1800(:,5));
BMEP1800=(((2*pi*Torque1800*2)/.0059))/1000;
FR1800=mean(RPM1800(:,7));
MF1800=(FR1800/60)*.86;
BSFC1800=(MF1800*1000*3600)/BP1800;
AF1800=mean(RPM1800(:,14));
AR1800=AF1800/MF1800;
Nv1800=(2*AF1800)/(1.181*.0059*(1800/60))*100;
Nt1800=83.3333/(BSFC1800)*100;
%%RPM 2000
ind12=T2(:,3)<2020;
RPME=T2(ind12,:);
ind13=RPME(:,3)>1999;
RPM2000=RPME(ind13,:);
Torque2000=mean(RPM2000(:,4));
BP2000=mean(RPM2000(:,5));
BMEP2000=(((2*pi*Torque2000*2)/.0059))/1000;
FR2000=mean(RPM2000(:,7));
MF2000=(FR2000/60)*.86;
BSFC2000=(MF2000*1000*3600)/BP2000;
AF2000=mean(RPM2000(:,14));
AR2000=AF2000/MF2000;
Nv2000=(2*AF2000)/(1.181*.0059*(2000/60))*100;
Nt2000=83.3333/(BSFC2000)*100;
%%RPM 2200
ind14=T2(:,3)<2220;
RPMF=T2(ind14,:);
ind15=RPMF(:,3)>2199;
RPM2200=RPMF(ind15,:);
Torque2200=mean(RPM2200(:,4));
BP2200=mean(RPM2200(:,5));
BMEP2200=(((2*pi*Torque2200*2)/.0059))/1000;
FR2200=mean(RPM2200(:,7));
MF2200=(FR2200/60)*.86;
BSFC2200=(MF2200*1000*3600)/BP2200;
AF2200=mean(RPM2200(:,14));
AR2200=AF2200/MF2200;
Nv2200=(2*AF2200)/(1.181*.0059*(2200/60))*100;
Nt2200=83.3333/(BSFC2200)*100;
%%RPM 2400
ind16=T2(:,3)<2420;
RPMG=T2(ind16,:);
ind17=RPMG(:,3)>2399;
RPM2400=RPMG(ind17,:);
```

```
Torque2400=mean(RPM2400(:,4));
BP2400=mean(RPM2400(:,5));
BMEP2400=(((2*pi*Torque2400*2)/.0059))/1000;
FR2400=mean(RPM2400(:,7));
MF2400=(FR2400/60)*.86;
BSFC2400=(MF2400*1000*3600)/BP2400;
AF2400=mean(RPM2400(:,14));
AR2400=AF2400/MF2400;
Nv2400=(2*AF2400)/(1.181*.0059*(2400/60))*100;
Nt2400=83.3333/(BSFC2400)*100;
```

**Appendix C -PART II 1300 RPM MATLAB CODE**

```
T1 = readmatrix('Pressure Volume data at 1300 RPM.xls');
plot(T1(:,3),T1(:,2));
xlabel('Volume(m^3)')
ylabel('Pressure(KPa)')
title('P-V diagram RPM 1300')
Int1=trapz(T1(:,3),T1(:,2));
```

**Appendix D-Part II 2400 RPM MATLAB CODE**

```
T = readmatrix('Pressure Volume data at 2400 RPM.xls');
plot(T(:,3),T(:,2));
xlabel('Volume(m^3)')
ylabel('Pressure(KPa)')
title('P-V diagram RPM2400')
plot(
Int=trapz(T(:,3),T(:,2));
```

**Appendix E – MATLAB Code for 1300RPM**

```
T = readmatrix('EGB322Diesel.xls');%Imported the diesel engine data set
into Matlab
ind1 =T(:,6)==100;%Applied a condition to coloumn 6 to equal 100%/Full Load
T1=T(ind1,:);%Creates a new matrix which displays all data that are at
50%/Half load
ind2=T1(:,3)<1320;%A condition to coloumn 3 to be less than 1320
RPM1300=T1(ind2,:);%Creates a new matrix which displays all data less than
1320 to represent 1300RPM data
FuelMassFlow=mean(RPM1300(:,7));
WaterTempIn=mean(RPM1300(:,9));
WaterTempOut=mean(RPM1300(:,8));
CoolantMassFlow=mean(RPM1300(:,13));
CalorimeterIn=mean(RPM1300(:,11));
CalorimeterOut=mean(RPM1300(:,10));
CalorimeterFlow=mean(RPM1300(:,12));
ExhTempIn=mean(RPM1300(:,15));
ExhTempOut=mean(RPM1300(:,16));
AirRatio=mean(RPM1300(:,14));
```

**Appendix F– MATLAB Code for 2400RPM**

```
T = readmatrix('EGB322Diesel.xls');%Imported the diesel engine data set
into Matlab
ind1=T(:,3)>2399;
RPM2400=T(ind1,:);
FuelMassFlow=mean(RPM2400(:,7));
WaterTempIn=mean(RPM2400(:,9));
WaterTempOut=mean(RPM2400(:,8));
CoolantMassFlow=mean(RPM2400(:,13));
CalorimeterIn=mean(RPM2400(:,11));
CalorimeterOut=mean(RPM2400(:,10));
CalorimeterFlow=mean(RPM2400(:,12));
ExhTempIn=mean(RPM2400(:,15));
ExhTempOut=mean(RPM2400(:,16));
AirRatio=mean(RPM2400(:,14));
```