# STUDY OF CRUDE PALM OIL DIESEL BLEND EMISSION ON DIESEL ENGINE

By

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Dissertation submitted in partial fulfilment of the requirements for the Bachelor of Engineering (Hons) Mechanical Engineering

January 2016

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CERTIFICATION OF APPROVAL

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Approved by,

_____________________________

(Mr Faizairi Bin Mohd Nor)

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR, PERAK
January 2016

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own expect as specified in the references and acknowledgement, and that original work contained herein have not been undertaken or done by unspecified sources or persons.

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MUHAMAD SYAMIM BIN HAJI HAMZAH

# ABSTRACT

Diesel fuels are widely used globally in many applications involving heavy industries and transportations. With the majority of heavy lifting machines, generators, military vehicles and industrial power horse are using diesel engines; diesel fuel demand is ever increasing and with the supply of fossil fuel decreasing, an alternative source of diesel is needed to provide sustainability. Recent studies shows that biofuels are the most sustainable source of biodiesel but requires special methods and catalysts in obtaining the biodiesel. This project however, focuses on the direct blending of Crude Palm Oil (CPO) with diesel to produce biodiesel. The blends are categorized with different Diesel to CPO volumetric ratio of 100:0, 75:25, 50:50, 25:50, and 0:100. The calorific value of the pure CPO obtained was 39590 J/g compared to 42579J/g of diesel. With each blend having even more calorific value than pure CPO, it shows a promising result on the application of the blends to work on diesel engines. The blended fuels were tested on the diesel engine and the emissions were analyzed to give the results in the results section.

# ACKNOWLEDGEMENT

First of all, I would like to express my highest gratitude to my supervisor, Mr Faizairi Bin Mohd Nor whom guided and mentored me throughout the span of this course. As a supervisor, he provided invaluable wisdom and knowledge concerning the project which inspired me to complete my project even with many complications arose.

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Last but not least, the expression of my gratitude would also be directed to my irreplaceable parents, Haji Hamzah Bin Ayob and Mdm Norleeda Binti Abdul Rahman for their undivided affection and inspiration. Their continuous support and advice provided me the strength and courage to face the seemingly endless problems during the span of the project. Thank you.

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## LIST OF ABBREVIATION

| | |
|---|---|
| CPO | Crude palm oil |
| PD | Palm to diesel ratio |
| ml | Millilitre |
| UTP | Universiti Teknologi Petronas |
| Hp | Horsepower |
| Rpm | Revolution per minute |
| cc | Cubic centimetre |
| kW | kilowatt |
| hr | Hour |
| SEDEX | Science, Engineering and Design Exhibition |

# Chapter 1

# Introduction

## 1.1 Background of study

In the modern era, diesel engines are the backbone of heavy industrial application. Used from transportation to power generation. With a variety of size and specifications, the diesel engines are pretty flexible and becoming more popular due to its durability and higher torque rating than spark ignited engines. With the highest thermal efficiency than any other types of engines, diesel engines have the best money for value in terms of economical approach.

The fuel it uses, diesel is among the highly used type of liquid fuel apart from gasoline and kerosene (jet fuels) [2]. In the upcoming decade, diesel usage will likely to increase due to the increment of affinity towards diesel based vehicles. Thus, diesel prices will be higher than gasoline is bound to happen with fossil fuel supply decreasing and the demand is increasing.

Diesel is also proven to be not environmental-friendly due to its emission of high amount of sulphur and particulate matters during combustion [3]. Even though vehicle manufactures implement the use of particulate filter in exhaust systems, the increase usage of diesel engines will still produce high pollution to the environment.

Therefore, the need for a more sustainable and cleaner fuel development is increasingly popular. The existing alternative called biodiesel which is produced through tranesterification of vegetable oil [4] was blended with diesel to reduce the emission of sulphur. However it is quite expensive to convert the vegetable oil to biodiesel making it unsuitable for a permanent alternative.

Fortunately, there few studies that have been found to use unconverted vegetable oil directly as fuel [5]. However, the vegetable oil alone is considered unsuitable for large scale and long term usage due to its high viscosity which atomizes the fuel poorly and poor air mixture in the combustion chamber [6]. To handle the problem, these vegetable oils should be blended with diesel prior of its use.

With the study conducted in Malaysia, the vegetable oil used would be crude palm oil as the country is one of the major producers of palm oil globally. By conducting the study, the value of palm oils in Malaysia could increase dramatically and give a new life on the industry. Therefore the country would have a more sustainable commodity in the future.

## 1.2 Problem Statement

With the increase of crude oil demand, the price of diesel is bound to exceed gasoline in the near future. Some countries are already experiencing the effects due to the majority of diesel engine usage. While Malaysia still uses a majority of gasoline engines, the conversion to diesel engines are bound to happen sooner or later. Thus, the blending of vegetable oil and diesel to be used directly in combustion chambers must be studied. By bypassing the conversion process of the vegetable oil into biodiesel, surely it will reduce the cost of fuel making it more relevant [1][7].

Although there are existing studies that have the appropriate proportion of diesel-vegetable oil such as sunflower and soy crude oils to be used in diesel engines, this study focuses of crude palm oil blended with diesel due to its abundance in Malaysia.

Therefore, a good understanding of the properties of the blended fuel must be obtained to fully utilize the diesel-crude palm oil blends as fuel in industrial diesel engines. The performance of different mixture proportions needs to be studied to obtain the best efficiency for large scale usage in the future [1].

## 1.3 Objectives

The main objectives of this study are;

1) To study the characteristics of blended diesel-crude palm oil at different volume ratio.
2) To investigate the emissions of the diesel engine using blended diesel-crude palm oil at different volume ratio.

## 1.4 Scope of Study

In this study, the main properties of blended diesel-crude palm oil in the volume ratios of 100:0, 75:25, 50:50, 25:75 and 0:100 will be analyzed – calorific value. Then, the diesel engine toxic-gas emission is investigated to determine the best volume ratio for the industrial diesel engine.

# CHAPTER 2

## Literature Review

### 2.1 Calorific value

Calorific value, or also known as heat of combustion, is the value of total energy released as heat energy when a material reacts with oxygen to through combustion. The reaction is typically hydrocarbons or other organic molecule reacting with oxygen to form carbon dioxide and water and release heat. It may be expressed with the quantities:

- energy/mole of fuel (kJ/mol)
- energy/mass of fuel
- energy/volume of the fuel

The heat of combustion is conventionally measured with a bomb calorimeter. It may also be calculated as the difference between the heat of formation $\Delta H^{\ominus}$ f of the products and reactants (though this approach is purely empirical since most heats of formation are calculated from measured heats of combustion). For a fuel of composition $C_cH_hO_oN_n$, the magnitude of the heat of combustion is 418 kJ/mol ($c$ + 0.3 $h$ – 0.5 $o$) to a good approximation (±3%).[11] The heat of combustion of all organic compounds has the sign corresponding to an exothermic reaction (negative in the standard chemical convention) because the double bond in molecular oxygen is much weaker than other double bonds or pairs of single bonds, particularly those in the combustion products carbon dioxide and water; conversion of the weak bonds in $O_2$ to the stronger bonds in $CO_2$ and $H_2O$ releases energy as heat.[11]

The **heating value** (or **energy value** or **calorific value**) of a substance, usually a fuel or food (see food energy), is the amount of heat released during the combustion of a specified amount of it. The energy value is a characteristic for each substance. It is measured in units of energy per unit of the substance, usually mass, such as: kJ/kg, kJ/mol, kcal/kg, Btu/lb. Heating value is commonly determined by use of a bomb calorimeter.

Heating value unit conversions:

- kcal/kg = MJ/kg × 238.846
- Btu/lb = kJ/kg × 2.3238
- Btu/lb = kcals/kg × 1.8

## 2.2 Viscosity

The **viscosity** of a fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress.[12] For liquids, it corresponds to the informal concept of "thickness". For example, honey has a much higher viscosity than water.[13]

Viscosity is a property arising from collisions between neighboring particles in a fluid that are moving at different velocities. When the fluid is forced through a tube, the particles which compose the fluid generally move more quickly near the tube's axis and more slowly near its walls: therefore some stress, (such as a pressure difference between the two ends of the tube), is needed to overcome the friction between particle layers to keep the fluid moving. For the same velocity pattern, the stress required is proportional to the fluid's viscosity.

A fluid that has no resistance to shear stress is known as an *ideal* or *inviscid* fluid. Zero viscosity is observed only at very low temperatures in superfluids. Otherwise, all fluids have positive viscosity, and are technically said to be viscous or viscid. In common parlance however, a liquid is said to be viscous if its viscosity is substantially greater than that of water; and may be described as mobile if the viscosity is noticeably less than water. A fluid with a relatively high viscosity, for example, pitch, may appear to be a solid

### 2.3 Density

The **density**, or more precisely, the **volumetric mass density**, of a substance is its mass per unit volume. The symbol most often used for density is $\boldsymbol{\rho}$ (the lower case Greek letter rho), although the Latin letter *D* can also be used. Mathematically, density is defined as mass divided by volume:[14]

$$\rho = m/V$$

where $\rho$ is the density, $m$ is the mass, and $V$ is the volume. In some cases (for instance, in the United States oil and gas industry), density is loosely defined as its weight per unit volume,[15] although this is scientifically inaccurate – this quantity is more specifically called specific weight.

For a pure substance the density has the same numerical value as its mass concentration. Different materials usually have different densities, and density may be relevant to buoyancy, purity and packaging. Osmium and iridium are the densest known elements at standard conditions for temperature and pressure but certain chemical compounds may be denser.

To simplify comparisons of density across different systems of units, it is sometimes replaced by the dimensionless quantity "relative density" or "specific gravity", i.e. the ratio of the density of the material to that of a standard material, usually water. Thus a relative density less than one means that the substance floats in water.

The density of a material varies with temperature and pressure. This variation is typically small for solids and liquids but much greater for gases. Increasing the pressure on an object decreases the volume of the object and thus increases its density. Increasing the temperature of a substance (with a few exceptions) decreases its density by increasing its volume. In most materials, heating the bottom of a fluid results in convection of the heat from the bottom to the top, due to the decrease in the density of the heated fluid. This causes it to rise relative to more dense unheated material.

The reciprocal of the density of a substance is occasionally called its specific volume, a term sometimes used in thermodynamics. Density is an intensive property in that increasing the amount of a substance does not increase its density; rather it increases its mass

## 2.4 Characteristics diesel fuels

Diesel fuel is a mixture of hydrocarbon which is produced by distilling crude oil [1][3]. The major property that is used to characterize diesel fuel includes cetane number, density, viscosity, cold behaviour and sulphur content. Diesel fuel specification differs with a variety of fuel grades in different countries. Table 1 illustrates the standard kinematic viscosity, density, and calorific value of diesel fuel [2].

Table 1: Properties of Diesel Fuel

| **Properties** | **Standard Value** |
|---|---|
| Kinematic viscosity | >2.7 cs |
| Density | 0.80 g/ml – 0.86/ml |
| Calorific Value | 10170 kcal/kg |

The biggest issue with diesel fuel is its high pollutant emission of Particulate Matter (PM) and Nitrogen Oxides (NOx). Researchers are being conducted to improve the quality of emissions, by developing and improving the engine, post treatment of the exhaust system, deep desulphurization and dearomatization and even formulating diesel fuels into oxygenated diesel fuels or biodiesel [2].

The standard biodiesel refers to the fuel derived from biological sources. Usually it is alkyl esters made from transesterrification of vegetable oils or animal fats or both. Biodiesel is typically more expensive than the usual petroleum diesel [4] but more environmentally friendly.

## 2.5 Characteristics of Crude Palm Oil

Palm oil is an edible vegetable oil which can be obtained by processing the fruits of palm trees. The natural colour of the palm oil is reddish due to its high content of beta-carotene. The advantages of using palm oil as diesel fuel is due to its renewability, low sulphur and aromatic content, higher flash point, higher biodegradability and non – toxicity [1].

However, crude palm oils are naturally high in viscosity, low in cetane number with low calorific value and volatility [4]. Table 2 illustrates the main properties of crude palm oil [7][8].

Table 2: Properties of Crude Palm Oil

| Properties | Standard Value |
|---|---|
| Kinematic viscosity | 45 cs |
| Density | 0.89956 g/ml |
| Calorific Value | 8925 kcal/kg |

Under room temperature environment, crude palm oil solidifies and increases the viscosity. The viscosity of palm oil can be reduced by preheating the fuel before using it in the engine but it will cost extra energy and money.

# CHAPTER 3

# Methodology

## 3.1 Process Flow of Project

The steps required to obtain the desired results during the project involves studying the literature review, procurement of samples, blending, experiments and result analysis. Figure 1 illustrates the flow of the project.

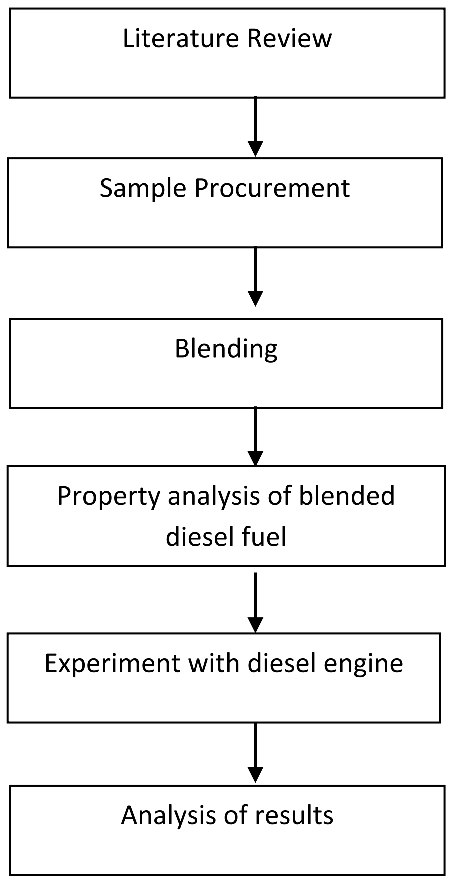


Figure 1: Flow Chart of project

### 3.1.1 Materials and Equipment

Tables 3 and 4 below represent the materials and equipments used during the experiment respectively.

Table 3: List of materials used

| No | Material | Amount | Purpose |
|---|---|---|---|
| 1 | Crude Palm Oil | 8 litres | Blending Component |
| 2 | Diesel Fuel | 8 litres | Blending Component |

Table 4: List of the equipments used

| **No** | **Equipment** | **Purpose** |
|---|---|---|
| 1 | Yanmar L70V diesel engine | The main experimentation engine |
| 2 | Bosch Gas analyser | To measure the emissions from the engine |
| **2** | Cylindrical volume | To measure the volume of fluids |
| **3** | Volumetric flask | To hold the blended samples |
| **4** | 500ml beakers | Used as a pouring medium |
| **5** | Bomb Calorimeter | To measure the calorific value |

## 3.2 Sample Procurement

For this study, samples are required for the purpose of experimentation. Thus acquiring the unprocessed samples are vital for relevancy of this project. The sample mentioned is the crude palm oil which can be obtained at Felcra Palm Mill in Kampung Gajah, Perak. Another sample is diesel fuel which can be obtained at any petrol stations nearby. These samples should be obtained with an excess volume for backup purposes and testing the blended fuel for its characteristics.

## 3.3 Blending

After obtaining the crude palm oil and diesel, they will be blended together with a volumetric ratio of diesel with palm oil at 100:0, 75:25, 50:50, 25:75 and 0:100. Each sample will be denoted as ‘PD’. PD denotes the ratio of the palm oil in the blend. As an example, PD5 denotes that the palm oil is only 5% of the blended volume while the other 95% is diesel. A pure diesel mixture will be used and denoted as PD0 for the purpose of becoming the control experiment sample [1].

The blending of the samples is carried out at room temperature, by adding measured volume of the palm oil into the diesel while being stirred continuously [1]. The blended fuels are then stored in a container located in the fume chamber. Table 5 illustrates the denotation of each blend with its respected volume ratio percentage.

Table 5: Volumetric ratio of Palm oil – diesel blend

| Denotation | Palm Oil | Diesel |
|---|---|---|
| PD0 | 0% | 100% |
| PD25 | 25% | 75% |
| PD50 | 50% | 50% |
| PD75 | 75% | 25% |
| PD100 | 100% | 0% |

Figure 2 shows the Crude Palm Oil in its original state and form, filtered from any particulates. Apparently, crude palm oil solidifies under room temperature, the oil gained for this project was gained by letting the fresh oil settled down and the solidified particulates goes down to become sediment. The pure liquid top layer of the oil was then scooped and filtered to ensure good quality of oil.

Figure 2: Crude Palm Oil

Figure 3 illustrates the blending product of 25% Crude Palm Oil with 75% diesel fuel denoted as PD25. With a volume of 400 ml as the targeted sampling volume, 100 ml of crude palm oil was blended with 300 ml of diesel to produce PD25.

Figure 3: PD25 Blend

Figure 4 illustrates the blending product of 50% Crude Palm Oil with 50% diesel fuel denoted as PD50. With a volume of 400 ml as the targeted sampling volume, 200 ml of crude palm oil was blended with 200 ml of diesel to produce PD50.


Figure 4: PD50 Blend

Figure 5 illustrates the blending product of 75% Crude Palm Oil with 25% diesel fuel denoted as PD75. With a volume of 400 ml as the targeted sampling volume, 300 ml of crude palm oil was blended with 100 ml of diesel to produce PD50.


Figure 5: PD75 Blend

The density and calorific value of each of these blends are determined using apparatuses explained in the next section.

## 3.4 **Property analysis of blended fuel**

### 3.4.1 Calorific Value

A fuel calorific value determines the total heat released per unit mass of fuel on its complete combustion. Even though cetane numbers determine the combustion performance, calorific value sets the maximum possible output power [2]. The value is important when considering the thermal efficiency of equipment producing power or heat [1].

The calorific value is determined by using a bomb calorimeter according to ASTM D240-92 (Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter) as shown in Figure 6. A weighed sample is burned in the bomb calorimeter under controlled conditions. The combustion heat was computed before, during and after the combustion with proper allowance for thermochemical and heat transfer corrections [1].


Figure 6: UTP’s Bomb Calorimeter Equipment

Before the testing could commence, each of the blends was sampled with a mass around 0.5 g to 1.0 g as the procedure demands the size of sample to be in that range to ensure accurate results. Figure 7 shows the sample preparation with the Bomb Calorimeter sample jig.

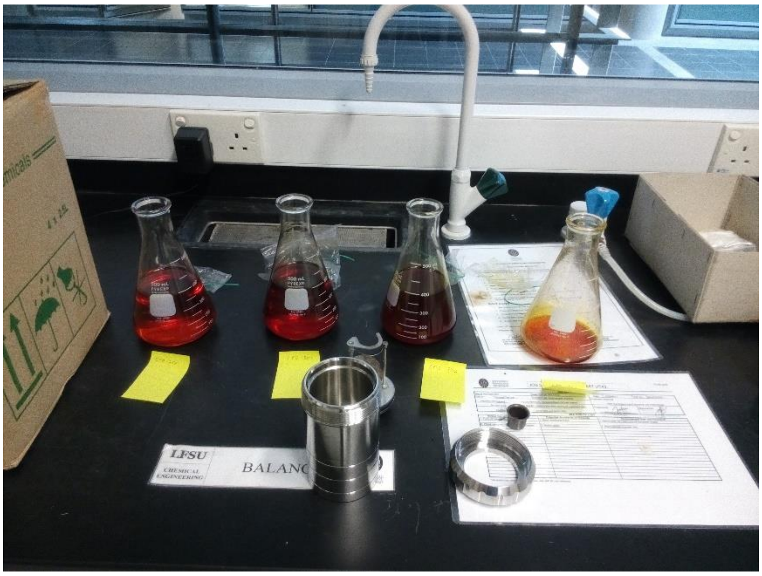


Figure 7: Bomb Caloriemeter testing preparation.

### 3.5 Experiments with Diesel Engine

The emission test is conducted using a direct injection, air cooled, single cylinder 4 stroke Yanmar L70V diesel engine with a displacement of 320cc as shown in figure 8. Having a maximum power of 5.8hp (4.3kW) @ 3600 rpm and a fuel consumption rate of 270 g/kW-hr [9]. The engine emissions are analyzed using exhaust gas analyzer as shown in figure 9. [10]

Figure 8: Yanmar L70V diesel engine on a mounting

Figure 9: Bosch exhaust gas analyzer

### 3.5.1 Experiment procedure

The experiment is kicked off with engine performance testing by using the pure diesel fuel as the control experiment before using the blended fuels. The procedure of the experiment is as follows;

Warm up the engine for about 15 minutes to prep the engine, cooling system and lubrication systems before testing. Make sure the lubricant is at optimum condition to make sure peak engine performance [10].

↓

Set the maximum rotational speed (rpm) of the engine. This is to maintain air fuel ratio at each engine speed for each blend

↓

The toxic gas emissions must be monitored at each blend. 40 readings were taken for each run.

↓

Proceed with testing the other blended fuel ratio. Make sure the remaining fuel is completely drained and emptied from the engine before the new batch of fuel is poured in.

↓

Tabulate the data accordingly.

Figure 10: Experiment procedure

## 3.6 Gantt Chart and Key Milestones

The time flow is represented as Gantt charts in Table 6 for FYP1 and Table 7 for FYP 2.

Table 6: FYP 1 Gantt Chart

| No | Week / Details | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FYP1 | | | | | | | | | | | | | | | |
| 1 | Selection of Project title | | | | | | | | | | | | | | |
| 2 | Consultation with Supervisor | | | | | | | | | | | | | | |
| 3 | Preliminary Research works and Literature Review | | | | | | | | | | | | | | |
| 4 | Submission of Extended Proposal | | | | | | | | | | | | | | |
| 5 | Preparation for Oral Proposal Defence | | | | | | | | | | | | | | |
| 6 | Oral Proposal Defence Presentation | | | | | | | | | | | | | | |
| 7 | Continuation of Project Work | | | | | | | | | | | | | | |
| 8 | Preparation of Interim Report | | | | | | | | | | | | | | |
| 9 | Submission of interim Draft Report | | | | | | | | | | | | | | |
| 10 | Submission of Interim Final Report | | | | | | | | | | | | | | |

Table 7: FYP2 Gantt chart

| No | Week / Details | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FYP 2 | | | | | | | | | | | | | | | |
| 1 | Consultation with Supervisor | | | | | | | | | | | | | | |
| 2 | Preparation of Progress Report | | | | | | | | | | | | | | |
| 3 | Pre-SEDEX | | | | | | | | | | | | | | |
| 4 | Preparation of Draft Final Report | | | | | | | | | | | | | | |
| 5 | Preparation of Dissertation (Soft Bound) | | | | | | | | | | | | | | |
| 6 | Preparation of Technical Paper | | | | | | | | | | | | | | |
| 7 | Viva | | | | | | | | | | | | | | |
| 8 | Preparation of Project Dissertation (Hard Bound) | | | | | | | | | | | | | | |

| Legends | |
|---|---|
| | Gantt chart |
| | Key Milestone |

Table 8: Gant chart Legends

# CHAPTER 4

# RESULTS

## 4.1 Calorific Value, Density and Viscosity of Blended Fuel

The calorific value of each blend was obtained after running an experiment with the bomb calorimeter as stated in table 9 and as shown in figure 11.

Table 9: Calorific value of blended fuels

| Denotation | Palm Oil | Diesel | Calorific Value |
|---|---|---|---|
| PD 0 | 0% | 100% | 44800 J/g |
| PD 25 | 25% | 75% | 43667 J/g |
| PD 50 | 50% | 50% | 42328 J/g |
| PD 75 | 75% | 25% | 40942 J/g |
| PD 100 | 100% | 0% | 39590 J/g |

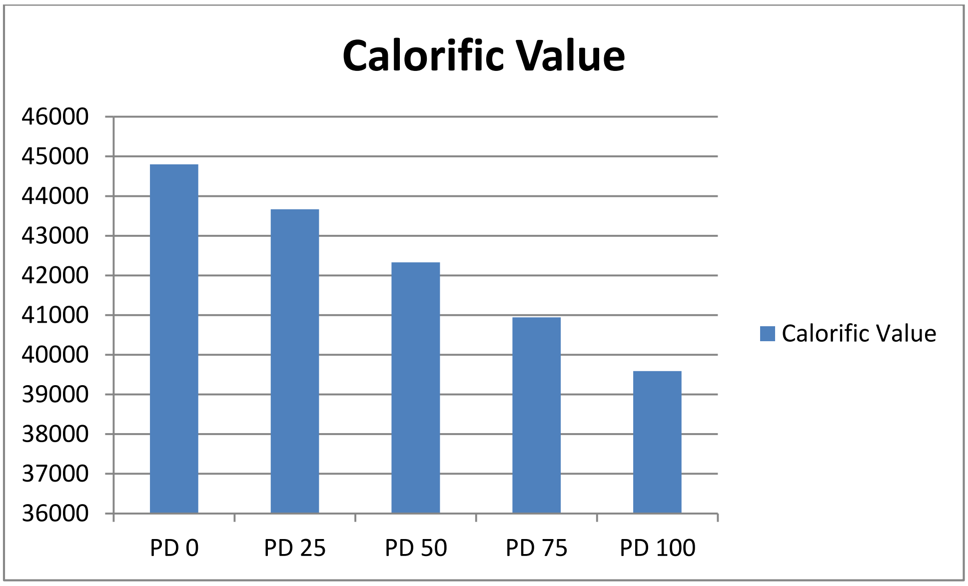


Figure 11: Calorific Value bar Chart

From figure 11, the graph shows a steady decline of calorific value from PD 0 onwards in a linear line. With the highest calorific value of 44800 J/g for PD 0 and lowest of 39590 J/g for PD 100, the difference is only 5210 J/g between them. It shows, even with 100% increment of crude palm oil into diesel blend, the calorific value decreases only 11.63% from the highest calorific value.

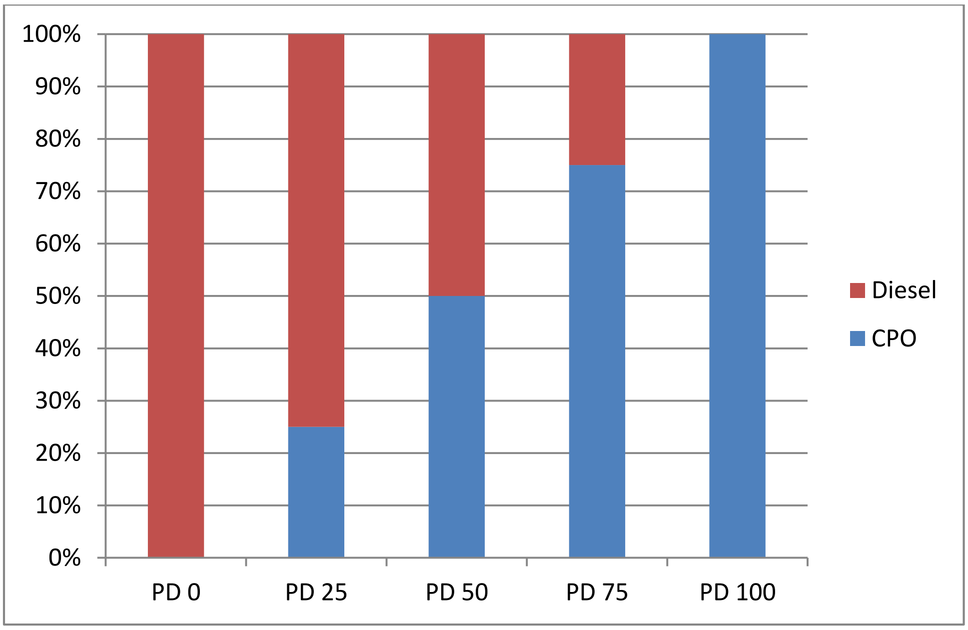


Figure 12: Blending percentage chart

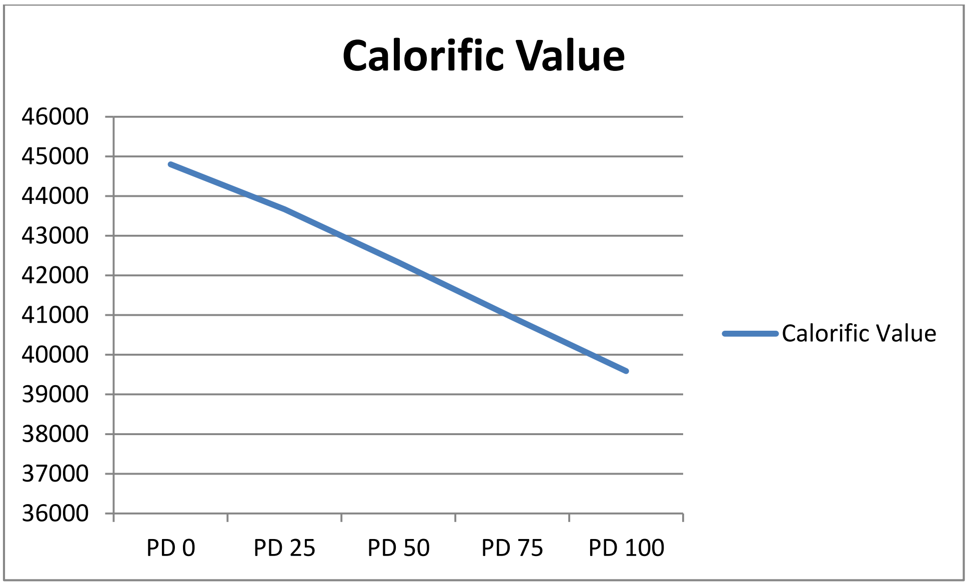


Figure 13: Calorific value Line graph

Figure 12 show the blending percentage illustrated by the graph. Each blend has an increment of 25% crude palm oil to diesel blend composition. Figure 13 shows the line graph of the calorific value with a decrement gradient of 52.1 from PD 0. Although the calorific value doesn't differ too much, the viscosity and volatility changes significantly and play a more important role in internal combustion engines.

Table 10: Density of blends

| Denotation | Density (kg/m$^3$) |
|---|---|
| PD 0 | 833.00 |
| PD 25 | 846.63 |
| PD 50 | 860.25 |
| PD 75 | 873.88 |
| PD 100 | 887.50 |

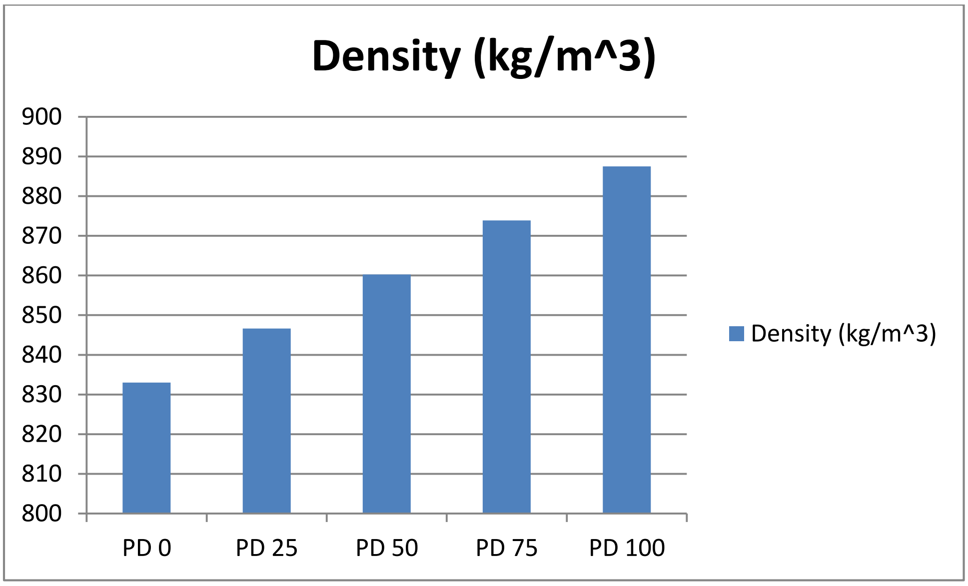


Figure 14: Fuel blend density chart

From figure 14, we can see that the density increases with each blend, thus meaning that the density increases linearly with every increment of percentage of palm oil to diesel. PD 100 exhibits the highest density of 887.5 kg/m$^3$ and PD 0 being the lowest with the value of 833.0 kg/m$^3$.

4.2 Emissions from the diesel engine

After running the experiments with the Yanmar L70 diesel engine while using the Bosch gas analyzer, the readings were obtained as shown in figures 15, 16 and 17 for PD 0, PD 25 and PD 50 respectively. Only three blends were able to be used on the engine because the diesel engine could not even start when using PD 75. In order to avoid further damage to the internal components of the engine, blends PD 75 and PD 100 were not experimented upon. The readings taken were calculated and tabulated as an average as shown in table 11.

Table 11: Averaged emission readings

| **Blend** | **Avg CO % volume** | **Avg HC concentration (ppmvol)** | **Avg CO2 % volume** | **Avg O2 % volume** | **Avg NO concentration (ppmvol)** |
|---|---|---|---|---|---|
| **PD 0** | 5.525 x 10^-3 | 0.275 | 0.176 | 20.802 | 1.850 |
| **PD 25** | 5.375 x 10^-3 | 0.450 | 0.075 | 20.483 | 1.100 |
| **PD 50** | 4.625 x 10^-3 | -1.200 | 0.052 | 21.143 | 2.175 |

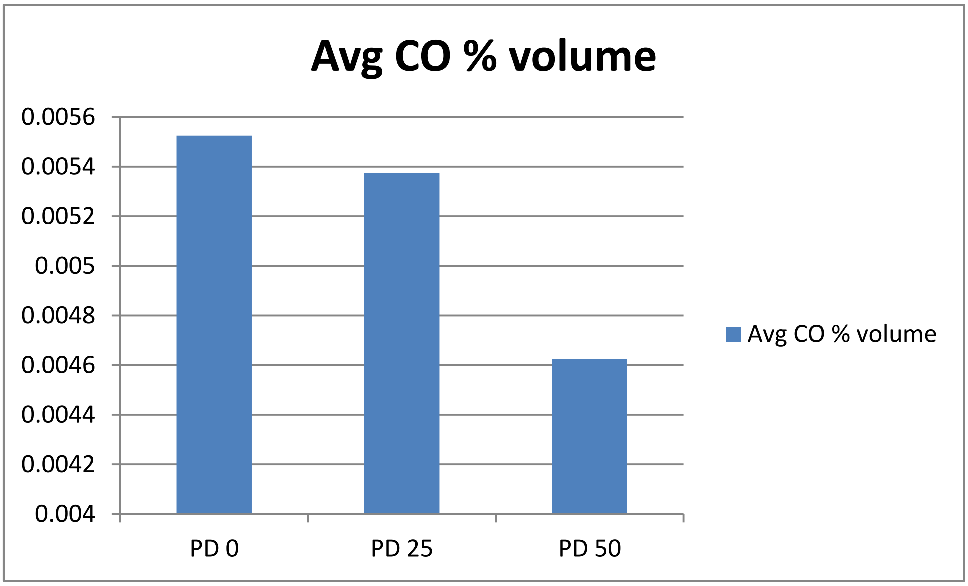


Figure 15: Average Carbon Monoxide volume percentage chart

From the figure 15, we can see that the percentage of carbon monoxide emission reduces with each blend used. With PD 50 emits the least carbon monoxide emission of 0.004625 % per volume of air.

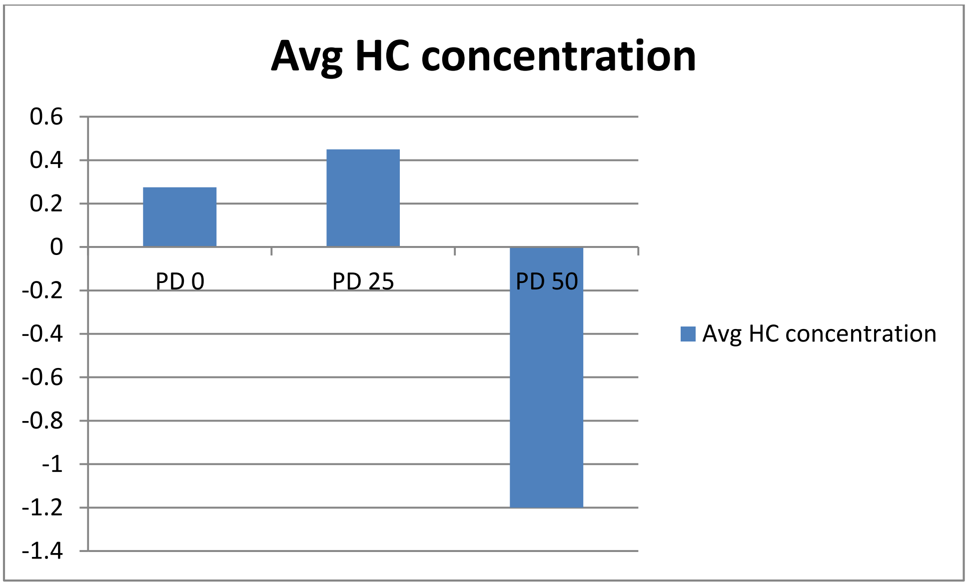


Figure 16: Average hydrocarbon concentration chart

In figure 16, the average hydrocarbon concentration shows an increasing pattern from PD 0, 0.275 ppmvol to PD 25, 0.450 ppmvol, but a negative value in PD 50's reading which shows -1.200 ppmvol. This is likely due to miss readings from the equipment as all the readings for PD 50 were negative. The other factor might as well be from the inconsistency of the engine combustion, thus the readings were misled.

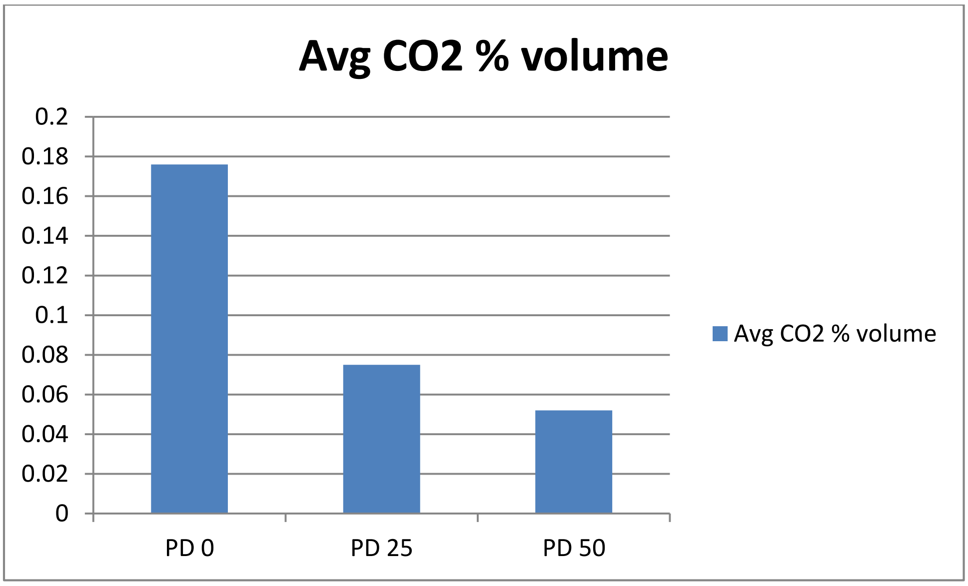


Figure 17: Average Carbon Dioxide volume percentage chart

The average carbon dioxide volume percentage from figure 17 shows an exponential decrease from PD 0 to PD 50. With PD 0 having the highest carbon dioxide emission and PD 50 having the least, indicates that the fuel blend either have lesser CO2 content or the fuels did not combust completely.

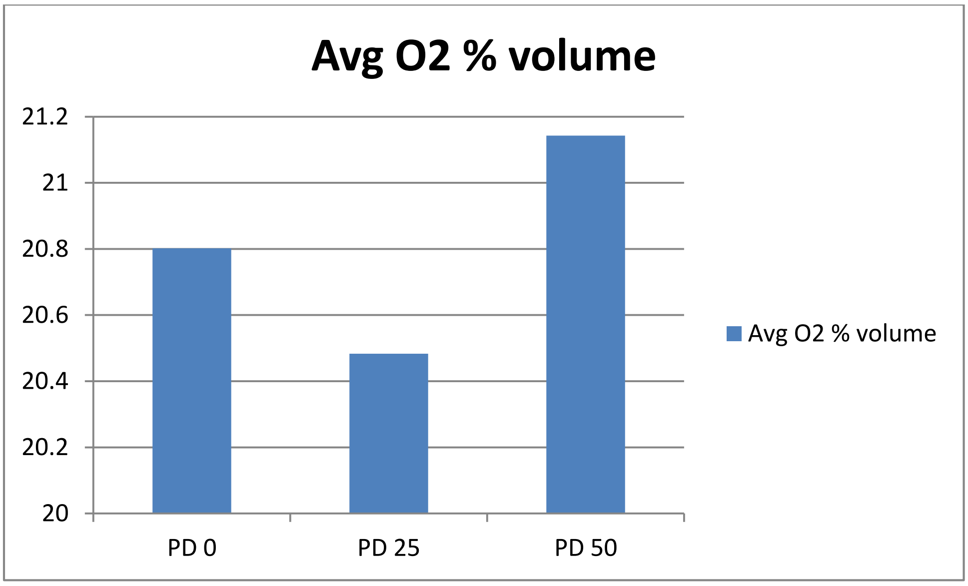


Figure 18: Average Oxygen volume percentage chart

Figure 18 illustrates the average oxygen volume percentage content in the air. The readings show an inconsistency pattern from PD 0 to PD 50. From PD 0 to PD 25, a decrease in oxygen content can be seen but increases 20.483% to 21.143% when PD 25 was changed to PD 50.

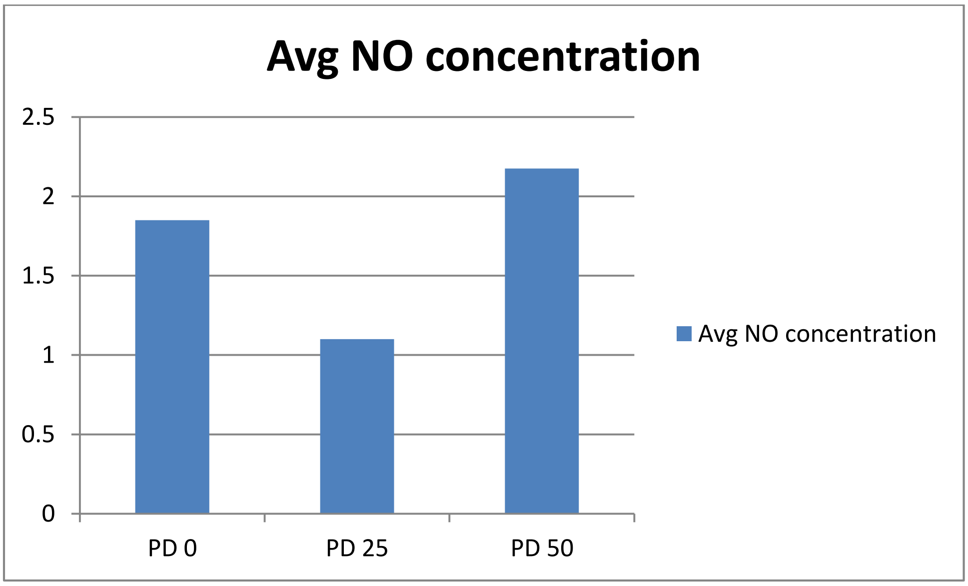


Figure 19: Average Nitrogen Oxide concentration chart

Similar to the pattern of figure 18, figure 19 exhibits an irregular pattern in the average nitric oxide concentration. From PD 0 to PD25, the concentration decreases from 1.850 ppmvol to 1.100 ppmvol. However, from PD 25 to PD 50, the NO concentration increases substantially from 1.100 ppmvol to 2.175 ppmvol. According to the literature review, the NO concentration should decreases with each higher palm oil blend.

Apparently there is a fatal flaw with the experiment conducted n this project. The diesel engine was not connected to any load during experimentation, thus making the results actually being very inaccurate. That is the main reason of the result’s values being so small compared to existing emission data. With the engine in constant free load, the fuel consumption were very low, thus emissions were low as well.

From observing the engine behaviour, when using PD 0 as the control experiment, the engine was running smooth emitting almost no smoke from the exhaust. However, the behaviour changes from smooth running to violent vibrations when PD 25 fuel blend was used. Smoke was sometimes seen coming out from the exhaust indicated there was incomplete combustion but the engine kept running without stalling. Only when PD 50 fuel blend was used that the engine vibrated even more violently and the engine speed was very inconsistent while emitting plenty of smoke from the exhaust. With the engine stalling occasionally by using PD 50 fuel blend, the readings were hard to acquire as the engine can keep running only a few seconds at a time. Hence, the emission data acquired from using PD 50 was not accurate and consistent due to rushed data procurement and emission inconsistency. From the observation of running the engine with PD 50, the experiment for PD 75 fuel blend was not continued in fear of permanently damaging the diesel engine.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

The direct blending of crude palm oil and diesel fuel produces a mixture of biodiesel which have a high calorific of 43667 J/g at 25% crude palm oil mixed into diesel. With each increment of 25% crude palm oil, the calorific values decreases to 42328 J/g, 40942 J/g and 39590 J/g for PD 50, PD 75 and PD 100 respectively. Although the viscosity increases for each increment of blending percentage, the viscosity can be reduced back by preheating the blend prior to engine testing.

When applied to the diesel engine, only PD 0, PD 25 and PD 50 blends were able to start the engine. PD 25 shows lesser emission for carbon monoxide, nitric oxide and carbon dioxide, while the hydrocarbon content is slightly higher compared to the control, PD 0. However, by using PD 50 fuel blend, the emission shows inconsistency readings with a decreased carbon monoxide and carbon dioxide emissions while nitric oxide concentrations increased as compared to PD 0. The reasons for the inconsistency may due to the incomplete combustions occurred in the engine, thus emitting inconsistent emission.

## 5.2 Recommendation

Throughout the project span, there are difficulties and limitations occurred and a few improvised planning are recommended by me. The first would be using a proper fuel mixer to blend the fuels together in order to obtain the most accurate blend mixture. Proper blending will ensure the composition of the solution is properly mixed thus eliminating imbalance mixtures.

Second, the diesel engine should be configured properly in order to easily operate it during experimentation like adding an ignition starter and attaching it to a dynamometer. These additions will help starting the engine easier and controlling the speed better with maximum load applied to it, thus the readings obtained will be accurate.

# CHAPTER 6

## References


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# APPENDICCES

**Bosch diagnosis gas values**

| Rpm rpm | Oil temp. | CO %vol | COc 2S %vol | COc 4S %vol | HC ppmvol | CO2 %vol | O2 %vol | Lambda | NO ppmvol |
|---|---|---|---|---|---|---|---|---|---|
| 0 | — | 0,005 | — | — | 0 | 0,15 | 20,80 | — | 3 |
| 0 | — | 0.005 | — | — | 0 | 0.15 | 20.80 | — | 3 |
| 0 | — | 0,005 | — | — | 0 | 0,15 | 20,80 | — | 3 |
| 0 | — | 0,005 | — | — | 0 | 0,15 | 20,80 | — | 3 |
| 0 | — | 0,005 | — | — | 0 | 0,15 | 20,79 | — | 2 |
| 0 | — | 0.005 | — | — | 0 | 0.15 | 20.78 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0,15 | 20,78 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0,15 | 20,78 | — | 2 |
| 0 | — | 0.005 | — | — | 0 | 0.15 | 20.78 | — | 2 |
| 0 | — | 0,006 | — | — | 1 | 0,15 | 20,79 | — | 2 |
| 0 | — | 0,006 | — | — | 1 | 0,15 | 20,79 | — | 2 |
| 0 | — | 0.006 | — | — | 1 | 0.15 | 20.79 | — | 0 |
| 0 | — | 0,006 | — | — | 1 | 0,15 | 20,79 | — | 0 |
| 0 | — | 0,006 | — | — | 1 | 0,15 | 20,79 | — | 0 |
| 0 | — | 0,006 | — | — | 1 | 0,15 | 20,79 | — | 1 |
| 0 | — | 0.006 | — | — | 1 | 0.16 | 20.79 | — | 0 |
| 0 | — | 0,006 | — | — | 1 | 0,16 | 20,79 | — | 0 |
| 0 | — | 0.006 |  | — | 1 | 0.16 | 20.79 | — | 0 |
| 0 | — | 0,006 | — | — | 1 | 0,16 | 20,79 | — | 0 |
| 0 | — | 0,006 | — | — | 1 | 0,16 | 20,78 | — | 1 |
| 0 | — | 0,006 | — | — | 0 | 0,16 | 20,80 | — | 3 |
| 0 | — | 0.006 | — | — | 0 | 0.16 | 20.80 | — | 3 |
| 0 | — | 0,006 | — | — | 0 | 0,16 | 20,80 | — | 3 |
| 0 | — | 0,006 | — | — | 0 | 0,16 | 20,80 | — | 3 |
| 0 | — | 0,006 | — | — | 0 | 0.16 | 20.82 | — | 3 |
| 0 | — | 0,006 | — | — | 0 | 0,16 | 20,82 | — | 3 |
| 0 | — | 0,006 | — | — | 0 | 0,16 | 20,83 | — | 2 |
| 0 | — | 0.006 | — | — | 0 | 0.16 | 20.83 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,16 | 20,83 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,16 | 20,83 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0,16 | 20,81 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0.16 | 20.81 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0,16 | 20,81 | — | 2 |
| 0 | — | 0.005 | — | — | 0 | 0.16 | 20.81 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0,16 | 20,81 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0,16 | 20,81 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0,16 | 20,81 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0.16 | 20.82 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0,16 | 20,82 | — | 2 |
| 0 | — | 0,005 | — | — | 0 | 0,16 | 20,82 | — | 2 |

Figure 20: PD 0 emission readings

**Bosch diagnosis gas values**

| Rpm rpm | Oil temp. | CO %vol | COc 2S %vol | COc 4S %vol | HC ppmvol | CO2 %vol | O2 %vol | Lambda | NO ppmvol |
|---|---|---|---|---|---|---|---|---|---|
| 0 | — | 0,005 | — | — | 1 | 0,07 | 20,97 | — | 1 |
| 0 | — | 0.005 | — | — | 1 | 0.07 | 20.97 | — | 1 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,01 | — | 1 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,01 | — | 1 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,01 | — | 1 |
| 0 | — | 0,005 | — | — | 1 | 0.07 | 21.01 | — | 1 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,01 | — | 1 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,03 | — | 0 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,03 | — | 0 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,03 | — | 0 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,04 | — | 0 |
| 0 | — | 0.005 | — | — | 1 | 0.07 | 21.04 | — | 0 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,05 | — | 2 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,05 | — | 2 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,05 | — | 2 |
| 0 | — | 0,005 | — | — | 1 | 0.07 | 21,05 | — | 2 |
| 0 | — | 0,005 | — | — | 1 | 0,07 | 21,03 | — | 1 |
| 0 | — | 0.005 | | — | 1 | 0.07 | 21.03 | — | 1 |
| 0 | — | 0,005 | — | — | 0 | 0,07 | 21,02 | — | 0 |
| 0 | — | 0,005 | — | — | 0 | 0,07 | 21,02 | — | 0 |
| 0 | — | 0,005 | — | — | 0 | 0,07 | 21,02 | — | 0 |
| 0 | — | 0,005 | — | — | 0 | 0,08 | 20,95 | — | 1 |
| 0 | — | 0,005 | — | — | 0 | 0,08 | 20,95 | — | 1 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 20,92 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 20,92 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 20,92 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 21,00 | — | 1 |
| 0 | — | 0.006 | — | — | 0 | 0.08 | 21.00 | — | 1 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 20,95 | — | 1 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 20,95 | — | 1 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 20,95 | — | 1 |
| 0 | — | 0.006 | — | — | 0 | 0.08 | 20.95 | — | 1 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 20,96 | — | -1 |
| 0 | — | 0.006 | — | — | 0 | 0.08 | 21.04 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 21,04 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 21,04 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 21,04 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 21,04 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,09 | 21,08 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,09 | 21,08 | — | 2 |

Figure 21: PD 25 emission readings

**Bosch diagnosis gas values**

| Rpm rpm | Oil temp. | CO %vol | COc 2S %vol | COc 4S %vol | HC ppmvol | CO2 %vol | O2 %vol | Lambda | NO ppmvol |
|---|---|---|---|---|---|---|---|---|---|
| 0 | — | 0,006 | — | — | 0 | 0,08 | 21,04 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 21,04 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,08 | 21,04 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,09 | 21,08 | — | 2 |
| 0 | — | 0,006 | — | — | 0 | 0,09 | 21,08 | — | 2 |
| 0 | — | 0,002 | — | — | -3 | 0,03 | 21,16 | — | 2 |
| 0 | — | 0,002 | — | — | -3 | 0,03 | 21,16 | — | 2 |
| 0 | — | 0,003 | — | — | -3 | 0,03 | 21,16 | — | 3 |
| 0 | — | 0,003 | — | — | -3 | 0,03 | 21,16 | — | 3 |
| 0 | — | 0,003 | — | — | -2 | 0,04 | 21,14 | — | 1 |
| 0 | — | 0,003 | — | — | -2 | 0,04 | 21,14 | — | 1 |
| 0 | — | 0,003 | — | — | -2 | 0,04 | 21,14 | — | 1 |
| 0 | — | 0,003 | — | — | -2 | 0,04 | 21,14 | — | 1 |
| 0 | — | 0,003 | — | — | -2 | 0,04 | 21,14 | — | 1 |
| 0 | — | 0,003 | — | — | -2 | 0,04 | 21,14 | — | 1 |
| 0 | — | 0,003 | — | — | -2 | 0,04 | 21,14 | — | 1 |
| 0 | — | 0,003 | — | — | -2 | 0,04 | 21,14 | — | 1 |
| 0 | — | 0,004 | | — | -2 | 0,04 | 21,14 | — | 2 |
| 0 | — | 0,004 | — | — | -2 | 0,04 | 21,14 | — | 2 |
| 0 | — | 0,004 | — | — | -2 | 0,04 | 21,14 | — | 2 |
| 0 | — | 0,004 | — | — | -2 | 0,05 | 21,19 | — | 2 |
| 0 | — | 0,004 | — | — | -2 | 0,05 | 21,19 | — | 2 |
| 0 | — | 0,005 | — | — | -2 | 0,05 | 21,16 | — | 3 |
| 0 | — | 0,005 | — | — | -2 | 0,05 | 21,16 | — | 3 |
| 0 | — | 0,005 | — | — | -2 | 0,05 | 21,16 | — | 3 |
| 0 | — | 0,005 | — | — | -2 | 0,05 | 21,16 | — | 3 |
| 0 | — | 0,005 | — | — | -2 | 0,05 | 21,16 | — | 3 |
| 0 | — | 0,005 | — | — | -1 | 0,05 | 21,16 | — | 4 |
| 0 | — | 0,005 | — | — | -1 | 0,05 | 21,16 | — | 4 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,16 | — | 3 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,16 | — | 3 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,16 | — | 3 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,16 | — | 3 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,15 | — | 1 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,15 | — | 1 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,16 | — | 0 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,16 | — | 0 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,16 | — | 0 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,16 | — | 0 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,18 | — | 4 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,18 | — | 4 |
| 0 | — | 0,006 | — | — | -1 | 0,06 | 21,18 | — | 4 |
| 0 | — | 0,006 | — | — | -1 | 0,07 | 21,14 | — | 3 |
| 0 | — | 0,006 | — | — | -1 | 0,07 | 21,14 | — | 3 |
| 0 | — | 0,006 | — | — | -1 | 0,07 | 21,14 | — | 3 |

Figure 22: PD 50 emission readings