ANALYSIS OF DIESEL PARTICULATE MATTER ON SINGLE CYLINDER DIESEL ENGINE USING WASTE PLASTIC FUEL

MOHD RADZI B MOHD RASOL

Report submitted in partial fulfillment of the requirements
for the award of Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

UNIVERSITI MALAYSIA PAHANG

FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled “Analysis of Diesel Particulate Matter on Single Cylinder Diesel Engine using Waste Plastic Fuel” is written by Mohd Radzi B Mohd Rasol I have examined the final copy of this project and in my opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering With Automotive Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering. Bachelor of Engineering With Automotive Engineering.

MR. IDRIS B MAT SAHAT

Examiner Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive.

Signature
Name of Supervisor: DR.AGUNG SUDRAJAD
Position: SENIOR LECTURER
Date:18th JUNE 2012

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

Signature

Name: MOHD RADZI B MOHD RASOL

ID Number: MH09102

Date: 18th JUNE 2012

DEDICATION

I specially dedicate to my beloved parents
Mohd Rasol B Masrun and Noormah BTE Ma'on
and also those who have guided
and motivated me for this project

ACKNOWLEDGEMENT

I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. I would like to extend my sincere thanks to all of them.I am highly indebted to my supervisor project Dr Agung Sudrajad for their guidance and constant supervision as well as for providing necessary information regarding the project and also for their support in completing the project.

I would like to express my gratitude towards my parents & my team mate project under supervisor Dr Agung for their kind co-operation and encouragement which help me in completion of this project. I would like to express my special gratitude and thanks to lab staff for giving me such attention and time. Also give a hand during do a project my thanks and appreciations also to my colleague in developing the project and people who have willingly helped me out with their abilities.

ABSTRACT

This study deals with the size diameter and concentration distribution of particulate matter (PM) using single cylinder engine diesel using waste plastic disposal fuel. The experiment was devided by two. First experiment is to determine fuel characteristic and the second experiment to analyzed the size diameter and distribution of PM. The characteristic fuel is for determine affect to size diameter and concentration distribution for both fuel. For the experiment size diameter and concentration distribution of PM both fuel be test in 5 different speed which is 1200 rpm,1500 rpm, 1800 rpm, 2100 rpm and 2400 rpm. From the experiment, the result be determine is concentration of PM, dry soot(DS), soluble organic fraction (SOF) and size diameter. All the result can obtained by the calculation and analysis. The end of this analyis show the waste plastic disposal fuel is better than diesel in term produce of gas emission . where the result show waste plastic disposal fuel produce less PM ,NO_x, NO, CO_2, CO and O. While result for distribution of size diameter PM, waste plastic produce less PM with diameter below 100 nm than diesel fuel.

ABSTRAK

Kajian ini berkaitan dengan diameter dan pengagihan taburan bahan zarahan (PM) dengan menggunakan enjin diesel satu silinder menggunakan sisa plastik pelupusan bahan api. Eksperimen itu dibahagikan kepada dua eksperimen. Eksperimen pertama adalah untuk menentukan ciri-ciri bahan api dan eksperimen kedua untuk menganalisis saiz diameter dan taburan PM. Bahan api ciri adalah untuk menentukan memberi kesan kepada saiz diameter dan taburan kepekatan bagi kedua-dua bahan api. Untuk saiz diameter eksperimen dan pengagihan kepekatan PM kedua-dua bahan api akan diuji dalam 5 kelajuan yang berbeza iaitu 1200 rpm, 1500 rpm, 1800 rpm, 2100 rpm dan 2400 ppm. Daripada ujikaji tersebut, hasil akan menentukan kepekatan PM, jelaga kering (DS), pecahan organik larut (SOF) dan saiz diameter. Semua keputusan boleh diperolehi dengan menggunakan pengiraan formula dan akhir analisis ini menunjukkan minyak sisa pelupusan plastik adalah lebih baik daripada diesel dalam segi pelepasan bahan gas. Di mana menunjukkan hasil pembuangan sisa bahan api plastik menghasilkan kurang PM, NOx, NO, CO2, CO dan O. Manakala bagi pengedaran hasil PM saiz diameter, plastik sisa menghasilkan PM kurang dengan diameter di bawah 100 nm daripada bahan api diesel.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

°C	Degree Celsius
%	Percentage
Σ	Total sum
n_p	Number of particle
A_a	Cohesion are projection
A_p	Cohesion one ball dust
V_a	Volume
π	Pi
K_v	Factor the number of diameter to calculate fusion volume collection
$\overline{D_A}$	Arithmetic Mean Diameter
$\overline{Dg}$	Geometric Mean Diameter or Logarithmic Mean Diameter
$\overline{Dv}$	Volume Mean Diameter

LIST OF ABBREVIATIONS

PM	Particulate Matter
WPD	Waste plastic disposal Fuel
CO	Carbon monoxide
CO_2	Carbon monoxide
NO	Nitrogen monoxide
DI	Diect injection
DS	Dry soot
SOF	Soluble organic fraction
RPM	Revolution per minute
DPM	Diesel particulate matter
WPPM	Waste plastic particulate matter
CI	Compression ignition
SI	Spark ignition
EC	Element carbon
TDC	Top dead center
BDC	Bottom dead center
PAHs	Polycyclic aromatic hydrocarbons

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Today, solid waste management is a critical national issues. One of the issues regarding landsfills in malaysia is an abbreviate life span due to intesifying amount of the solid waste generation and human populationas well other concerns about environmental and public health as consequences of inefficeint waste management which result to fly production, odour, leachete and other posible negative effects.

On an average per person generation of solid waste is 1 kilogram per day in Malaysia - approximately 26 million people in the country produce 26 million kilograms of solid waste every single day. Over 180 landfill sites are located in the Peninsula alone with 50 percent being open dumping grounds. Composition for solid waste management for Kuala Lumpur at residential area in 2002 shown food waste is the bigger the most waste produce with 63.1%, follow by plastic with 14.3%, third mix papers 6.7%, yard waste 6.3%, others 2.8%, ferrous 2.3%, glass 2.1%, textiles 1.7%, rubber & leather 0.6 and last aluminum 2.8%. (Source: Nazeri 2002)

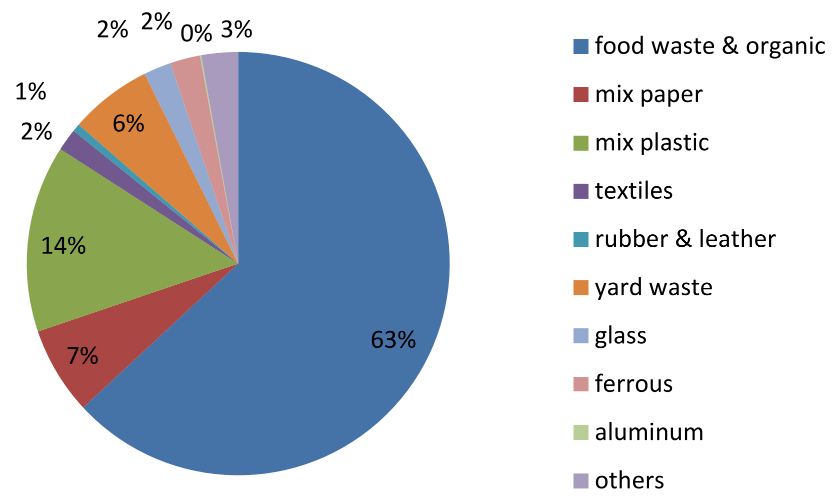


Figure 1.1: Pie chart for composition of solid waste management in malaysia 2005

Source: Nazeri 2002

Plastic is non biodegradable product or waste. So the alternative to reduce for the waste of the plastic, the engineer found the solution to convert the plastic become fuel. In the same time it can be addition new choices for source energy. A few research proves that plastic fuel can generated combustion in engine but still below performance than diesel.

Beside waste plastic problem, Malaysia also has problem about air pollution. Malaysia department of environment by according to 2000 data, about 29 percent of the population used solid or biomass fuels for their cooking and heating needs. Only 11 percent of the vehicles still use diesel while 89 percent have been using unleaded gasoline. Emissions from mobile and stationary sources are the most significant sources of pollution. Emissions from mobile sources contribute 80.4 percent of the total load, followed by emissions from stationary sources such as industrial fuel consumption (9 percent), industrial processes (1.2 percent), power stations (8.8 percent), domestic fuel (0.2 percent) and open burning at solid waste dumping sites (0.4 percent). (Source: World Health Organization 2005)

The air quality in Malaysia is reported as the Air Pollution Index (API). PM_{10} particulate matteris reported in µg/m^3. This scale at table 1.1 shows the health classifications used by the Malaysian government.

Table1.1: API standard for malaysia

API (µg/m^3)	*Air Pollution Level*	*Health Implications*
0 - 25	Low	Not expected.
26 - 50	Medium	Not expected for the general population.
51 - 100	High	Acute health effects are not expected but chronic effects may be observed if one is persistently exposed to such levels.
100 - 200	Very High	People with existing heart or respiratory illnesses may notice mild aggravation of their health conditions. Generally healthy individuals may also notice some discomfort.
201 - 500	Severe	People with existing heart or respiratory illnesses may experience significant aggravation of their symptoms. There may also be widespread symptoms in the healthy population (e.g. eye irritation, wheezing, coughing, phlegm and sore throats).

Source: Air Pollutan Index Management System (2011)

1.2 PROBLEM STATEMENT

Today, mostly vehicle in the world using fossil fuel to generated power for the engine of vehicle. The source of fossil fuel by year consumer for fossil fuel is increase. So, many scientist and engineer still seeking the best solution for replace the fossil fuel as energy. One of the solutions is using waste plastic fuel as replacement for fossil fuel.

In fact, vehicle using petroleum causes bad air quality especially engine using diesel fuel. So to overcome this problem, to find new source energy is needed to be replacing petroleum oil and safe used for people and environment.

1.3 PROJECT OBJECTIVES

The objectives of this project are to analyze diameter and concentration distribution of particulate matter (PM) running on single cylinder diesel engine using waste plastic fuel. This project objective to study the size diameter and concentration Of PM will produce by waste plastic when running in diesel engine. The size diameter and concentration distribution PM be compare to diesel fuel.

1.4 SCOPE OF STUDY

The following scopes of the project are determined in order to achieve the objectives of the project:

a) analysis of fuel characteristic of waste plastic fuel and diesel.
b) measure diameter of DPM and waste plastic particulate matter (WPPM).
c) analysis of size distribution of DPM and WPPM.

1.5 THESIS OVERVIEW

The next chapter will describe in the literature review. The description is about the information related for this study such as about particulate matter, diesel engine and so on, Chapter 3 will tell about methodology for the experiment. This chapter describes the equipment will used for the experiment and procedure for taken data.

Chapter 4 is about result and analysis. The result will be plot in graph. Every graph will be discussed the trend of the graph. Lastly the Chapter 5 is about Conclusion and recommendation for the future experiment. From the data analysis the conclusion can be made and the recommendation is for to improvement the experiment in future.

CHAPTER 2

LITERATURE REVIEW

2.1 DIESEL ENGINE

A diesel engine is a one of internal combustion engines where the products of combustions generated by the combustion of fuel and air within the cylinder form the working fluid. Diesel engine also know as compression ignition engines (CI) is initiated by the heat attained by the high compression of the air charge in the cylinder. CI engines works depend completely on compressing air enough to achieve a temperature capable of igniting the fuel.

2.1.1 Engine Components.

(i) Cylinder Block:

The cylinder block is the main supporting structure for the various components.

(ii) Cylinder:

Cylindrical vessel or space in which the piston makes a reciprocating motion. the varying volume created in the cylinder during the opertaion of the engine is filled with the working fluid for the thermodynamic process. The cylinder support in the cylinder block.

c) Piston:

It is a cylindrical component fitted into the cylinder forming the moving boundry of the combustion system. It forms the first link in transmitting the gas forces to the output.

d) Combustion chamber:

The space enclosed in the upper part of the cylinder, by the cylinder head and the piston top during the combustion process, is called combustion chamber.

e) Inlet manifold:

The pipe which connects the intake system to the inlet valve of the engine and through which air or air-fuel ixture is drawn into the cylinder is called the inlet manifold.

f) Inlet and Exhaust Valves:

Commonly look like mushroom. They are provided either on the cylinder head or on the side of the cylinder for regulating the charge coming into the cylinder (inlet valve) and for discharging the products of combustions (exhaust) from the cylinder.

g) Connecting rod:

It interconnects the pistons and the cranckshaft and transmits the gas forces from piston to crakshafts.

h) Crankshaft:

It converts the reciprocating motion of the piston into useful rotary motion of the output shaft.

i) Camshaft

The camshaft associated parts control the opening and closing inlet and exhaust valve

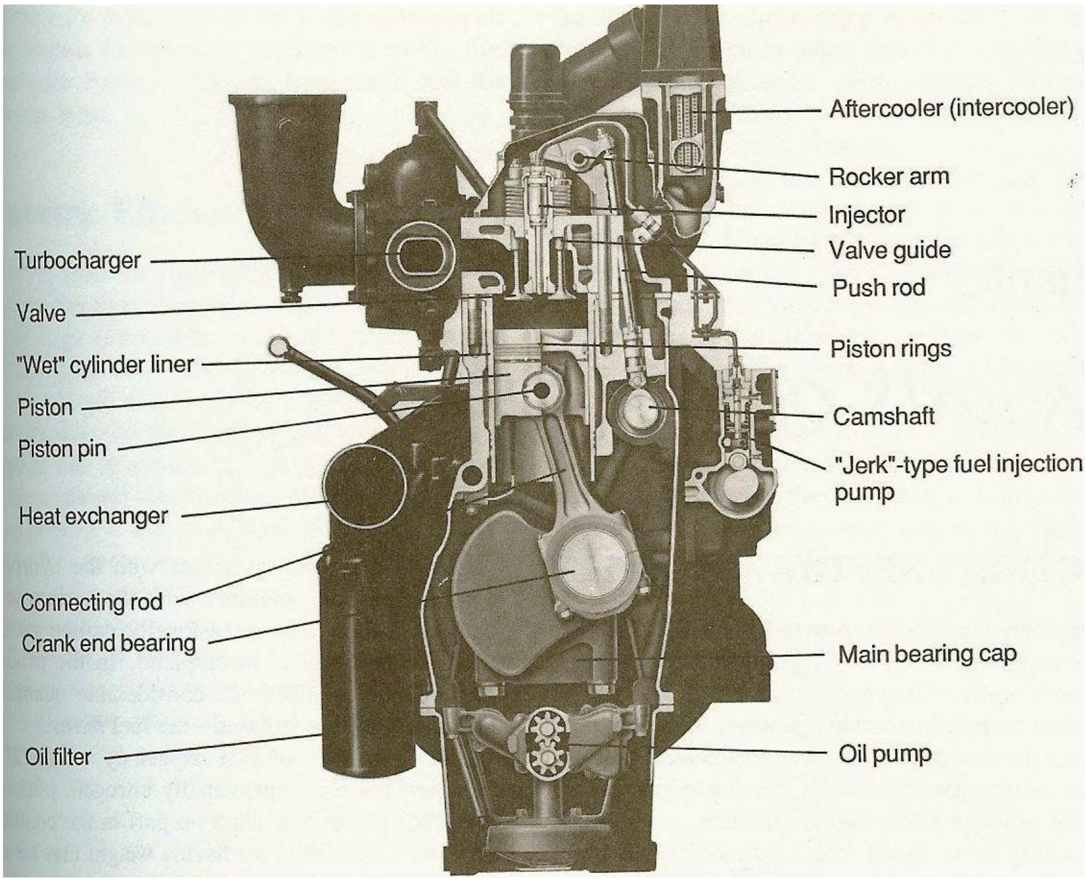


Figure 2.1: Diesel Engine diagram (Courtesy Marine Engine)

Source: Nigel Calders (2010)

j) Cam:

these are made as integral parts of the camshaft and are design in such a way to open the valves at the correct time ing and to keep them open for the necessary duration.

k) Fuel injector:

To spray atomized fuel into the combustion chamber of an internal combustion engine.

2.1.2 Diesel Cycle

Diesel engine or Compression ignition (CI) engine is similar to the Spark ignition (SI) engine except that at high compression ratio is used in the CI engines. The image below how four stroke compression ignition (CI) Engine work.

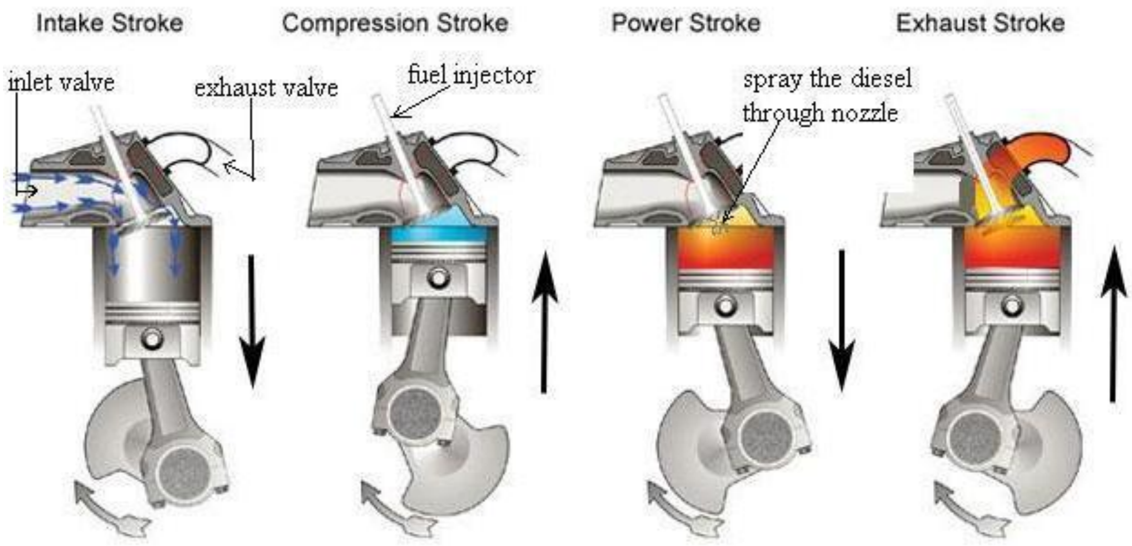


Figure 2.2: Process 4 stroke compression ignition

Source: 4Mechanical.com (2011)

During intake stroke, the inlet valve opens and only the air enters into the cycle as the piston moves from top dead center (TDC) to bottom dead center (BDC). With the inlet and exhaust valves closed, the piston compresses the air. Both the air pressure and temperatures rise. When the piston almost reaches on the TDC, fuel is injected in a finely divided form into the hot swirling air in the combustion space. Ignition occurs after a short delay, the gas pressure rise rapidly and a pressure wave is set up. Work is done by the gas pressure on the piston as the piston sweeps the maximum cylinder volume. During this expansions or power stroke, the temperature and pressure of the burns fall. When the piston approaches the BDC, the exhaust valves opens and the products of combustion are rejected from the cylinder during the exhaust stroke. (source: Ganesan, V. 2008)

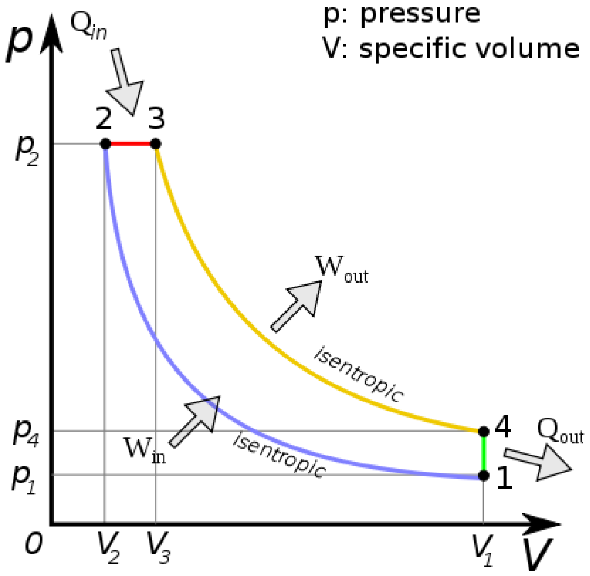


Figure 2.3: Ideal P-V diagram for a four stroke CI engine

Source: Eastop & McConkey (1993)

The Process 1-2 is isentropic compression of the fluid, then the Process 2-3 is reversible constant pressure heating. While Process 3-4 is isentropic expansion and lastly Process 4-1 is reversibleconstant volume cooling. The Diesel is a heat engine it converts heat into work. The isentropic processes are impermeable to heat and heat flows into the loop through the left expanding isobaric process and some of it flows back out through the right depressurizing process, and the heat that remains does the work.

2.2 Particulate Matter

Particulate matters is particle found in the air , including dust, dirt, soot, smoke and liquid droplet. Particle matters can be suspend in the air for the long time periods and some particles are large or dark can be seen as soot and smoke. Some particles matter so small and can be seen by elctron microscope. The particle matter come from variety sources such as cars, trucks, power plants, factories and others use combustion to produce energy.

2.2.1 Diesel Particulate Matters

Bud (2008) stated Diesel particulate matter (DPM) is a complex mixture of elemental carbon (EC) particles, soluble organic carbon, including 5-ring or higher polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene, as well as other metallic compounds. Also, DPM usually contains some small amounts of nitrates, sulfates and sulfuric acid that is created through reaction of sulfates with water molecules present in the air during ignition or after release into ambient air. Also, diesel exhaust contains some trace elements, water and unidentified components. DPM is made up almost entirely of tiny particles below 1-3µ (microns) as well as ultrafine particles that are smaller than 1µ.

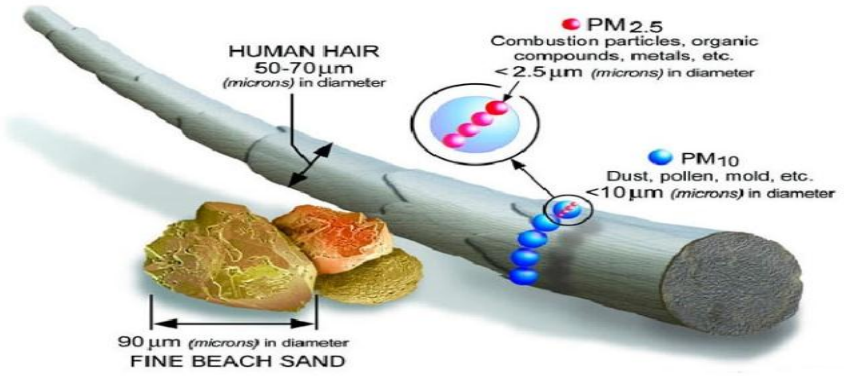


Figure 2.4: DPM next human hair

Source: Lizz Budd (2008)

DPM's danger depends on size of distribution. DPM's with small size inhaled into the deep lung and lower respiratory tract where it can damage lung cells. The small size of DPM also has a large area surface, allowing adsorbing large quantities of ash, organic carbon, organic compounds and sulphates.

2.2.2 Particle Filter Dust Measurement and Data Arrangement

PM can watch under electric microscope particle its to be one groups, the dust which the picture is just one simple particle. The data can be analyze and calculate by using formula.

The formula (Da) to calculate the size of cohesion to desire from particulate matter with electric microscope can use merger cohesion by cohesion by PLANI X-3 to reduce the error its need do it at 4 time to calculate and use the average. The number of particle is n_p with conclude in cohesion and calculate by this formula (source: Medalia – Heckman, 129) :

$$n_p = \left(\frac{Aa}{a_p}\right)^{1.15} \qquad \text{or : } Aa = a_p \cdot n_p^{\ 0.87} \qquad (2.1)$$

Where : A_a is cohesion are projection area.

A_p is only one ball dust area.

Cohesion from V_a (volume) is become:

$$V_a = n_p \left(\frac{\pi . da^3}{6}\right) = \left(\frac{Aa}{Ap}\right)^{1.15} . \frac{\pi . da^3}{6} \qquad (2.2)$$

Diameter for one particle can be calculate with this formula:

$$D_a = da \cdot np^{\frac{1}{3}} = d_a \left(\frac{4.Aa}{\pi . da^2}\right)^{0.383} \qquad (2.3)$$

Where: d_a is the diameter of the dust in cohesion is almost same

$K_v = 1$, where K_v is factor the number of diameter to calculate fusion volume collection between ball dust.

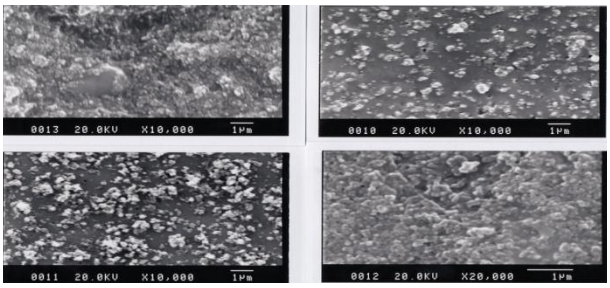


Figure 2.5: Particulate Matter (PM) picture under electric microscope with resolution 50000

Source : Wibawaningrum (2005)

Then, change cohesion can devise some number of cohesion (Na), next calculate all equal value projection area.

After that, calculate all equal value projection area, change cohesion we device some number of cohesion (Na)

$$A_a = \left[\sum_{i=1}^{Na} Aai^{1,15} \right]^{1/1,15} \quad (2.4)$$

Where : A_{ai} is cohesion projection area in inside of change cohesion N_a is number of cohesion

Applicable for equal 1 and 2 and we can calculate equal value (Da) which is like volume of change cohesion. Average diameter of dust at position is Np, diameter (dp) of Np simple dust and Da of Na cohesion or change cohesion.

And N = Na + Np which are simple ball dust, cohesion and change cohesion contain the picture at same point. The average diameter can define by

(i) $\overline{D_A}$ is Arithmetic Mean Diameter

$$\overline{D_A} = \frac{\sum Da + dp}{N} \quad (2.5)$$

(ii) $\overline{Dg}$ = Geometric Mean Diameter or Logarithmic Mean Diameter

$$\overline{Dg} = \exp\left(\frac{\sum \ln Da + \sum \ln dp}{N} \right) \quad (2.6)$$

(iii) $\overline{Dv}$ = Volume Mean Diameter

$$\overline{Dv} = \left(\frac{\sum n_p.d_a{}^3 + \sum d_p{}^3}{\sum n_p + N_p} \right) \quad (2.7)$$

2.2.3 Health Effects of Particulate Matter

EPA (1997) stated The size of particles is directly linked to their potential for causing health problems. Small particles less than10 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream.

Numerous scientific studies have linked particle pollution exposure to a variety of health problems. Wellenius GA (2005) stated *"It appears that air pollution has only a small effect on acute ischemic events of either the heart or brain, but everybody in those cities is exposed. So, while the relative risk may be small, the absolute risk in terms of excess number of strokes can be quite high, especially when you realize that someone in the United States has a stroke every 45 seconds,"* from his statement the particulate has only a small effect to acute ischemic in relative risk but absolute risk it high to someone get a stroke disease.

Particulate matter also can cause increase risk of heart attack in the elderly. Zanobetti etc al (2005) in his research found overall, there was a small association between daily PM10 concentrations and increased risk of hospital admission for heart attack. The risk doubled for those with a previous admission for COPD. The relationship was nearly linear, but risks increased most sharply at daily concentrations less than 50 µg/m3.

Beside this problem EPA (1997) stated a few a health problem cause by particulate matter its including premature death, asthma, chronic bronchitis, decreased lung function and acute respiratory. The most people get risk cause by particulate matter mostly elderly, the lung disease patient and children.

2.2.4 Environments effect of Particulate Matter

EPA (1997) stated that fine particles not only also cause serious health effects but it also major cause of visibility impairment in many parts of the US. Many parts of the US the visual range has been reducing to 70% from natural condition. Fine particles can remain suspended in the air and travel long distances example a puff of exhaust from a diesel truck in Los Angeles can end up over the Grand Canyon, where one-third of the haze comes from Southern California.

Particulate matters also can cause ecosystem damage. Emissions of particulate matter and secondary particle formation caused by oxidation of sulfur dioxide, nitrogen dioxide and aerosol organic carbon species contribute to overall levels of airborne particles. Pollutant concentration, particle size, and chemical composition to determine the relative roles these factors play in contributing to materials damage. In urban environments this greatly affects many construction materials and paints, while its effects in agricultural and natural ecosystems range.

Beside that, particulate can effects ozone damage. Motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents are some of the major sources of NOx and Volatile Organic Compounds (VOC), also known as ozone precursors, and significant components of fine PM. Nitrogen oxides and VOC are the primary precursors of trophospheric ozone. As a result of oxidation reactions in the atmosphere, these compounds form ozone. These same oxidation reactions convert sulfur oxides and nitrogen dioxides to their sulfate and nitrate forms, leading to acid deposition.

2.3 WASTE PLASTIC FUEL

2.3.1 Waste Plastic Disposal

Plastic are non bidegradable polymers mostly containing carbon, hydrogen and few other elements like nitrogen. The plastic waste contribute significantly to the problem of waste management. M.Mani (2009) stated today about 129 million tonnes of plastic are produced annually all over the world, out of wich 77million tonnes are produce from petroleum.Most of these plastic come from from packaging and food industries.

2.3.2 Waste Plastic fuel

Plastic are produced from petroleum derivates and composed primarily of hydrocarbons but also contain additives such as antioxidants, colorants and other stabilizers. Waste plastic oil is a mixture C_{10} to C_{30} and Mani, M. (2009) stated waste plastic oil has high calorific value but still below than diesel. The waste plastic can produce with process called catalytic pyrolysis to efficiently convert plastics to crude oil. The system provides an integrated plastic waste processing system which offers an alternative to landfill disposal, incineration, and recycling. While also being a viable, economical, and environmentally-responsible waste management solution.

Figure 2.6: Sample type of product waste plastic fuel

Source: JBI.inc (2012)

2.3.3 Pyrolysis

Pyrolysis also termed thermolysis is a process of chemical and thermal decomposition, generally leading to smaller molecules. Pyrolysis can be conducted at various temperature levels, reactions times, pressure and in the presence or absence of reactive gases or liquids, and of catalysts. Plastics pyrolysis proceeds at low

(<400^{0}C), medium (400^{0}C - 600^{0}C) or high temperature (>600^{0}C). The pressure is generally atmospheric. Subatmospheric operation, either using vacuum or diluents examples steam, may be selected if the most desirable products are thermally unstable, example easily repolymerizing, as in the pyrolysis of rubber or synthetics. Pyrolysis processes involve breaking bonds and are often endothermic, so that ensuring a supply of heat to the reacting materials is essential an generally rate determining. Partial oxidation supplies such heat internally, but the pyrolysis products are diluted by oxidation supplies such heat internlly, but the pyrolysis products are diluted by oxidation or combustion products.

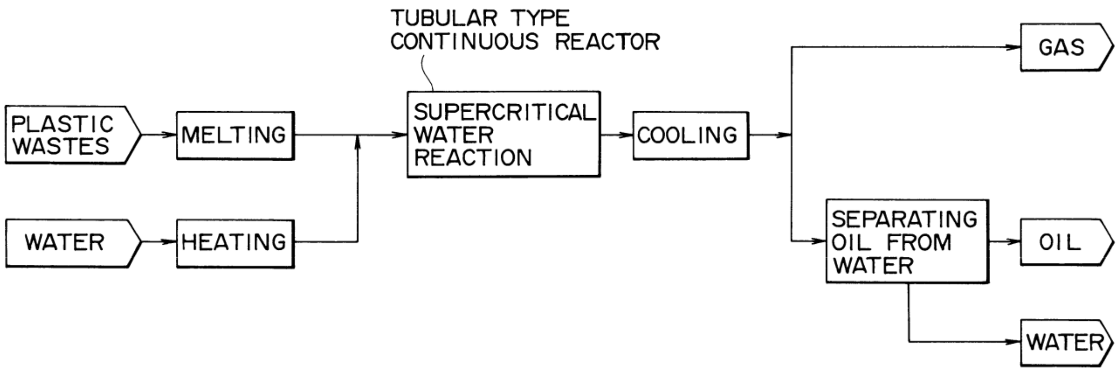


Figure 2.6: Schematic of pyrolysis

Source: Mitsubishi (2003)

2.3 FUEL CHARACTERISTICS

T.C Zannis (2009) stated the most significant fuel characteristics examined in these studies were aromatic structure and content, sulphur content, hydrocarbon molecular structure, cetane number, fuel heating value, density, viscosity and distillation temperatures. The effects of these fuel characteristics on diesel pollutant emissions have been assessed in various types of diesel engines (direct and indirect) and vehicles under diverse operating conditions (steady-state and transient).

2.4.1 Gross Calorific Value

Gross calorific value is the energy released as heat when a compound undergoes complete combustion with oxygen under standard conditions. The heat of combustion is conventionally measured with a bomb calorimeter. It is measured in units of energy per unit of the substance, usually mass, such as: kJ/kg, kJ/mol, kcal/kg, Btu/lb.

2.4.2 Cetane Number

Cetane number is measurement of quality diesel fuel during compression fuel. Higher cetane fuels will have shorter ignition delay periods than lower cetane fuels. Generally, diesel engines operate well with a CN from 40 to 55.

2.4.3 Fuel's Viscocity

Viscocity is measure of a fuel resistance to flow due to internal friction. Much higher viscocity causes a higher peak injection pressure at high temperatures in non-pressure- regulated systems. For this reason, mineral oil diesel may not be applied at the maximum permitted primary pressure.

2.4.4 Flash Point

The lowest temperature at which it can vaporize to form an ignitable mixture in air. The flash point is often used as a descriptive characteristic of liquid fuel, and it is also used to help characterize the fire hazards of liquids. There are two basic types of flash point measurement: open cup and closed cup. In open cup devices the sample is contained in an open cup which is heated, and at intervals a flame is brought over the surface. While for closed the cups are sealed with a lid through which the ignition source can be introduced.

2.4.5 Sulphur Content

Diesel fuel contain chemically bonded sulphur, and the actual quantities depend on the quality of the crude petroleum and the components added at the refinery. Good diesel fuel must have low sulphur content it to desulfurize fuel, sulfur removed from the middle distillate by hydrogenation at high pressure and temperature in the presence of catalyst

CHAPTER 3

METHODOLOGY

3.1 FLOW CHART METHODOLOGY

The flow chart shows every single step in methodology process as a guideline during running the project. In the beginning , the project start with receiving the title of the project, understanding the title, determining the projects objectives, scopes and the project background. Next process is literature review, where all related sources, journals, research through internet are used to be reference project and literature review. All source literature review data can gain idea and information to do a project.

Then the methodology of the project which in this project has two expeiment need to be done. First experiment to determine fuel properties and second experiment to determine size concentration and diameter of particulate matter. After that, experiment be analysis. all the result be table and the analysis to be graph it for easy during make a disscussion.

After all process done, the next step process is make conclusion. This process will review the result and analysis process than conclude the overall project done

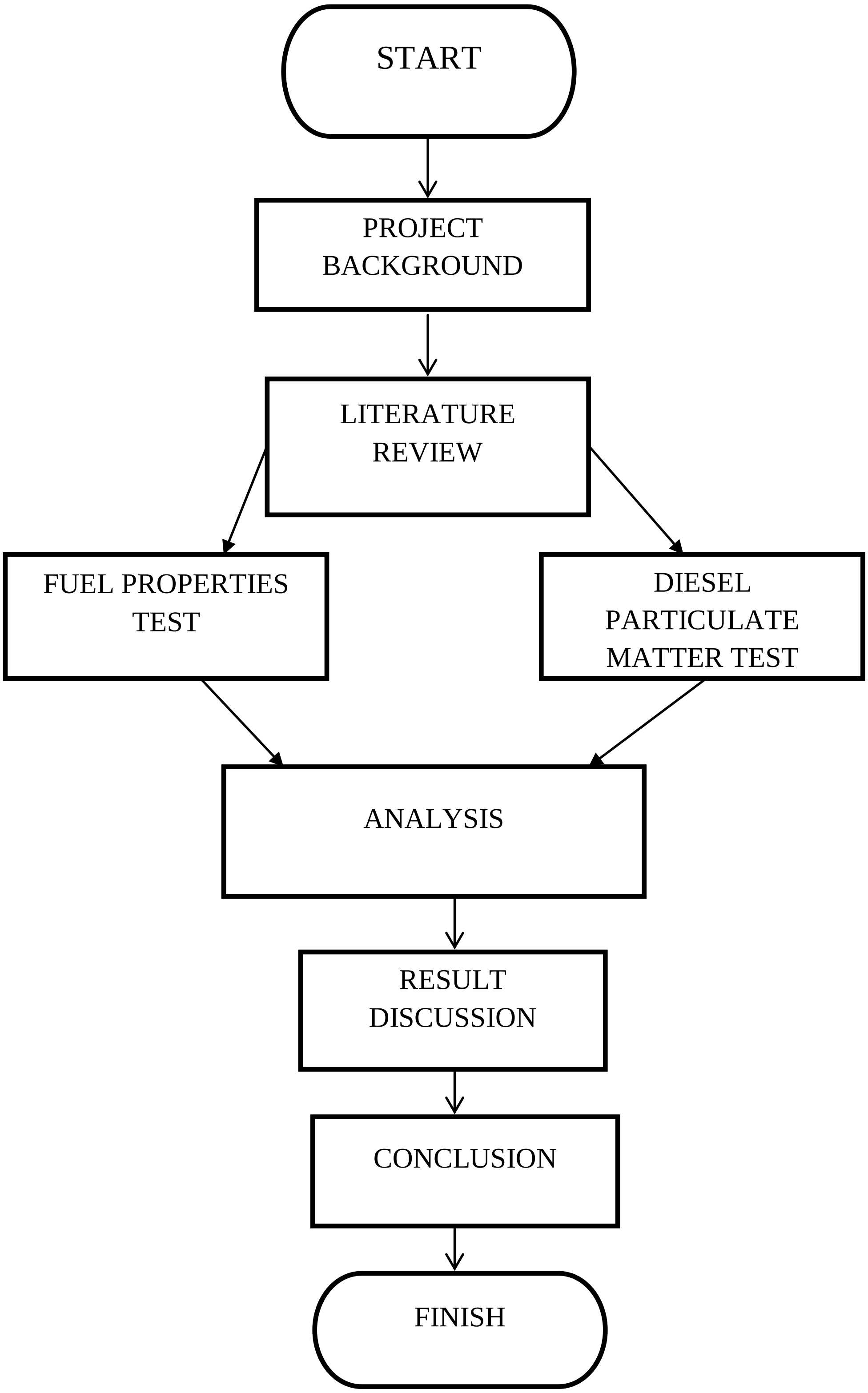


Figure 3.1: Flow Chart methodology

3.2 EXPERIMENT SCHEMATIC DIAGRAM

This experiment start with characteristic fuel experiment. Than continue with the next experiment which is take a data of size and distribution of particulate matter of waste plastic fuel and diesel fuel. Beside that, we also measure of composition emission from exhaust gas, where it including NO,SO_2, CO_2 and O_2.

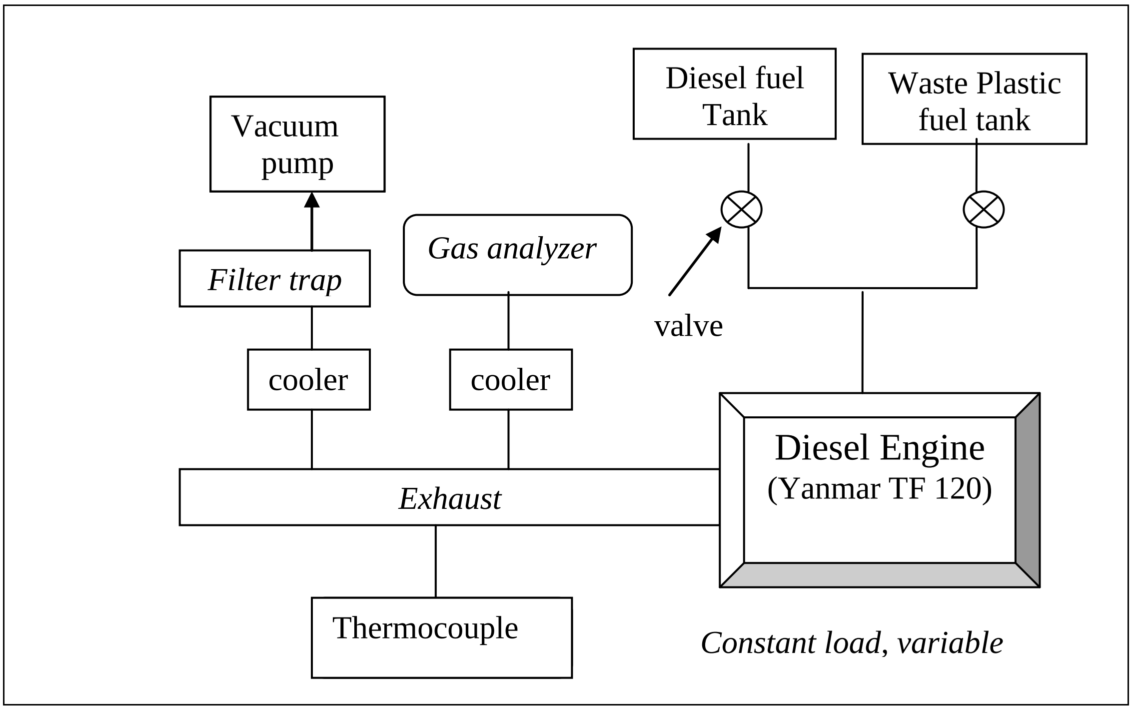


Figure 3.2: Schematic diagram of experiment

3.3 FUEL CHARACTERISTIC EXPERIMENT EQUIPMENT

3.3.1 Bomb Calorimeter (Gross heat)

A bomb calorimeter is measure of calorify value of material. Calorimeter used in measuring the heat of combustion of a particular reaction. Bomb calorimeters have to withstand the large pressure within the calorimeter as the reaction is being measured. Electrical energy is used to ignite the fuel; as the fuel is burning, it will heat up the surrounding air, which expands and escapes through a tube that leads the air out of the calorimete

Figure 3.3: Oxygen Bomb Calorimeter

3.3.2 Octane Meter SHASX-200 (Cetane Numbers)

This Octane meter with the purpose of expansion of adaptation capabilities of the device for various application conditions. One of the capabilities of test is cetane number. Procedure to use this device is first pour in the fuel or oil in octane meter detector about 5 - 10 ml . The measurement and updating take not more than 5 seconds. Than the oil can be pour out than the octane meter detector can be clean.

Figure 3.4: Octane meter

3.3.3 Portable Density or Specific Gravity Meter (Density)

Density meter is for to measure of density of substance. This device have two button to press, first button for suction of fluid and button for push fluid out from tube. The measurement can read at LCD screen. Make sure the fluid not bubbling in tube capillary.

Figure 3.5: Density meter

3.3.4 U-tube Viscometer (Viscocity)

Viscometer function to measure kinematic viscocity and viscocity. In this U-tube , one arm have precise vertical narrow bore or cappilary. There are two bulb at capillary side. In use, liquid is drawn into the upper bulb by suction, then allowed to flow down through the capillary into the lower bulb. At lower bulb have two marks for taken time during fluid drawn. the fluid will suck until the arive at upper bulb and it let drawn. the time will taken after the fluid pass upper mark and stop after arrive at lower mark.

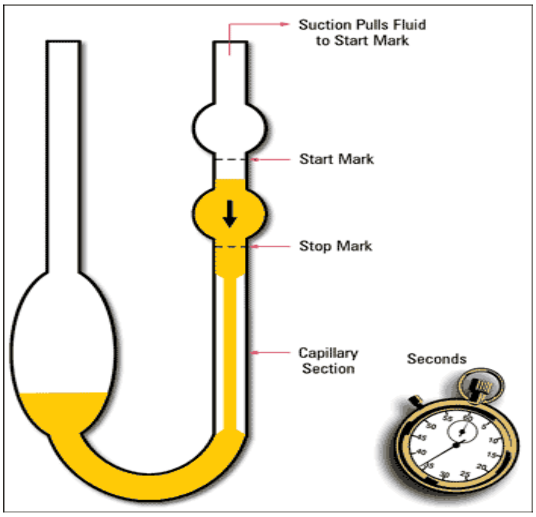


Figure 3.6: Ostwald Viscometer

Source: Machinerylubrication.com (2011)

Then after finish this experiment the value of viscocity and kinematic viscocity can find using formula at below.

Kinematic Viscocity (cSt) = efflux time x constant Viscocity (3.1)

Viscocity (cP) = Density x Kinematic Viscocity (3.2)

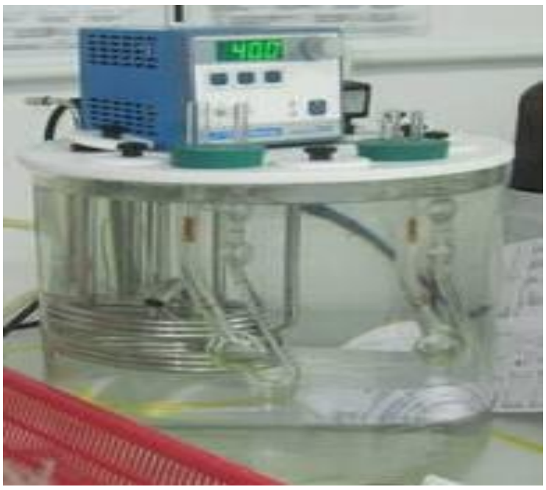


Figure 3.7: viscometer

3.3.5 Flash Point

The device use for measure flash point is petrotset. Actually flash point has 2 type experiment it is open cup tester and closed cup tester. This type of petrotest is closed cup test where the method test is be like this, a brass test cup is filled with a test fuel and fitted with a cover. The fuel is heated and stirred at specified rates depending on what it is that is being tested. An ignition source is directed into the cup at regular intervals with simultaneous interruption of stirring until a flash that spreads throughout the inside of the cup is seen. The corresponding temperature is its flash point.

Figure 3.8: Petrotest

3.4 PARTICULATE MATTER APPARATUS

3.4.1 Diesel Engine

The engine use in this experiment is Yanmar TF 120 single cylinder. The specification of this engine shown at table 3.1.

Table 3.1: Diesel engine specification

Item	Description
Type of Engine	Horizontal single cylinder 4 stroke diesel engine (YANMAR TF 120)
Cylinder bore x stroke	Φ92 x 96
Displacement	0.638 litres
Dry weight (electric start)	102 Kg
Dimesion (length /width / height)	695 mm/348.5mm/530mm
Cooling type	Radiator
Fuel tank capacity	11 litres
1 hour rating Output	12.0hp @2400 rpm

Figure 3.9: Diesel Engine Yanmar

3.4.2 Vacuum

Vacuum using to suck the emission out from the exhaust valve from engine. In this experiment the brand vacuum used are SKC Flite 2 high Volume air sampling Pum – Pro Model 901-2011

Figure 3.10: Vacuum pump

Table 3.2 : Vacuum specification

Specification	
Dimensions	178m W x115mm H x 206mm D
Weight	2.24kg (without battery)
	3.56kg(with battery)
Flow range	2-26 liter/min
Maximum sampler back pressure	62kPa
Power supply	12V lead/acid battery
Storage/ operating temperature	-5 to +50 ^{0}C
Charging temperature	-5 to +50 ^{0}C
Relative humidity	0 to 95% RH

3.4.3 Exhaust Gas Temperature Sensor

The temperature exhaust gas be measure using thermocouple as sensor than the value temperature shown at temperature display unit.

Figure 3.11: Thermo couple sensor

3.4.4 Engine Speed Sensor

In this experiment photoelectric sensor use for measure speed engine. The photoelectric sensor will be attached at engine rig. The flywheel need tobe marking for enable the sensor detect the engine speed. The speed be measure in RPM. The measure be display at tachometer.

Figure 3.12: Tachometer

3.4.5 Mechanical oven

Oven be use to heating filter before start taken emission gas experiment. It is for get rid of moisture in filter. The filter need to heating for 2-3 hours with 45^0C. In this experiment I used oven redline RF53.

Figure 3.13: Mechanical oven

Table 3.3: Oven specification

Dimensions	
Exterior dimension	600mm W x 680mm H x 620mm D
Internal dimension	401mm W x 400mm H x 330mm D
Temperature Data	
Temperature uniformly at 150 ^{0}C	+/- 3.5 ^{0}C
Temperature fluctuation at 150 ^{0}C	+/- 0.2 ^{0}C
Heating up time at 150 ^{0}C	28 min
Recovery time after door was opened	10 min

3.4.6 Weight Scales

Weight scale using for measure weight of filter. the filter be measure before and after experiment. The weight measure in miligram.

Figure 3.14: Electronic weight scale

3.4.7 Dichloromethane

Dichloromethane use for soak filter after the experiment. In this process the filter will be soak in 24 hours. This purpose for showed Soluble Organic Fraction (SOF) and Dry Soot(DS).

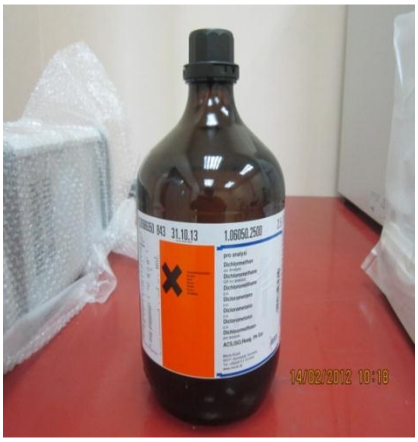


Figure 3.15: Dichlormethane

3.4.8 Filter

Purpose using filter for filter emission gas and particulate matter out from exhaust engine. The filter be placed between pipe exhaust and vacuum. The vacuum will gas emission and gas need through the filter. The type filter using is composite type with diameter 0.6mm. the specification of filter such as at table below:

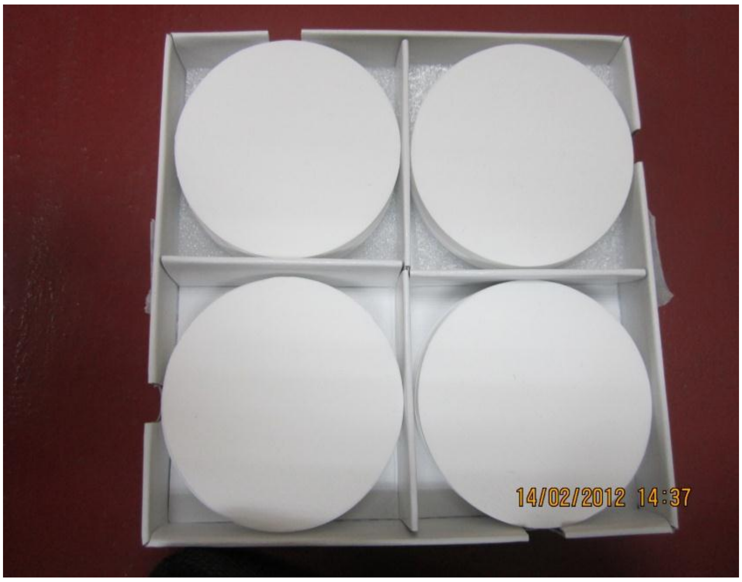


Figure 3.16: Membrane Filter

Table 3.42: Specification of filter

Name	**Filter Paper**
Material	Composite
Merks	Advance
Kinds	PG-60
Side	$47mm^2$
Quality	100 leaf
Serial Number	305/9713
Manufacturer	Toyo Roshi kaisya ltd

3.4.8 Fuel

There are two types of fuel used in this experiment which is diesel fuel and waste plastic fuel. Diesel fuel use in this experiment is Petronas diesel for syncronize the experiment and prevent the error

(a)

(b)

Figure 3.17: (a) waste plastic fuel (b) diesel fuel

3.5 EXPERIMENT PROCEDURE

3.5.1 Particulate Matter Trap Procedure

Prior data acquisition must be ready and check. The filter need to heating in 2 hours. Then ready the oil will be use. The experiment beginning with set speed engine to be 1200 rpm. The exhaust gas that is come out from the exhaust than vacum will suck the emission gas throuh the filter. The flow rate of gas between 20*l* /min otherwise temperature gas need to be measure too. After that repeat the experiment with 1500rpm, 1800rpm, 2100rpm, and 2400rpm.

After all experiment done. The filter need to be heating for 2 hours in oven. Then after 2 hours filter need to be weighing and label each filter. The next step, filter willl be soak in 100m*l* dichloromethane in 24 hours. This purpose for precipitate the particle organic at filter. After 24 hours the filter need to be weighing. All data obtained are filled in the table.

3.5.2 Particulate Matter Size Diameter and Distribution Data

The filter was soak at dichloromtehane will bring at lab material for trace particulate matter at filter using Microscope electric. Then from here we need calculate the size of diameter particulate matter and concentration of particulate matter. This calculate can using formula 2.1, 2.2, 2.3, 2.4, 2.5, 2.6 and 2.7.

CHAPTER 4

RESULTS AND DISCUSSION

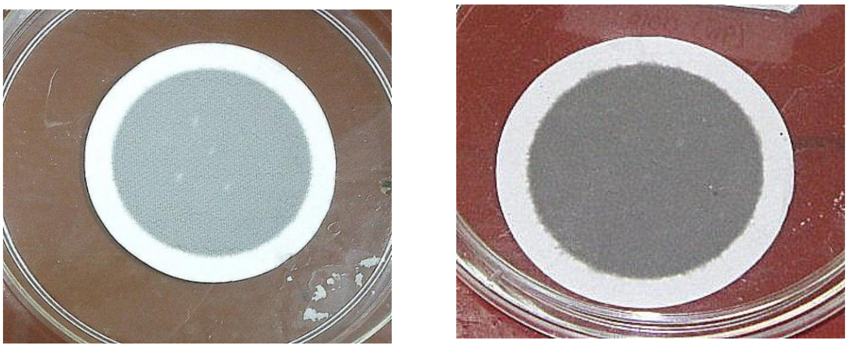
4.1 THE RESULT OF FUEL CHARACTERISTIC

Table 4.1: Properties of diesel and waste plastic fuel

Properties		**Waste plastic fuel**	**Diesel**
Density (g/cm^3)		0.7710	0.8416
Cetane Number		64.4	68.2
Kinematic Viscocity@ 40 ^0C (cP)		1.2	2.22
Flash Point (^0C)		72	84
Gross clarify Value (MJ/kg)		34.7247	42.4915
Boiling Point (^0C)	ASTM D4249	186	193
Sulphur content (%)	ASTM D 86	0.019	0.042

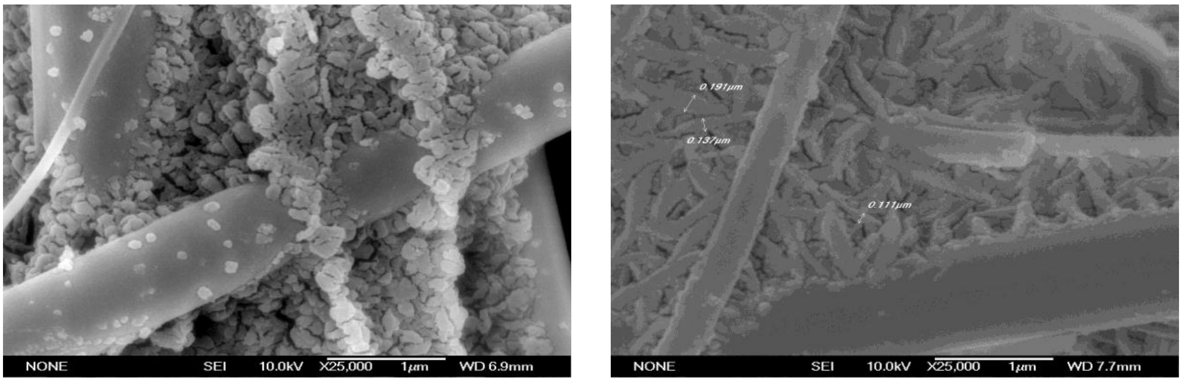
The result show waste plastic fuel have a close to equal quality diesel fuel. The density of waste plastic less than diesel with waste plastic fuel with 0.7710 g/m^3 and diesel 0.8416 g/m^3. Density affects the mass of fuel injected and air-fuel ratio because injection pump meters fuel by volume thus denser have more mass/volume while high cetane number cetane number have good cold start and smooth run. Low cetane number tend to increase gaseous and particulate and from the result both of fuel has high cetane number with waste plastic cetane number is 64.4 and diesel fuel is 68.8. The third characteristic is viscocity where high fuel viscosity reduces the fuel amount vaporized prior to combustion and fouling of injector and diesel high viscocity than waste plastic fuel. With 2.22 cPs for diesel and waste plastic is 1.2 cPs. Lastly for the result sulphur content is one of component produce particulate matter. The higher sulphur content can cause of the form of particulate matter.

4.2 FILTER AFTER EXPERIMENT AND PM VIEW UNDER SCANNING ELECTRON MICROSCOPE (SEM)



(a) (b)

Figure 4.1: (a) Diesel filter at 2100 rpm (b) Waste platsic fuel filter at 2100 rpm



(a) (b)

Figure 4.2: (a) Diesel PM at 2100 rpm (b) Waste Plastic Fuel PM at 2100 rpm

4.3 EFFECT OF FUEL CONSUMPTION

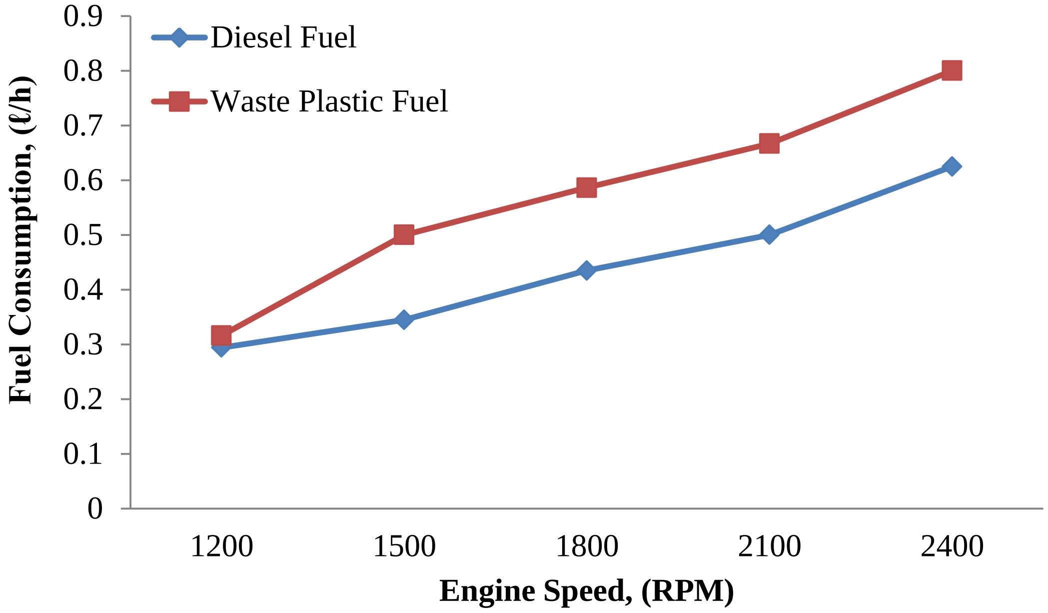


Figure 4.3: Variation of fuel consumption

Figure 4.3 show the comparison fuel consumption between waste plastic disposal fuel and diesel Fuel. Both graph increase due increase of engine speed rpm. It is clearly fuel consumption usage by waste plastic disposal fuel is more higher than diesel fuel. The higher fuel consumption usage are waste plastic disposal at 2400 rpm where the fuel consumption 0.80028 l/h and for the diesel fuel the usage is 0.625 l/h Average of usage fuel consumption for waste plastic disposal fuel more 29.75 % than diesel. Probably fuel consumption of waste plastic fuel high because of the gross heat in waste plastic fuel disposal lower than diesel fuel. The other reason is the viscocity of fuel is lower than diesel fuel.

4.4 EFFECT OF EXHAUST TEMPERATURES

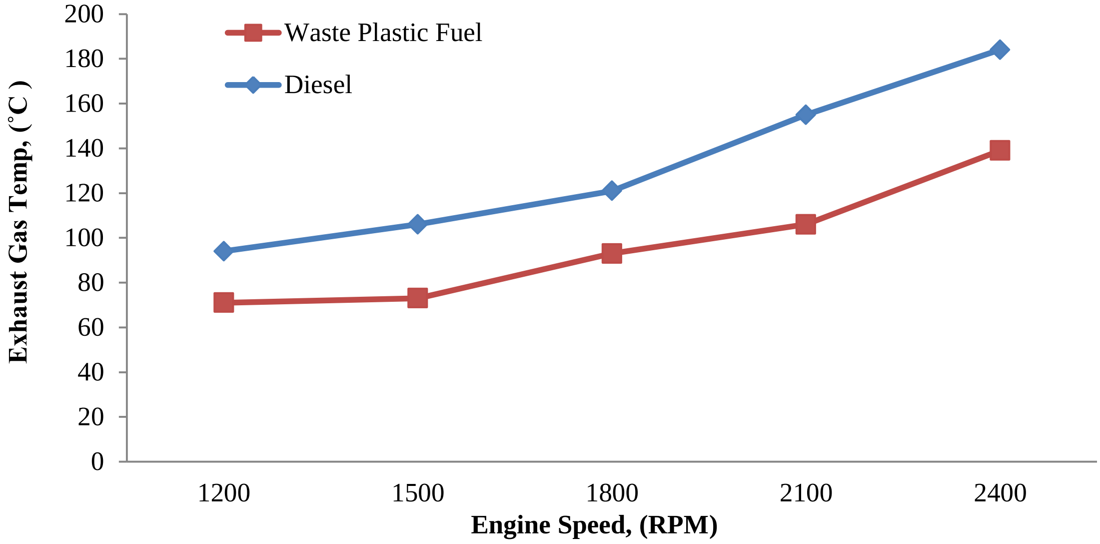


Figure 4.4: Variation of exhaust temperatures

Figure 4.4 show the effect of engine speed on the exhaust gas temperature is measured by a thermocouple attached to the exhaust manifold . The variation of temperature with the increase of engine speed for both cases be plot in Figure 4.4. The exhaust gas temperature increases with the increase of engine speed in both cases. This could be due to a greater amount of fuel combustion inside the combustion chamber at higher speed compared to lower speed. At higher speed complete combustion of the fuel is happened (s. muhanaranugan). From the graph at Figure 4.4 we can see the exhaust temperature using diesel fuel more higher than using waste plastic fuel. Exhaust temperature using Waste plastic fuel less about 26.96% for average overall engine speed be tested. Due the temperature exhaust is high, the power energy produce also increase. The other cause of low exhaust temperature is some molecul or element in waste plastic disposal fuel not complete combustion.

4.5 EFFECT OF PARTICULATE MATTERS (PM) BY ENGINE SPEED

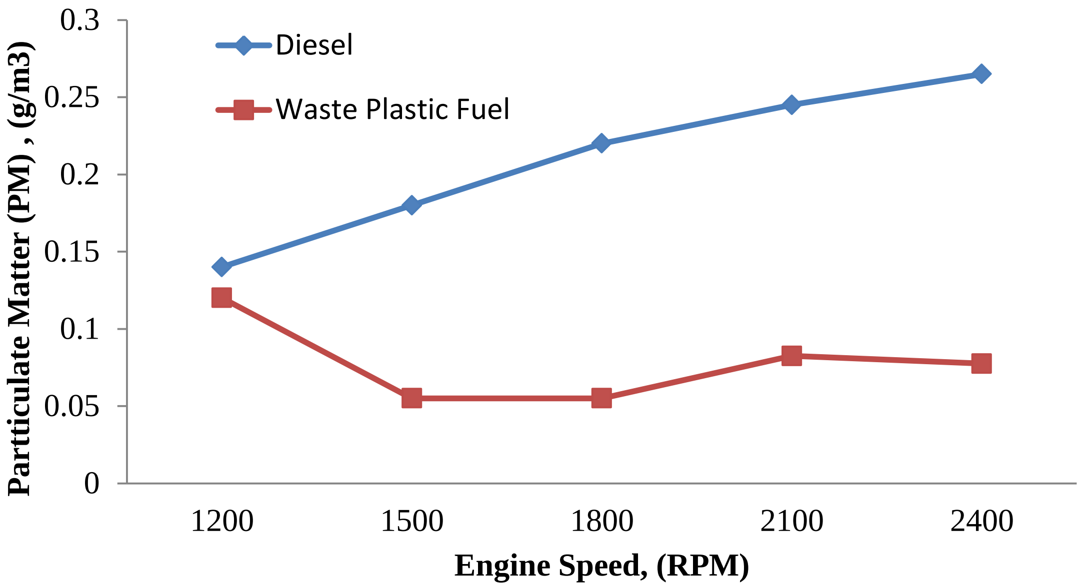


Figure 4.5: PM variation by engine speed.

The Figure 4.5 show effect of PM by engine speed. Trend for the diesel fuel is it increase since at the lower rpm which is the lower PM produce is 0.14 g/m^3 and the higher is 0.265 g/m^3 but it different for Waste Plastic Disposal Fuel (WPD). It start at the higher PM produce which is 0.12 g/m^3 and it decrease after 1500 rpm at the lower PM produce which is 0.055 g/m^3 and no movement until 1800 rpm. Then it increase back until 2400 rpm. The average of PM for diesel fuel is higher than waste plastic disposal fuel by 59.16%. The value of particulate matter decrease at 1500 rpm and 1800 probably waste plastic fuel achieved optimum of engine operation in this range. When the engine operate in optimum condition complete combustion occur and the PM produce is low.

4.6 EFFECT OF SOLUBLE ORGANIC FRACTION (SOF)

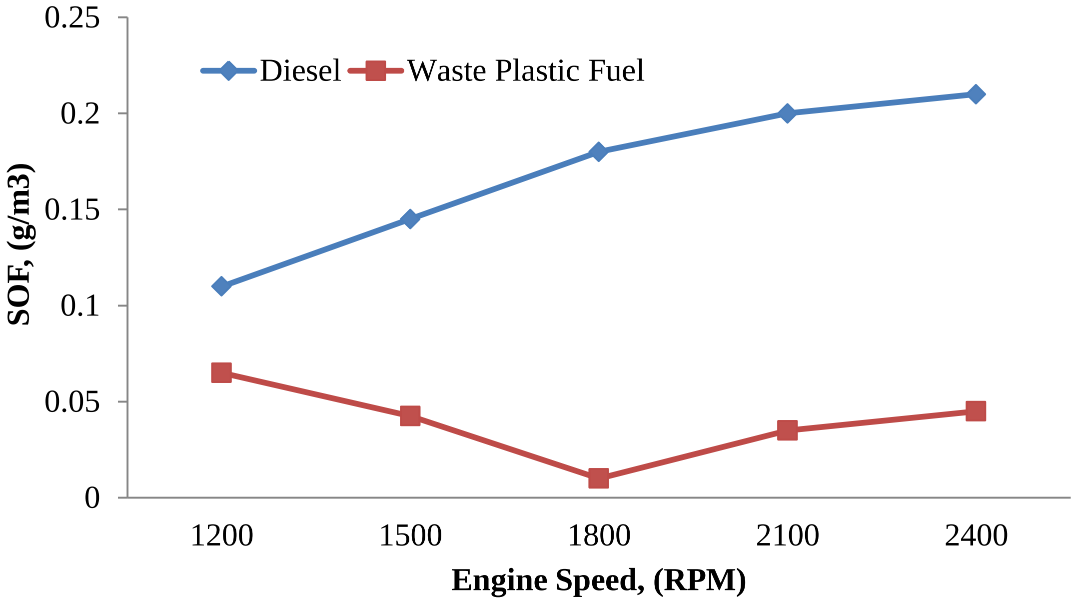


Figure 4.6: Soluble organic fraction (SOF) variation by engine speed

Figure 4.6 was shown the effect of Soluble Organic Fraction (SOF) due to variation engine speed. From the graph the trend graph is diesel produce more SOF than Waste Plastic Disposal .The trend SOF for Diesel increase due to increase of engine speed but for the waste plastic dispoasl fuel it decrease after the 1200 rpm until 1800 rpm and then it increase after the rpm engine over 1800 rpm. The lowest SOF produce by WPD is 0.01g/m^3 at 1800 rpm and the higher is 0.065 g/m^3 at 1200 rpm. While for Diesel the lower SOF produce is 0.11 g/m^3 at 1200 rpm and the higher is 0.21 g/m^3 at 2400 rpm. The average of soluble organic fraction for diesel fuel is higher than waste plastic disposal fuel by 59.16%. Possibility waste plastic fuel of produce low PM than diesel fuel it could be of sulphur content found in waste plastic fuel is more lower than diesel fuel. From the previous graph at figure 4.4 and graph at figure 4.5 it clearly support the optimum operation of engine is in range 1800 rpm.

4.7 EFFECT OF DRY SOOT (DS)

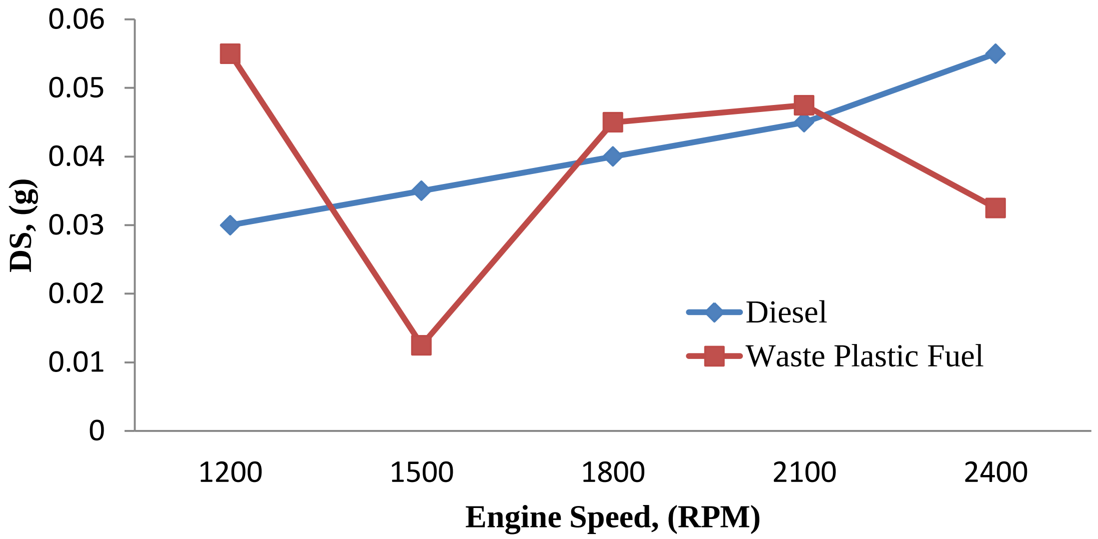


Figure 4.7: Variation of dry soot by engine speed

Figure 4.7 show comparison of dry soot by engine speed for fuel test. Trend graph for diesel fuel is increase due to increase of rpm and while for WPD fuel in early it produce the higher dry soot which is 0.055g at 1200 rpm after the rpm increase to 1500 rpm the weight dry soot decrease in drastic wihich is only 0.0125g. then trend of graph of waste plastic disposal fuel is increase back until at 2100 rpm and it drop back at 2400 rpm. Average dry soot produce by diesel is 0.041g while average dry soot produce by waste plastic fuel is 0.0385g and diesel produce dry soot more 6.09% than waste plastic disposal fuel. Waste plastic produce average low dry soot probably the the higher sulphur content in diesel fuel cause or form dry soot. While waste plastic disposal fuel produce lower dry soot at 1500 rpm could be of optimum engine operation and the lower formation of sulfur content at this rpm.

4.8 DISTRIBUTION OF PM TO DIAMETER SIZE PM

4.8.1 Distribution PM Versus Size Diameter PM at 1200 rpm

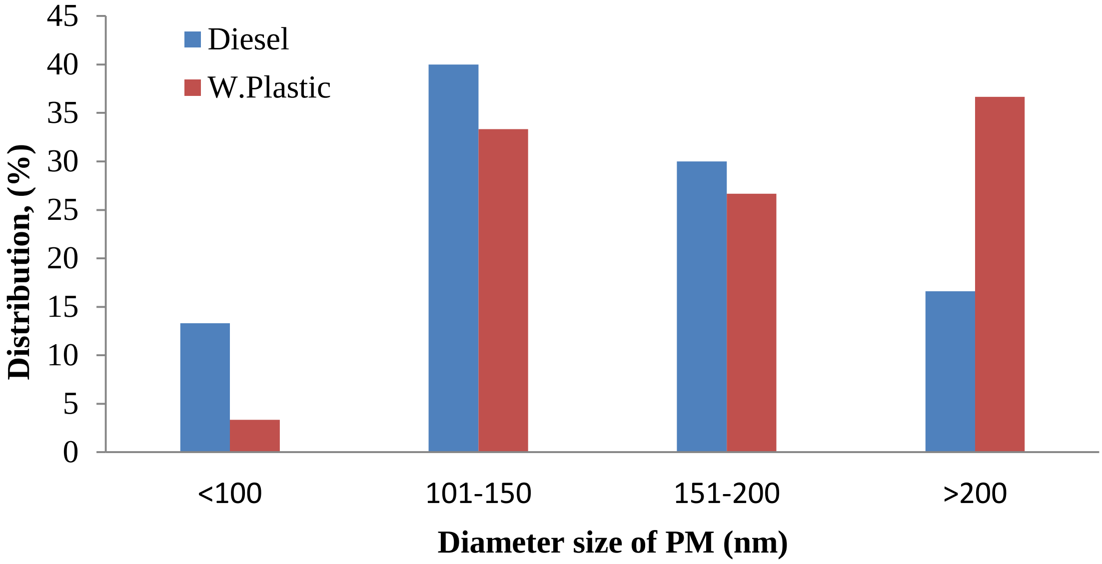


Figure 4.8: Distribution PM versus Diametr of PM at 1200 rpm

Figure 4.8 show bar chart of distribution PM versus diameter of PM at 1200 rpm. Distribution of diesel at less than 100 nm is more 10 % than waste plastic fuel. While the higher distribution for diesel at diameter 101-150 with 40 % distribution overall distribution for diesel and more 6.66 % istribution than waste plastic fuel. For waste plastic fuel, the higher distribution of PM is at diameter more than 200 nm with distribution 36.67 % and for diesel at same diameter is 16.6 %. Lastly the diameter, 151 – 200 nm diesel contribute 30 % of distribution PM and for waste plastic fuel at same diameter less 3.33 % distribution than diesel fuel.Very small particles less than 100 nanometers also known as ultrafine particle may pass through the lungs to affect other organs (F.Dominici etc, 2006). Probably it the small particle form because of, condensation of low vapour pressure substances formed by high-temperature vaporization especially for the diesel fuel.

4.8.2 Distribution PM Versus Size Diameter PM at 1500rpm

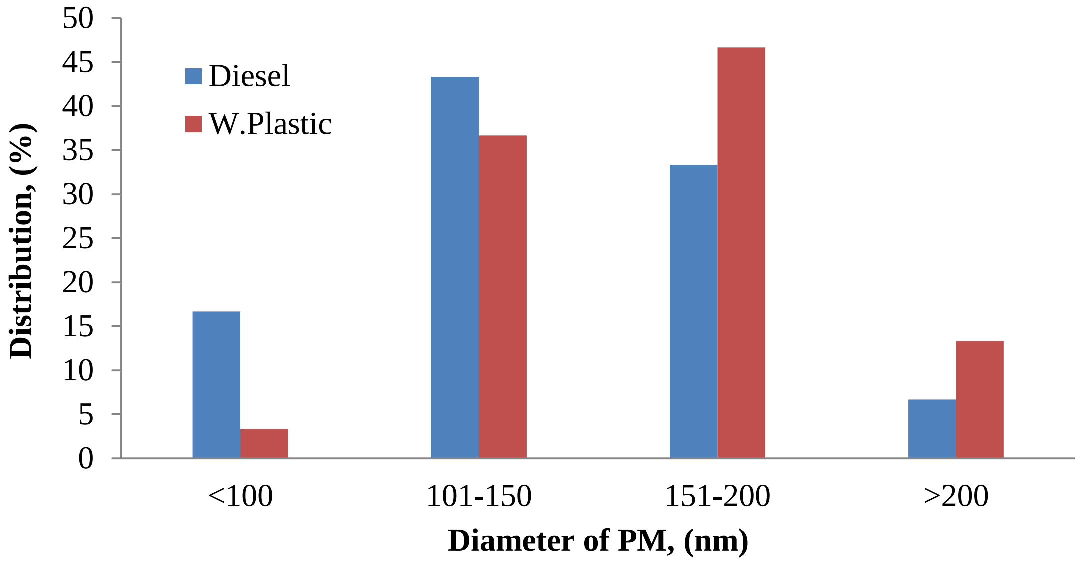


Figure 4.9: Distribution PM versus Diametr of PM at 1500 rpm

Figure 4.9 chart of distribution PM versus diameter of PM at 1500 rpm. Distribution of PM for diesel at range diameter less than 100 nm is 16.67 % and for waste plastic fuel only contribute 3.33 %. While at range diameter 101 – 150 nm , diesel fuel distribute 43.33 % and for waste plastic at same diameter less 6.7 % than diesel fuel. Waste plastic distribution at range 151 – 200 nm is the higher than other range which is 46.67 % and for diesel less 13.24 % at this range. The last range more than 200 nm , waste plastic fuel contribute 13.33 % higher than diesel which is only 6.67 %. The data show distribution of PM for diesel fuel less than 100 nm is increase from previous rpm probably it because the increase of rpm will increase the heat and the pressure is still not satisfied to reduce of form particle less than 100 nm but the increase of temperature cause of distribution particle less than 100 nm is increase.

4.8.3 Distribution PM Versus Size Diameter PM at 1800rpm

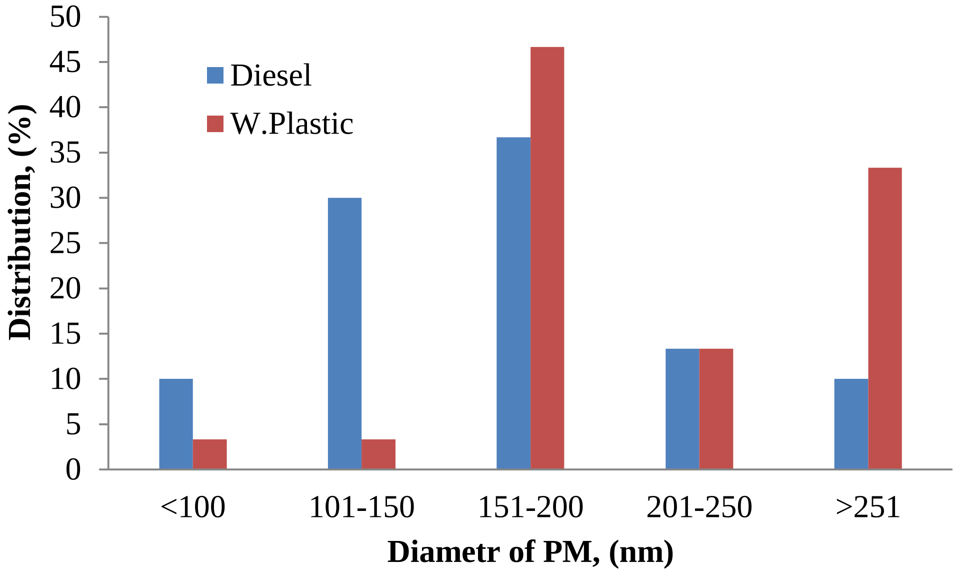


Figure 4.10: Distribution PM versus Diametr of PM at 1800 rpm

Figure 4.10 chart of distribution PM versus diameter of PM at 1800 rpm. Distribution of PM for diesel at range diameter less than 100 nm is 10 % and for waste plastic is 3.33%. While at range 101 – 150 nm distribution for diesel is 30 % and different to waste plastic is about 26.33% distribution. At range 151 – 200 distribution waste plastic fuel is increase in drastic as much 46.67 % and for diesel is 36.67 % in this range is the higher distribution for both fuel. The next range is 201 – 250 nm the both fuel show even with distribution 13.33 %. Lastly , range more than 251 nm distribution of waste plastic fuel is 33.33 % higher than diesel fuel and different distribution as much 23.33 %. For the diameter distribution at diameter less than 100 nm not much different for waste plastic fuel but diesel PM distribution it decrease from 1200 and 1500 rpm to 10% .Probably this occur is the pressure is increase and change to form ultrafine particle possibilities is decrease.

4.8.4 Distribution PM Versus Size Diameter PM at 2100rpm

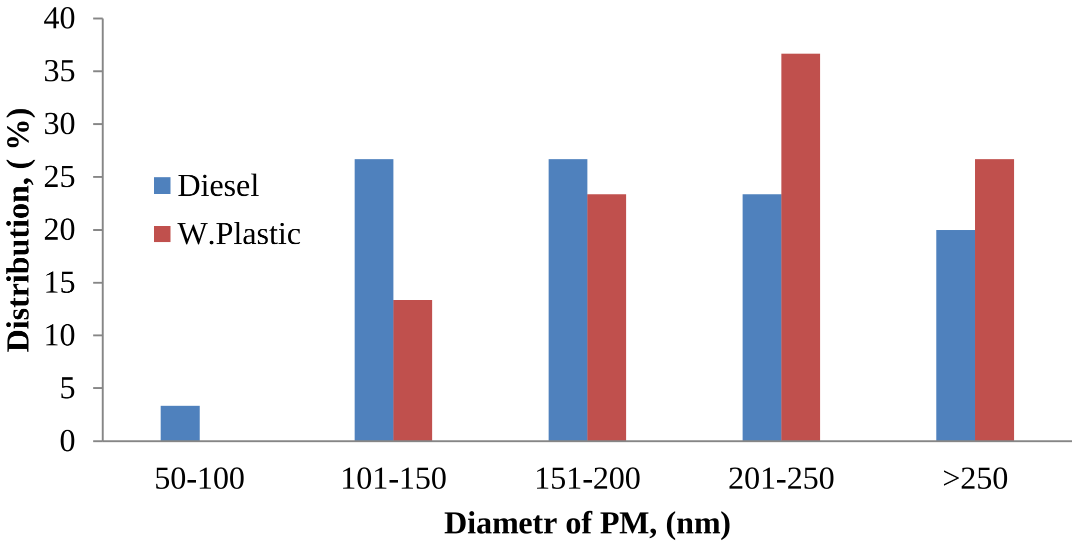


Figure 4.11: Distribution PM versus Diametr of PM at 2100 rpm

Figure 4.11 chart of distribution PM versus diameter of PM at 2100 rpm. Distribution of PM for diesel at range diameter less than 100 nm is 3.33 % and no distribution for waste plastic fuel at this range. Distribution at diameter 101 - 150 nm for diesel contribute 26.67 % and for waste plastic fuel 13.33 %. While at third range diameter 151 – 200 nm different distribution both fuel is not far where diesel produce 26.67 % and waste plastic fuel 23.33%. At fourth range from 201 – 250 nm size diameter PM, waste plastic produce higher distribution than other class with 36.67 % and diesel only 23.33 %. Lastly range is more than 250 nm diameter , where waste plastic produce 26.67 % and 20 % distribution for diesel. Based on the result show waste plastic fuel produce size diameter higher than 100 nm , it probably that to form of ultrafine particle is is need low vapour pressure but at this rpm the pressure is high and probability to form is decrease or imposible.

4.8.5 Distribution PM Versus Size Diameter PM at 2400rpm

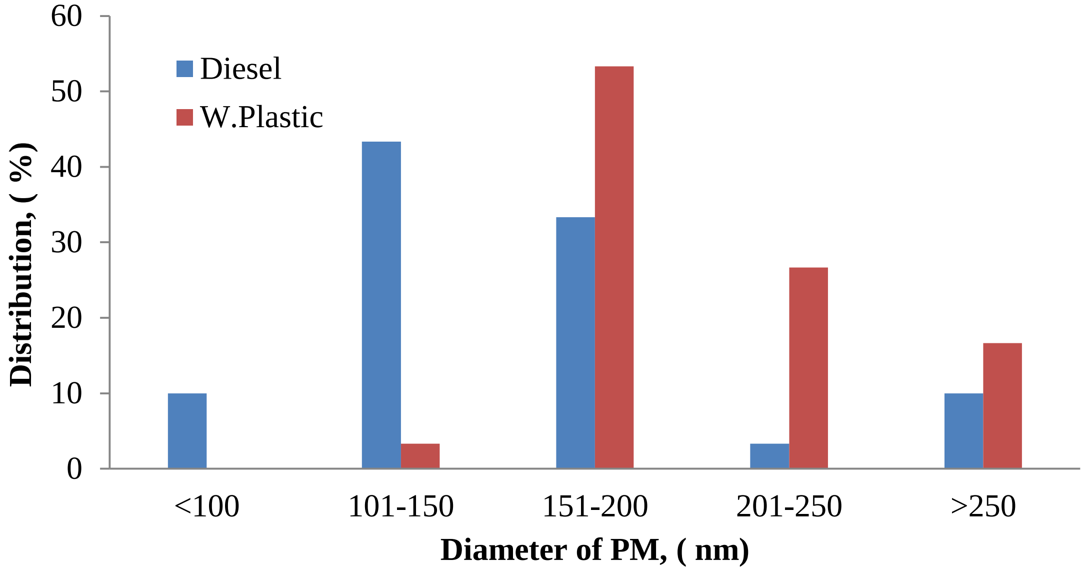


Figure 4.12: Distribution PM versus Diametr of PM at 2400 rpm

Figure 4.12 chart of distribution PM versus diameter of PM at 2400 rpm. Distribution of PM for diesel at range diameter less than 100 nm is 10 % and no distribution for waste plastic at this range. Second range is form 101 – 150 nm with diesel produce 43.33 % and waste plastic fuel 3.33 %. Third range waste plastic produce high distribution than other range with 53.33 % while diesel produce 33.33 % at same range. The fourth range is 201 – 250 nm where diesel only produce 3.33 % and waste plastic produce 26.6 %. Lastly , at more than 250 diameter PM waste plastic fuel produce 16.66% higher than diesel with 10 %. Based on the bar chart at diameter less than 100 nm, waste plastic fuel produce no distribution same as with previous rpm but diesel increase as much 6.66 % than previous rpm

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The main objective of this study is to analyze of size diameter and concentration distribution of diesel particulate matter running on single cylinder diesel engine using waste plastic fuel and the second objective to determine characteristic fuel tested.

First objective the experiment is conducted to analyzed size distribution and concentration of particulate matter for both type fuel.. The results both fuel are plotted on the graph and compared for analyzed. From the study , waste plastic disposal fuel consumption higher than diesel as much 29.75%. For exhasut gas temperature diesel fuel higher than waste plastic about 26.96%. Due to PM weight Diesel fuel produce more than waste plastic fuel as much 59.16%. Furthermore , Diesel fuel produce dry soot and SOF higher than waste plastic disposal with dry soot by 6.09% and SOF by 59.16%.

Based on the results obtained, waste plastic fuel disposal produce lower PM and optimum operation engine is range at 1500 rpm to 1800 rpm where the PM concentration PM is 0.055g/m^3. While for the result distribution is waste plastic fuel distribute less PM with diameter less than 100 nm at low rpm from 1200 rpm , 1500 rpm, a1800 rpm where only produce 3.33% and at the higher rpm from 2100 rpm and 2400 rpm the diameter <100 nm is null. The diesel fuel at low rpm it produce higher PM with diameter <100 nm with more than 15% but it decrease when the rpm increase but the trend not as smooth such as waste plastic fuel.

5.2 RECOMMENDATION FOR FUTURE RESEARCH

After all the study complete, there a few reccomendation for future research. The recommendation for further future research for waste plastic fuel is study the fuel performance for waste plastic fuel with installing dynanometer. The performance of the engine such as torque can be measured and give more information about the engine performance when using waste plastic fuel. The second recommendation is for PM measurement and distribution with using Condensation Particle Counter (CPC) . This method more accuracy from this project medalia heckman method, where CPC method can detect sub micron particles since the diameter is equal or smaller than the wavelength of light.

REFERENCE

Budd, L. 2008. Diesel particulate matter (online). http://www.eoearth.org/article/Diesel_Particulate_Matter (20 October 2011)

Cader, N. 2006. *Marine diesel engine.: maintenance, troubleshooting and repair*. 3rd ed. USA: McGraw-Hill.

Department of Environment. 2011. *Air pollutant index* (online). http://www.doe.gov.my/portal/air-air-quality/air-pollutant-index-api (5 October 2011

Eastop, T.D and McConkey, A. 1993. *Applied thermodynamic for engineering techmologies*. 5th ed. England: Pearson Education. Ltd

EPA. 1997. *Health and enviromental effects of particulate matter*. USA: United State Enviroment Protection Agency

Fisher, C. 2008. *Preparing a waste management plan*. Slide

Ganesan, V. 2008. *Internal combustion engine*. 3rd ed. New Delhi: Tata McGraw-Hill

Mani, M., Subash, C., and Nagarajan, G. 2009. Performance, emission and combustion characteristics of a DI diesel engine using waste plastic oil. *Applied thermal engineering*. **29**(13), Pp 2738-2744

Medalia, A. I. and Heckman, F. A. (1969). Morphology of aggregates-11. *Size and Shape Factors of Carbon Black aggregates from electron microscopy*, **7**(1), Pp 567.

Wellenius G.A., Bateson T.F., Mittleman M.A., Schwartz J. 2005. Particulate air pollution and the rate of hospitalization for congestive heart failure among Medicare beneficiaries in Pittsburgh, Pennsylvania. *American Journal of Epidemiology*. **161**(11), Pp. 1030-1036

WHO. 2005. *Malaysia: Enviromental health country profile*. Malaysia: World Health Organization.

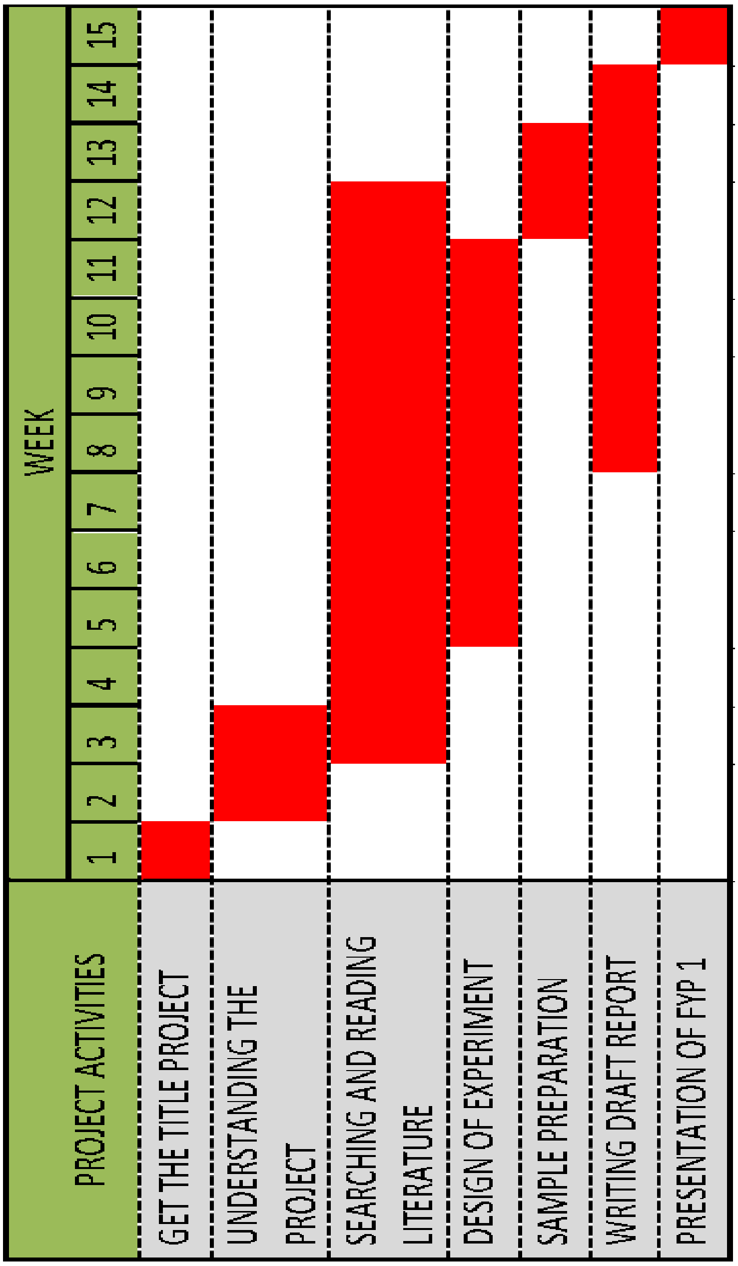
Wibawaningrum, R. 2005. *Experimental Study on Effect of Sulfur Content in MDO to Exhaust Gas.* Bachelor Thesis. University of Kobe, Japan.

Zannis, T., Hountalas, D., Papagiannakis, R., and Levendis, Y. 2008. Effect of Fuel Chemical Structure and Properties on Diesel Engine Performance and Pollutant Emissions: Review of the Results of Four European Research Programs.*SAE International Journal of Fuels and Lubricant*. **1**(1), Pp 384-419

Zanobetti, A and Schwartz, J. 2005. The Effect of Particulate Air Pollution on Emergency Admissions for Myocardial Infarction: A Multicity Case-Crossover Analysis. *Environmental Health Perspectives*. **113**(8), Pp 978-982

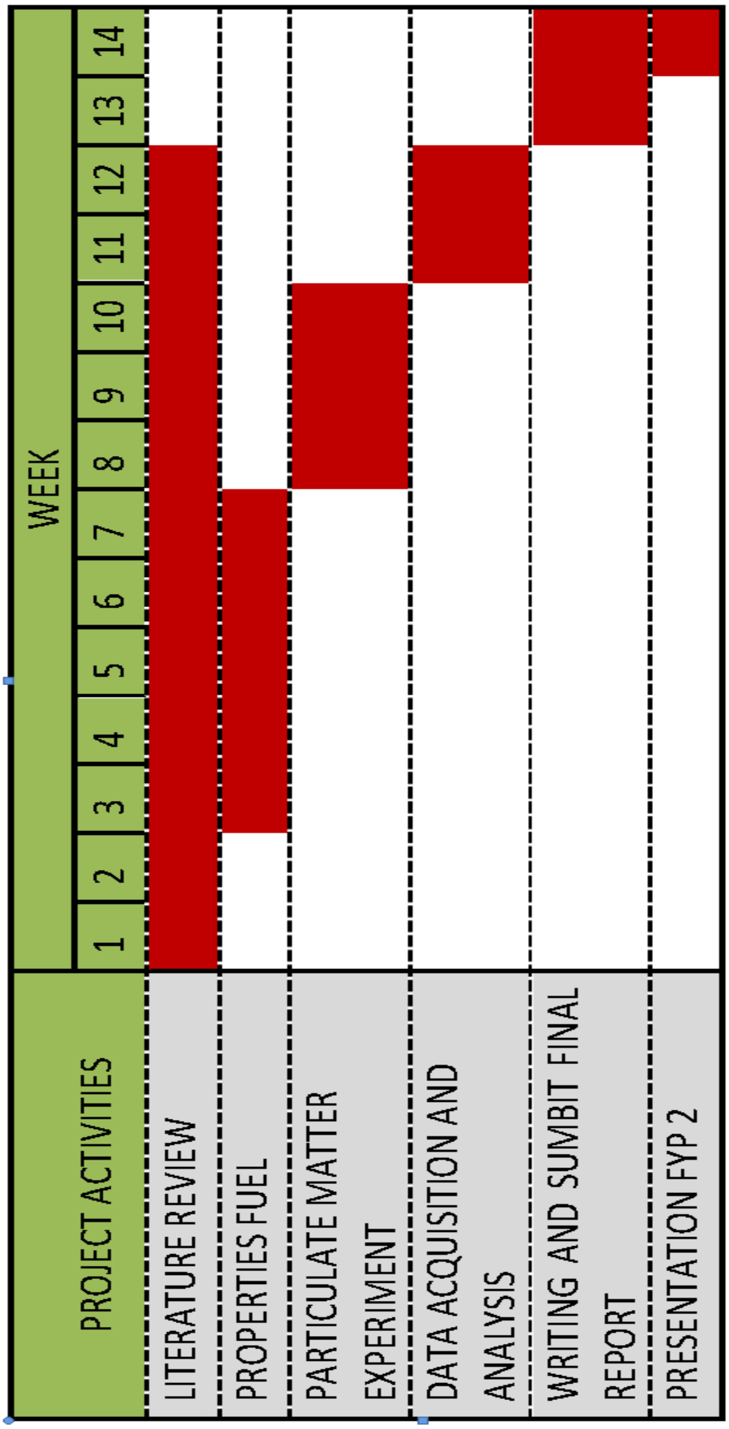
APPENDIX A1

Gantt chart for Final Year Project 1



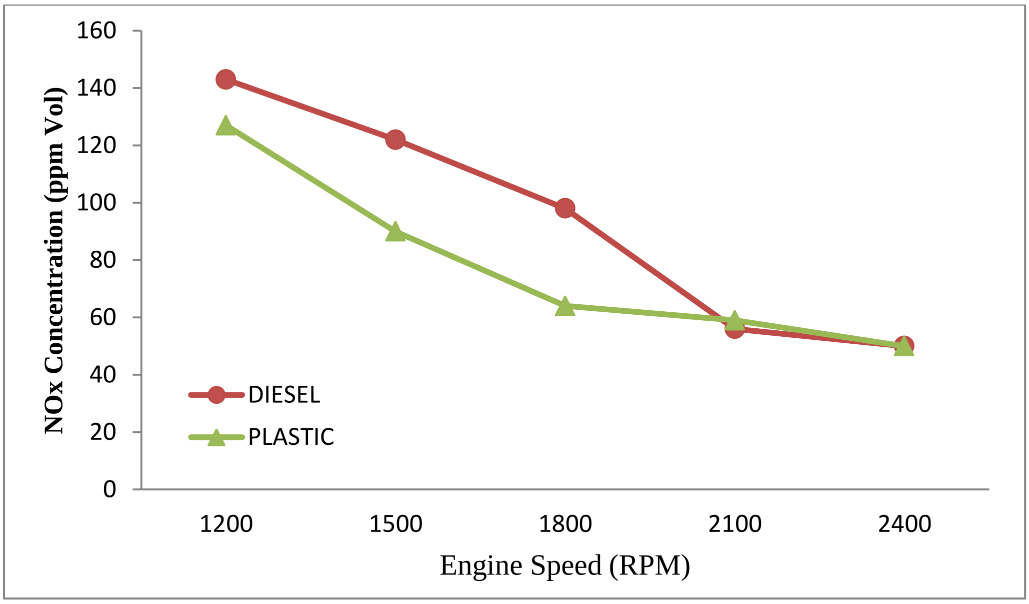
APPENDIX A2

Gantt chart for Final Year Project 2

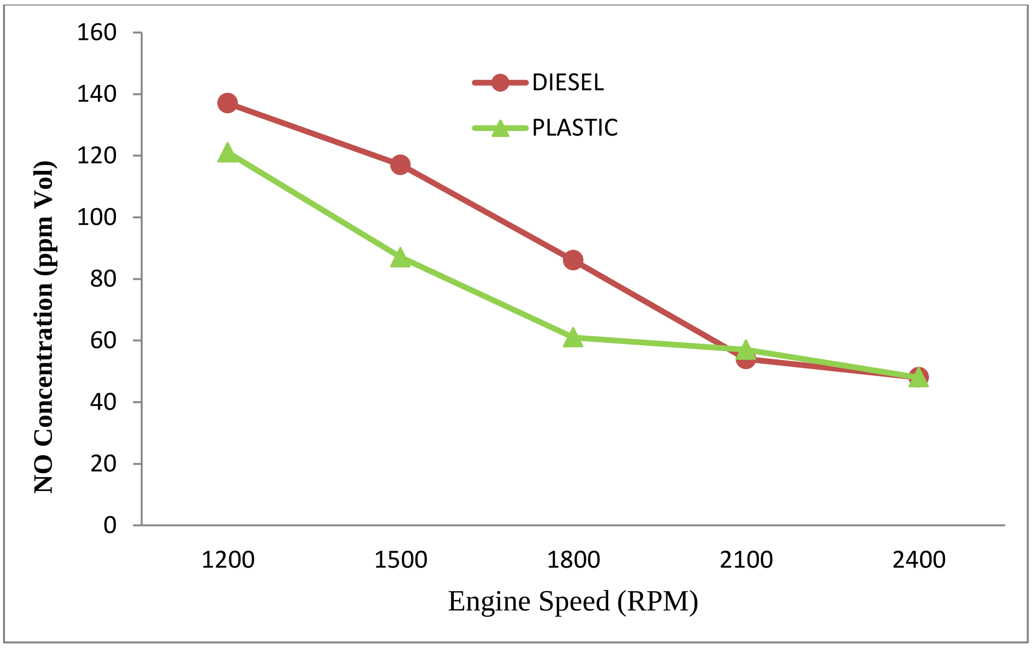


APPENDIX B

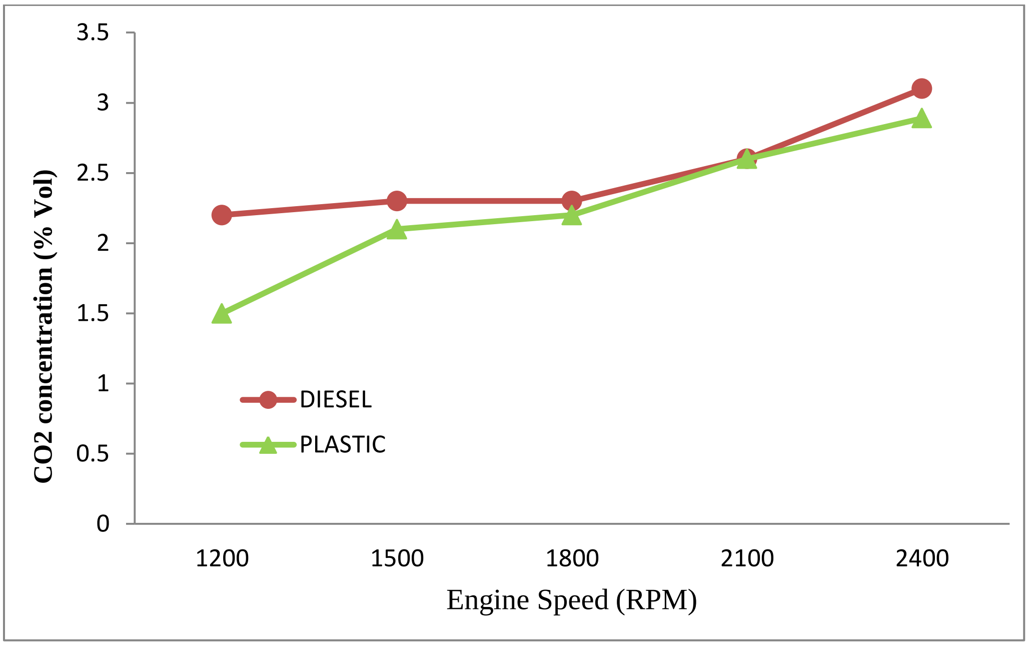
Result of Exhaust Gas Analyzer



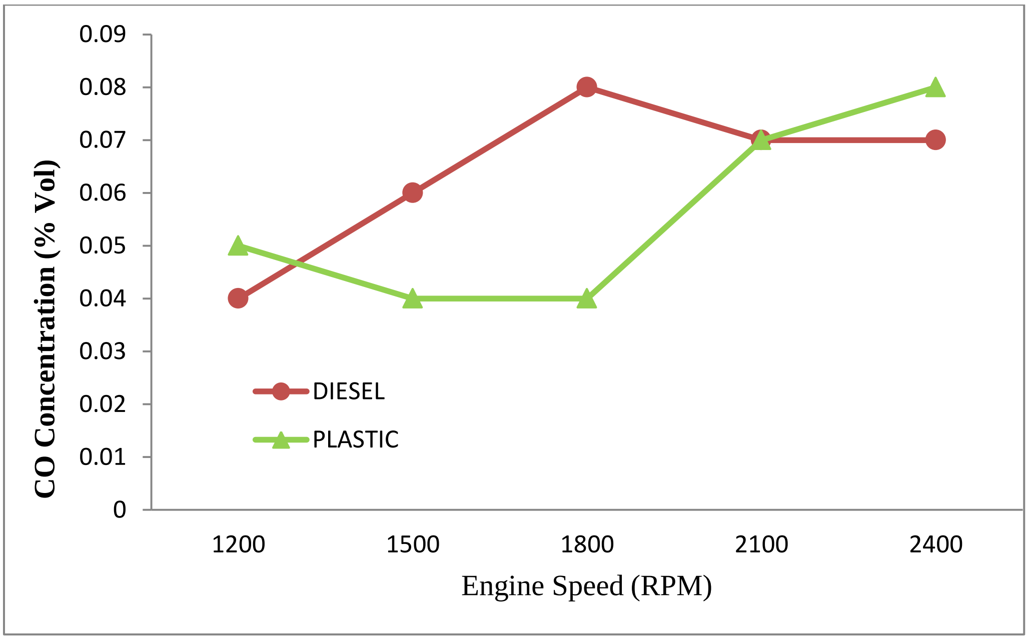
Graph 4.11: Nox versus engine speed (rpm)



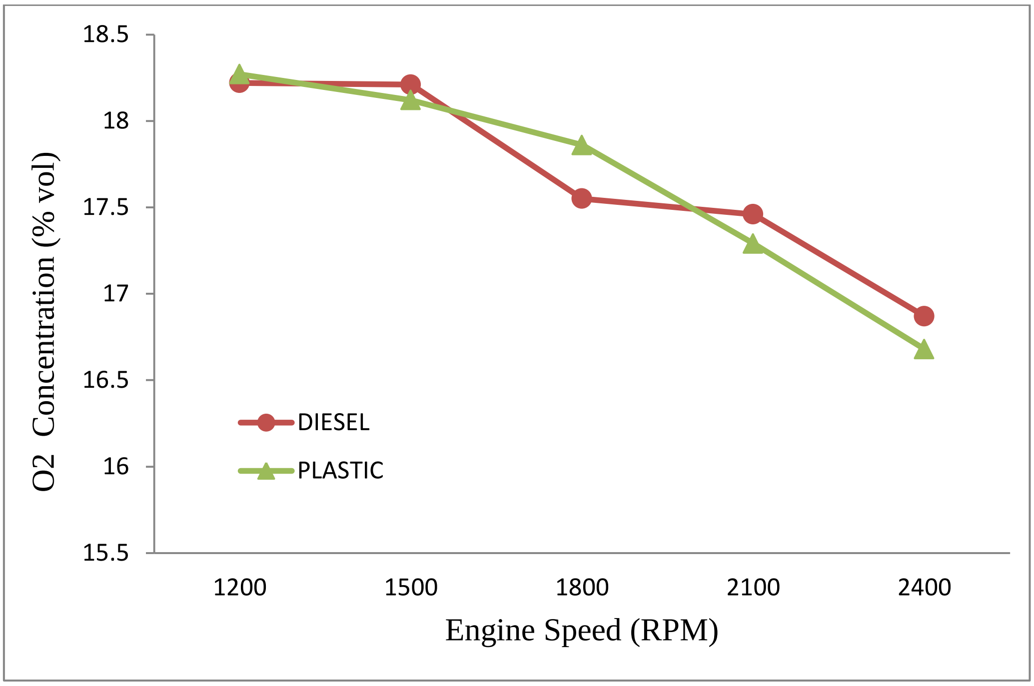
Graph 4.12: No versus engine speed (rpm)



Graph 4.13: CO_2 versus engine speed (rpm)



Graph 4.14: CO versus engine speed (rpm)



Graph 4.15: O_2 versus engine speed (rpm)

APPENDIX C

Particulate Matter under SEM

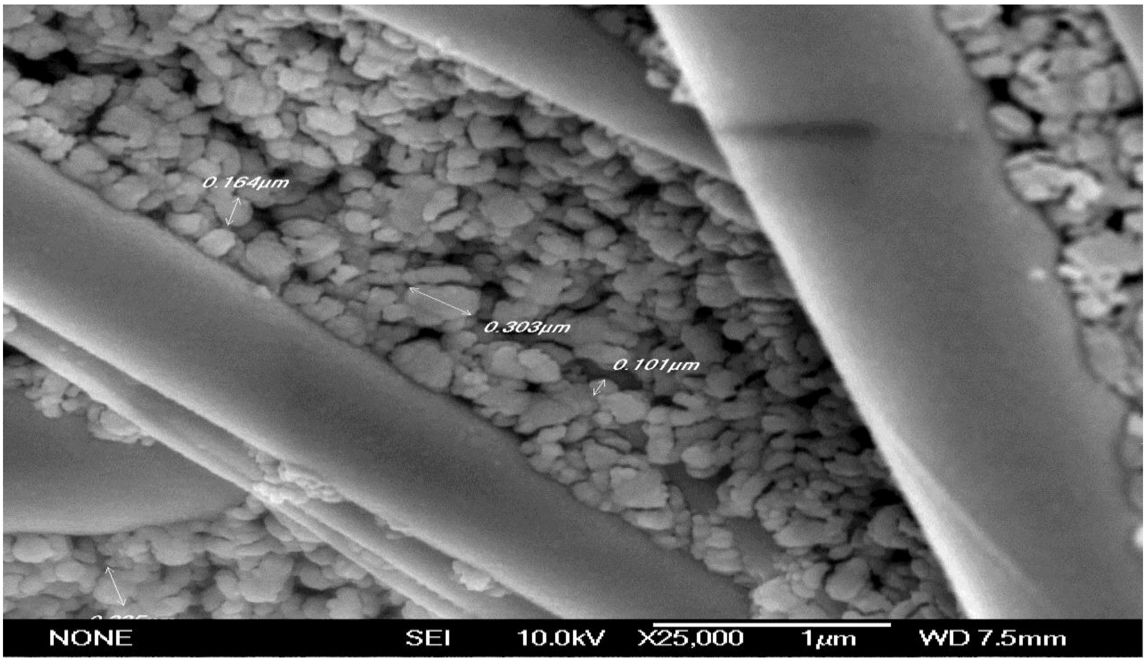


Figure 4.3 : Waste Plastic Fuel PM under SEM at 1200 rpm

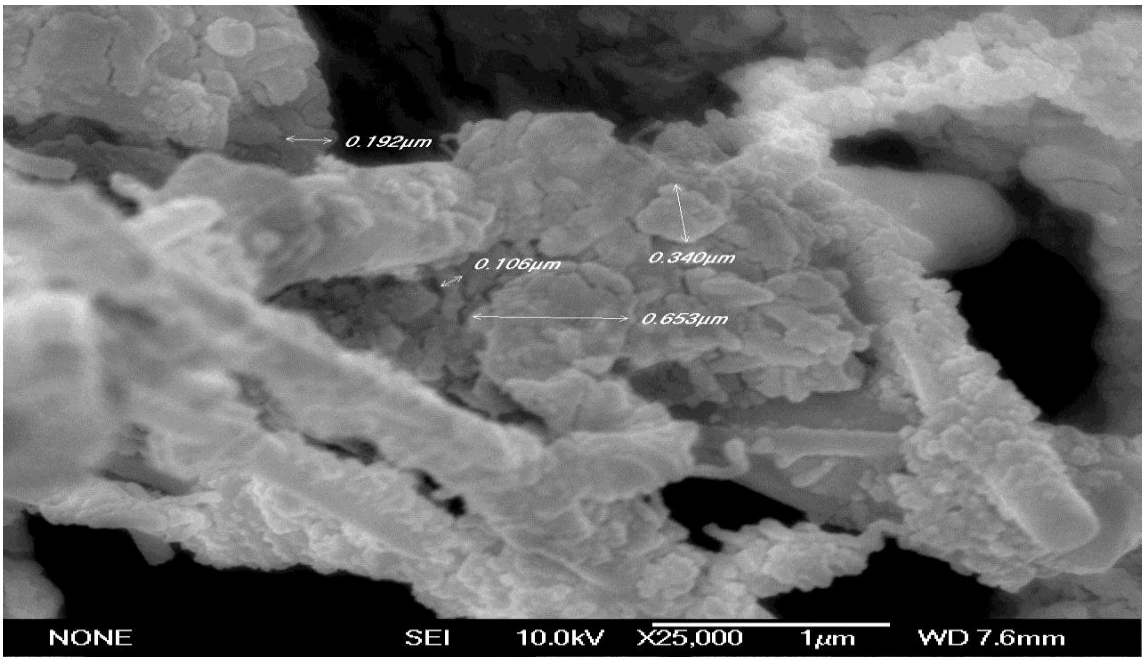


Figure 4.4 : Waste Plastic Fuel PM under SEM at 1500 rpm

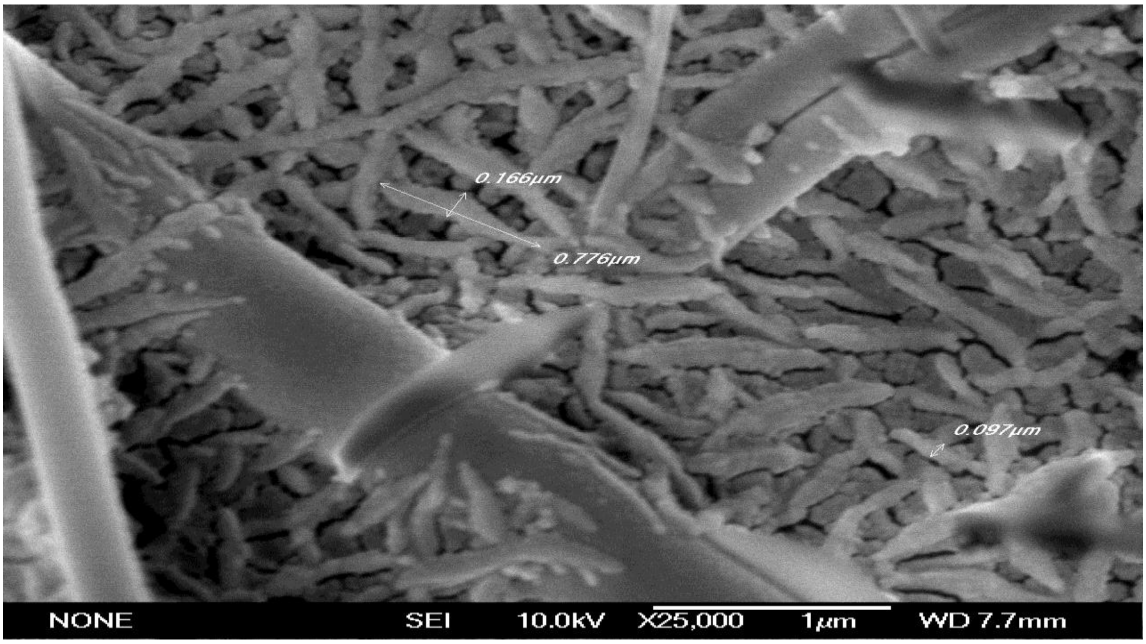


Figure 4.5 : Waste Plastic Fuel PM under SEM at 1800 rpm

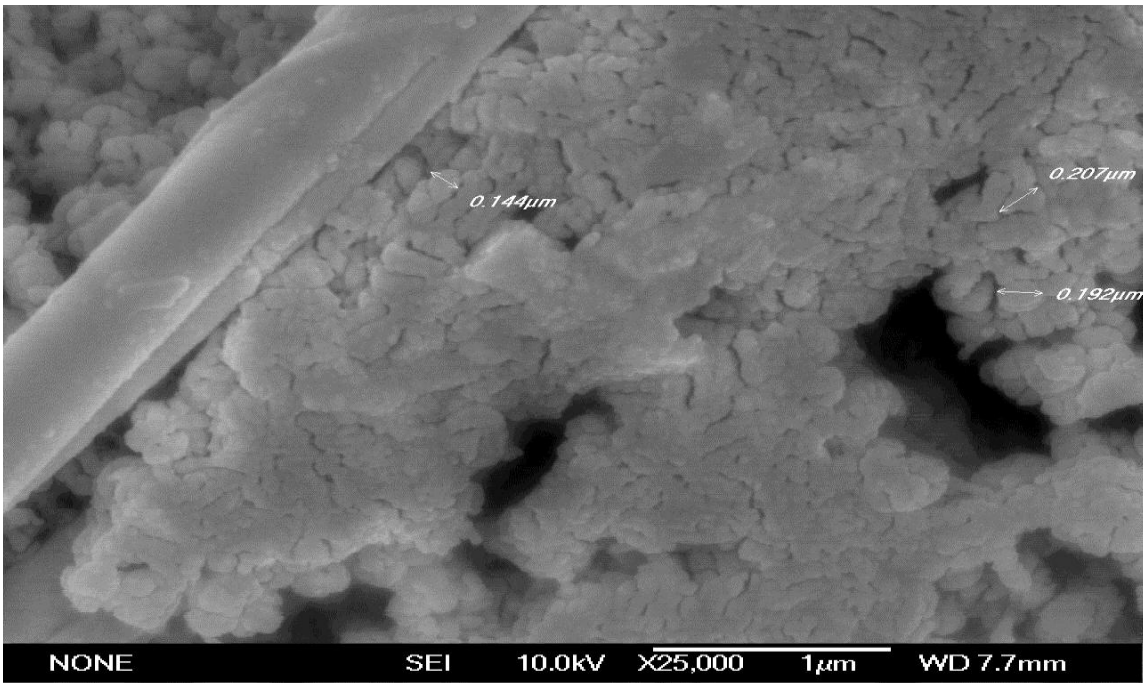


Figure 4.6 : Waste Plastic Fuel PM under SEM at 2400 rpm

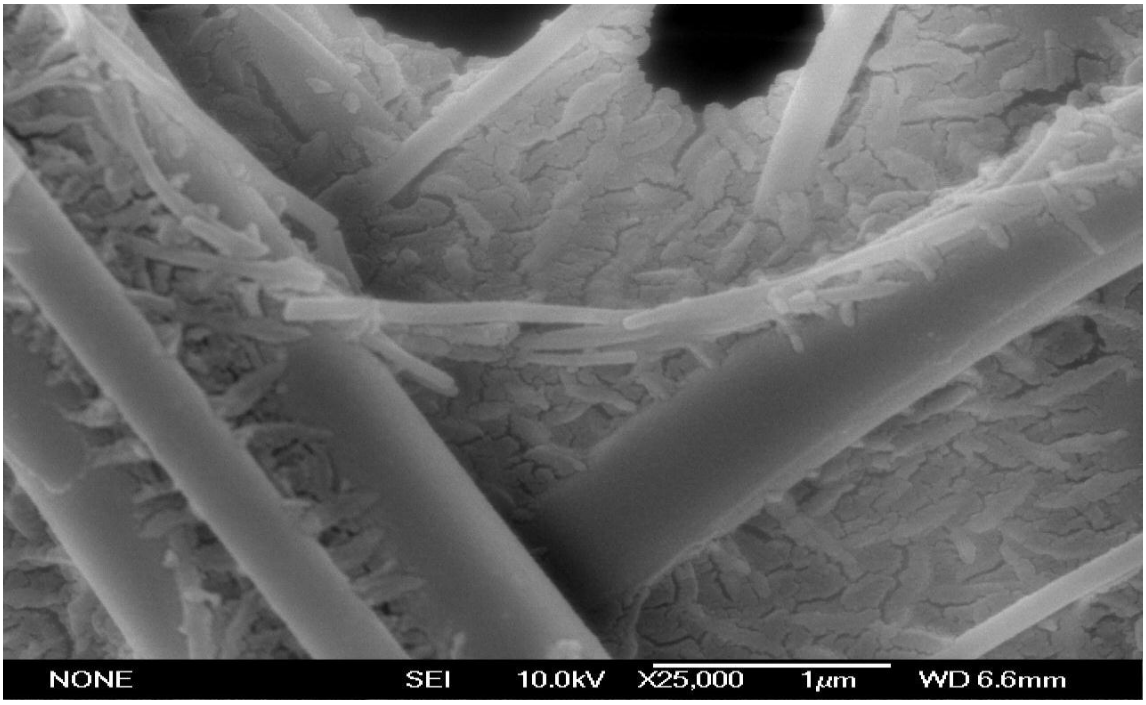


Figure 4.7 : Diesel Fuel PM under SEM at 1200 rpm

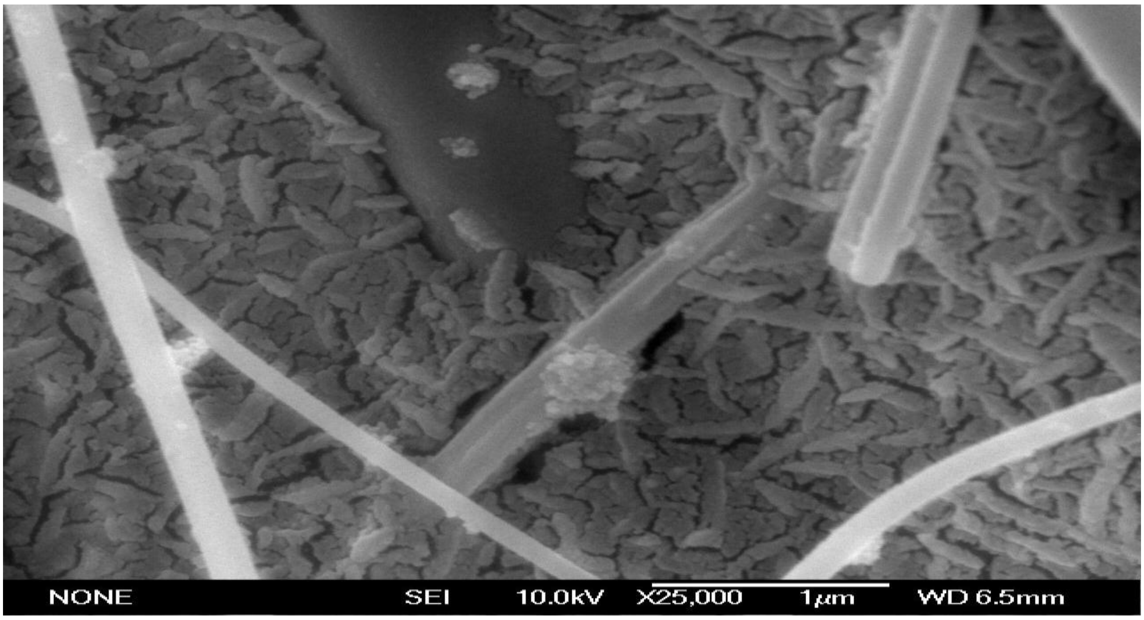


Figure 4.8 : Diesel Fuel PM under SEM at 1500 rpm

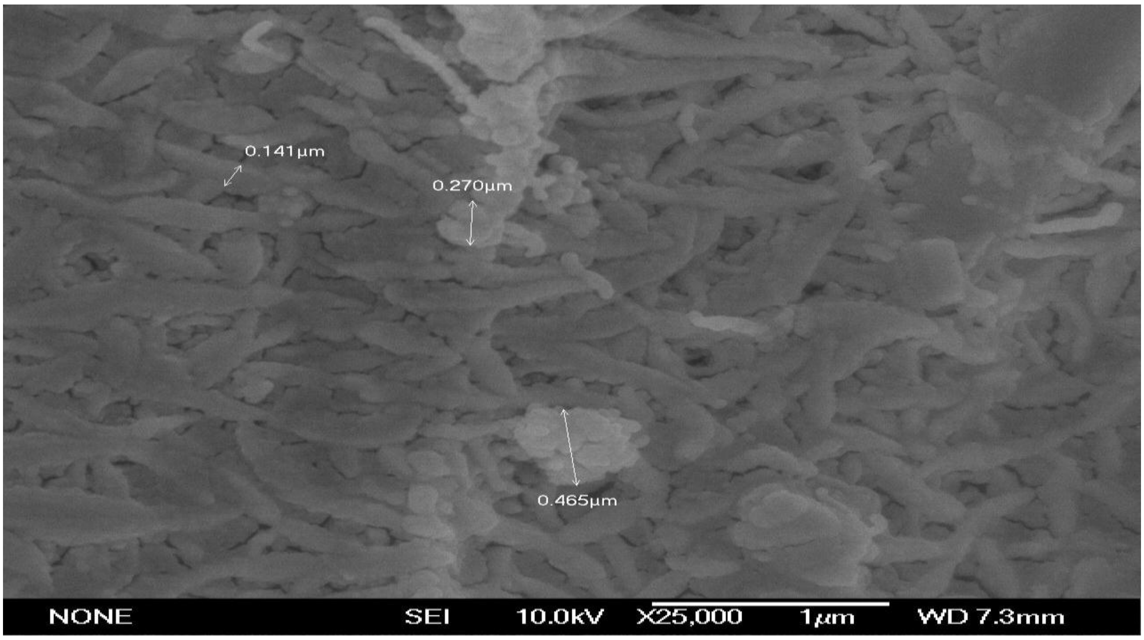


Figure 4.9 : Diesel Fuel PM under SEM at 1800 rpm

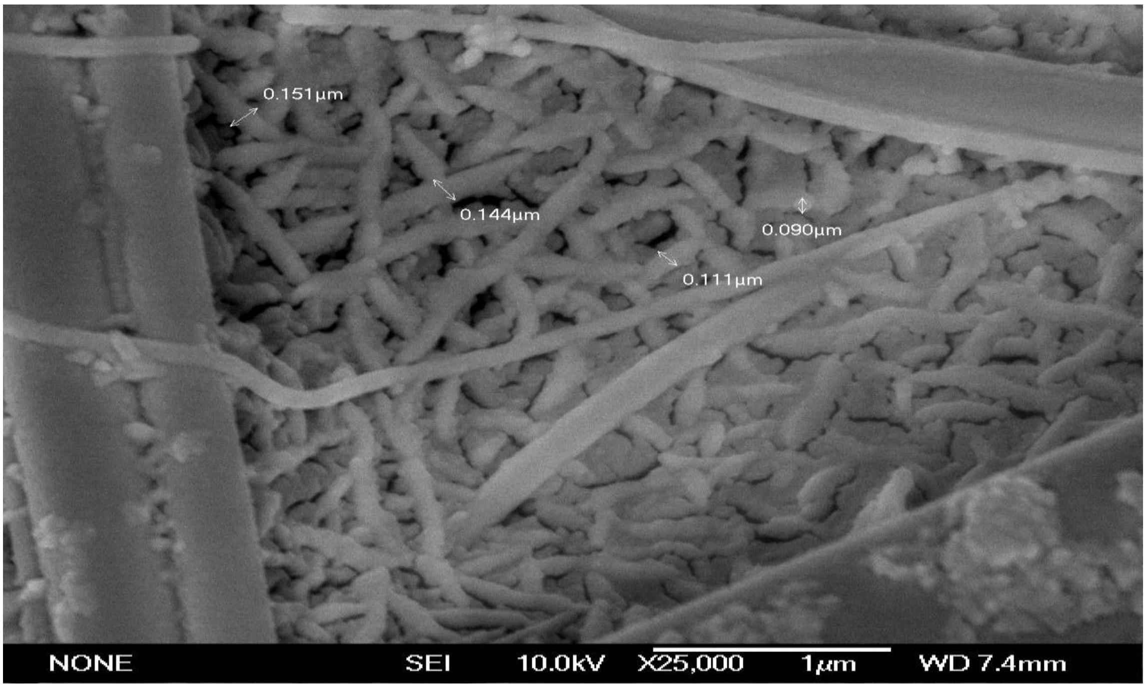


Figure 4.10 : Diesel Fuel PM under SEM at 2400 rpm