EXHAUST EMISSION OF SINGLE CYLINDER DIESEL ENGINE BY USING TIRE DISPOSAL FUEL

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FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "*Exhaust Emission of Single Cylinder Diesel Engine by Using Tire Disposal Fuel*" is written by *Mohd. Herzwan Bin Hamzah*. 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. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Engr. Zamri Bin Mohamed

Examiner Signature

EXHAUST EMISSION OF SINGLE CYLINDER DIESEL ENGINE BY USING TIRE DISPOSAL FUEL

MOHD. HERZWAN BIN HAMZAH

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

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

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 Engineering.

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Name of Supervisor : DR. AGUNG SUDRAJAD

Position : SENIOR LECTURER

Date : 06 DISEMBER 2010

STUDENT'S DECLARATION

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

Signature :

Name : MOHD. HERZWAN BIN HAMZAH

ID Number : MH 07061

Date : 06 DISEMBER 2010

“**In the name of ALLAH, the Most Beneficent, the Most Merciful**”

This report is dedicated to:

Beloved father and mother;

HAMZAH BIN MAJID

WAHIDAH BINTI HUSSIN

for your love, trust and support along my journey as a student. You are my source of inspiration and spirit for me along my study and life.

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ABSTRACT

This report deals with the emission of a single cylinder diesel engine and also the fuel consumption. The objectives of this report are to study the emission characteristics and the fuel consumption of a single cylinder diesel engine that are using tire scrap fuel compared to diesel fuel. This report describes the experimental setups and procedures for analyzing the emission characteristics and also the fuel consumption due to usage of the both fuels with the diesel engine running with no load exerted on it. The engine speed is variable. Detail studies about the experimental setup and components have been done before the experiment started. Data that are required for the analysis is obtained from the experiments. The fuel consumption is analyzed using the fuel flow meter and results for both fuel usages are compared in graph. The exhaust gas emission such as NO, NOx, CO, CO_2, and O_2 is analyzed using the exhaust gas analyzer and the results for both fuel usages are plotted in graph and compared. Calculations and analysis have been done after all the required data needed for the report is obtained. The results from the experiment show that the diesel fuel is better than tire scrap fuel in term of fuel consumption, CO emissions and CO_2 emissions and vice versa for the other parameters.

ABSTRAK

Laporan ini membentangkan hasil eksperimen berkaitan pembebasan asap dari enjin diesel silinder tunggal dan juga penggunaan bahan bakar. Tujuan laporan ini adalah untuk mempelajari ciri-ciri pembebasan asap dan penggunaan bahan bakar enjin diesel satu silinder yang menggunakan bahan bakar ban bekas dibandingkan dengan minyak diesel. Laporan ini menjelaskan setup dan prosedur eksperimen untuk menganalisis ciri-ciri pembebasan asap dan juga penggunaan bahan bakar oleh penggunaan kedua-dua bahan bakar dengan mesin diesel bekerja dengan tanpa beban dikenakan padanya. Kelajuan enjin adalah diubah-ubah. Kajian tentang setup dan dan prosedur eksperimen telah dilakukan sebelum eksperimen dilakukan. Data yang diperlukan untuk analisis diperolehi daripada eksperimen. Kadar penggunaan bahan bakar dianalisis menggunakan meter aliran bahan bakar dan keputusan untuk kedua-dua penggunaan bahan bakar berbanding dalam graf. Pembebasan gas buang gas seperti NO, NOx, CO, CO_2, dan O_2 dianalisis dengan menggunakan alat penganalisis gas dan keputusan untuk kedua-dua penggunaan bahan bakar diplot dalam graf dan dibandingkan. Pengiraan dan analisis telah dilakukan selepas semua data yang diperlukan yang diperlukan untuk laporan tersebut diperolehi. Hasil dari kajian ini menunjukkan bahawa bahan bakar diesel lebih baik daripada bahan bakar ban bekas dalam penggunaan bahan bakar, pembebasan gas CO dan pembebasan gas CO_2 dan sebaliknya untuk parameter yang lain.

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LIST OF ABBREVIATIONS

BHP	Brake horsepower
CO	Carbon monoxide
CO_2	Carbon dioxide
CSBR	Conical spouted bed reactor
DF	Diesel fuel
DI	Direct injection
DTPO	Distilled tire pyrolysis oil
H_2O	Water
HC	Hydrocarbon
MIG	Metal inert gas
NH_3	Ammonia
NO	Nitrogen monoxide
NO_x	Oxides of nitrogen
O_2	Oxygen
RPM	Revolution per minute
SOF	Soluble organic fraction
TDC	Top dead centre
TPO	Tire pyrolysis oil
WOT	Wide open throttle

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter discussed about the overall project background such as problem statement, objectives and scopes of the project. All the information is important to start this project. This project is focused on study about exhaust emission of single cylinder diesel engine that using tire disposal fuel.

1.2 PROJECT BACKGROUND

Tire disposal fuel is a type of fuel that is formed from used type by pyrolysis process. The pyrolysis process is the thermal degradation of waste in the absence of oxygen at elevated temperatures and pressures. The process is carried out at temperatures typically upwards of 430 °C. In practice, it is not possible to achieve a completely oxygen-free environment and so a small amount of oxidation occurs. The products of pyrolysis (from organic waste) are gases, small quantities of liquid, and a solid residue containing carbon and ash. The gases produced in the process can then be used to provide the heating energy for continuing the process.

The tire pyrolysis process essentially returns the high heating value of the rubber and oils that were initially used in the manufacture of the tires. By carefully controlling the temperature, pressure and oxygen level more pyrolysis oil and charcoal is encouraged. This pyrolysis oil can then be used as a replacement diesel fuel.

The main apparatus that are used for this project is a diesel engine type YANMAR TF120 model that is single cylinder with 638cc of displacement. The other specifications of this engine are it has 12 BHP of output and 10.5 BHP of continuous output. Its cooling system use water cooled cooling systems with radiator. This engine also uses direct fuel injection with a high pressure Bosch pump.

The basic characteristics of diesel engine are it is a four stroke, compression-ignition engine which the fuel and air are mixed inside the engine. The air required for combustion is highly compressed inside the combustion chamber. This generates high temperatures which are sufficient for the diesel fuel to spontaneously ignite when it is injected to the cylinder. The diesel engine thus uses heat to release the chemical energy contained within the diesel fuel and convert it into mechanical forces.

This project is focused on emission characteristic of diesel engine when tire disposal fuel is used compared to ordinary diesel fuel. Fuel consumption for both fuel usages are also calculated and compared.

1.4 PROBLEM STATEMENT

Nowadays, with the increase of usage of motorized vehicle, the production of scrap tires also increased. Chuan (2006) states that Malaysia generates about 150,000 tons of scrap tires every year. The numbers are expected to be increase due to increasing number of vehicles. If the scrap tires are not managed well, the scrap tires can give bad effect to environment and people's health.

One of the solutions that are available for this problem is recycling the scrap tires into useable product such as fuel. The production of this tire disposal fuel is done by pyrolysis process. The problem of this fuel usage to engine is the effect of usage of this fuel is unknown. The emission characteristic of an engine that are using this fuel is about to be analyzed in this report and also the fuel consumption.

1.5 PROJECT SCOPES

The scopes of this project are to analyze the gas emission characteristic of a diesel engine such as NO, NO_x, CO, CO_2 and O_2 which is using tire disposal fuel compared to ordinary diesel fuel. The fuel consumption of the engine that is running at several speeds with no load exerted to it are also analyzed and compared for both fuel usages.

1.6 PROJECT OBJECTIVES

The objectives of this project are to analyze the fuel consumption and the emission characteristic of a single cylinder diesel engine that are using tire disposal fuel compared to usage of ordinary diesel that are available in the market. Tire disposal fuel formed from pyrolyis process that it can be used as an alternative to ordinary diesel fuel usage but the effect of usage of this fuel is unknown. This project is conducted to analyze the emission like NO, NO_x, CO_2, and other emission gas and it is compared to the emission of the engine when diesel fuel is used. The fuel consumption of the engine due to usage of both fuel are also compared and analyzed. The engine will run without load exerted to it.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter described about the information which related to the project such as Internal Combustion Engine, Tire Disposal Fuel, characteristics of Diesel fuel and also the emission.

2.2 TYRE DISPOSAL OIL

This oil is produced from scrap tires through pyrolysis process. The simple diagram in producing this oil is shown below:

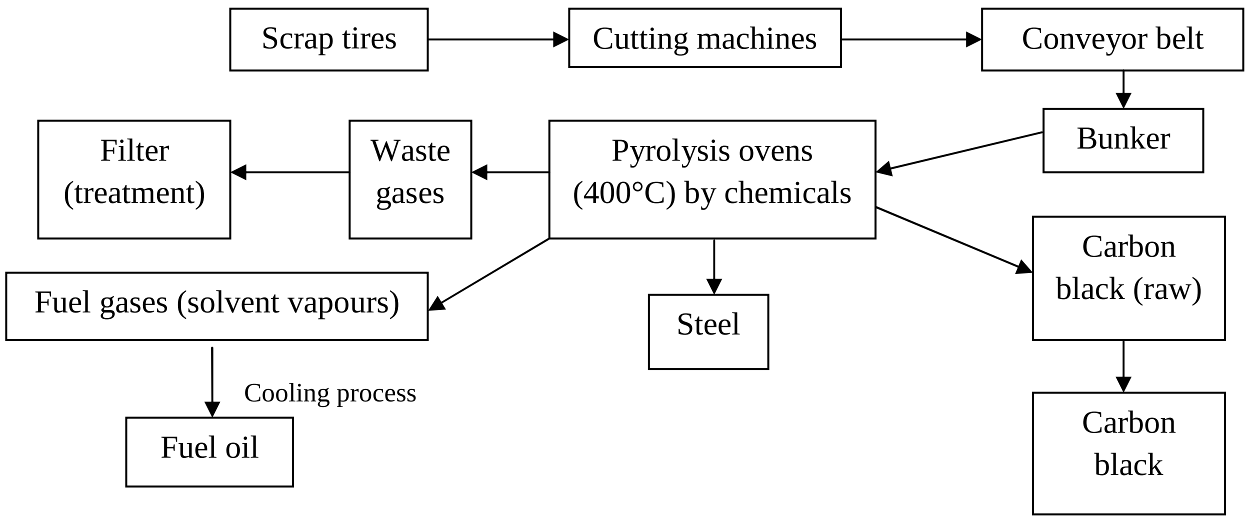

Figure 2.1: Pyrolysis process flow diagram

Source: Murugan et al. (2008)

Figure 2.2: Tire disposal fuel

Appearance and properties:

- Black in color.
- Strong “burned rubber” smell.
- Lead (ppm): 0.3
- Volatile matter, at 105°C at 2 hours: 20.4
- Flash point: 42°C
- Density: 747.5 kg/m^3
- Kinematic viscosity: 0. 000108109 m^2/s

From Murugan et al. (2008), explained about increase in energy demand, stringent emission norms and depletion of oil resources that led the researchers to find alternative fuels for internal combustion engines. Many alternate fuels like Alcohols, Biodiesel, LPG, CNG etc have been already commercialised in the transport sector. In this context, pyrolysis of solid waste is currently receiving renewed interest. The disposal of waste tyres can be simplified to some extent by pyrolysis. The properties of the Tyre pyrolysis oil (TPO) derived from waste automobile tyres were analysed and compared with the petroleum products. The crude TPO has a higher viscosity and sulphur content compared to diesel fuel. Early investigations reveal that TPO blended with diesel could be used as an alternate fuel for diesel engines. The maximum TPO concentration in the TPO-diesel blend was 70 % and the engine failed to operate satisfactorily beyond this concentration. An experiment have been conducted to study on the performance, emission and combustion characteristics of a single cylinder four stroke air cooled DI diesel engine running with the Distilled Tyre pyrolysis oil–diesel blends at higher concentrations From the experiment that have been conducted, it shown that engine is able to run upto 90% DTPO and 10% DF (DTPO90) and failed to run satisfactorily with 100 % DTPO. Brake thermal efficiency increases with increase in percentage of DTPO blends but lesser than DF. About 3 % drop in the thermal efficiency is noticed. NO_x is lower by about 21 % for DTPO80 and 18 % lower in DTPO90 operation than that of DF operation. HC and CO are higher than DF. This may be due to the presence of unsaturated hydrocarbon in the DTPO. Smoke is higher for DTPO-DF blends compared to DF.

From Arabiourrutia et al. (1995), explained about the problem of world production waste tires that amounts to 5×10^6 tones/year. While in Europe, 2×10^6 tones are produced and 2.5×10^6 tones in North America and lastly 0.5×10^6 tones in Japan, as has been reported by Galvagno et al. (2002). The complex nature of tires makes them difficult to recycle. Different alternatives for tire recycling such as retreading, reclaiming, incineration, grinding, etc. have been used. However, all have significant drawbacks and/or limitations. Pyrolysis can be considered a non-conventional method for tire recycling which is currently receiving renewed attention. In the pyrolysis process (heating without oxygen), the organic volatile matter of tires (mainly the rubber polymer/s) is decomposed to lower molecular weight products, liquids or gases, which can be useful as fuels or as a source of chemicals. The inorganic components (mainly steel) and the non-volatile carbon black remain as a solid residue, as has been demonstrated by Laresgoiti et al. (2000) tires. In his paper, a study is carried out on the performance of a conical spouted bed reactor (CSBR) for the pyrolysis of scrap Previous studies have proven that this reactor is especially suitable for the treatment of materials that are irregular or of sticky nature. Thus, benzyl alcohol polymerization (Olazar et al., 1994), pyrolysis of biomass (Aguado et al., 2000; Olazar et al., 2000) and pyrolysis of waste plastics (Aguado et al., 2002, 2003) have carried out successfully. Versatility in the gas residence time (from 20 ms to a few seconds) and turbulent gas–solid contact are the main features of this reactor. The conical spouted bed reactor (CSBR) is an interesting technology for the pyrolysis of scrap tires, due to its excellent hydrodynamic qualities and to the efficient heat transfer between phases of the spouted bed, apart from other characteristics of the conical geometry of the reactor, such as its versatility in gas and solid flow rates under stable and isothermal conditions in the bed. Moreover, pyrolysis in a CSBR does not have problems related to particle fusion of agglomerate formation, and it only requires a small amount of sand to help solid flow.

From Zabaniotou et al. (2003) described that in the present study the rubber portion of used car tires was transformed by atmospheric pyrolysis into oil, gas and char. The experiments have been performed in a captive sample reactor at atmospheric pressure, under helium atmosphere. The effect of temperature on the products yield was investigated. In a second step, alternative uses of pyrolysis char such as combustion, gasification and active carbons preparation were examined, in order to produce fuels and high added value materials. First, pyrolysis char was burned and its reactivity was measured in function with pyrolysis temperature. Second, char was gasified with Steam and CO_2 to produce fuel gases, in a tubular stainless steel reactor. It was also activated to produce high added value materials. It was shown that tire chars present higher reactivity with steam than with CO_2 and also active carbons produced from tire chars possess surface areas, comparable with those of commercially available active carbons.

Property	**Diesel**	**Crude TPO**	**DTPO**	**DTPO80**	**DTPO90**
Density at 15°C kg / m^3	830	935	871	860	865
Kinematic viscosity @ 40 °C	2	3.2	1.7	1.76	1.73
Gross Calorific Value MJ / kg	46.5	42.83	45.78	45.9	45.8
Flash Point, ^{0}C	50	43	36	39	37
Fire Point, ^{0}C	56	50	48	49	48
Sulphur Content, %	0.045	0.95	0.26	0.21	0.23
Ash Content, %	0.01	0.31	-	-	-
Carbon Residue, %	0.35	2.14	0.02	-	-
Aromatic content, %	26	64	-	-	-

Table 2.1: Comparison of DTPO and its blends with Diesel

Source: Murugan (2008)

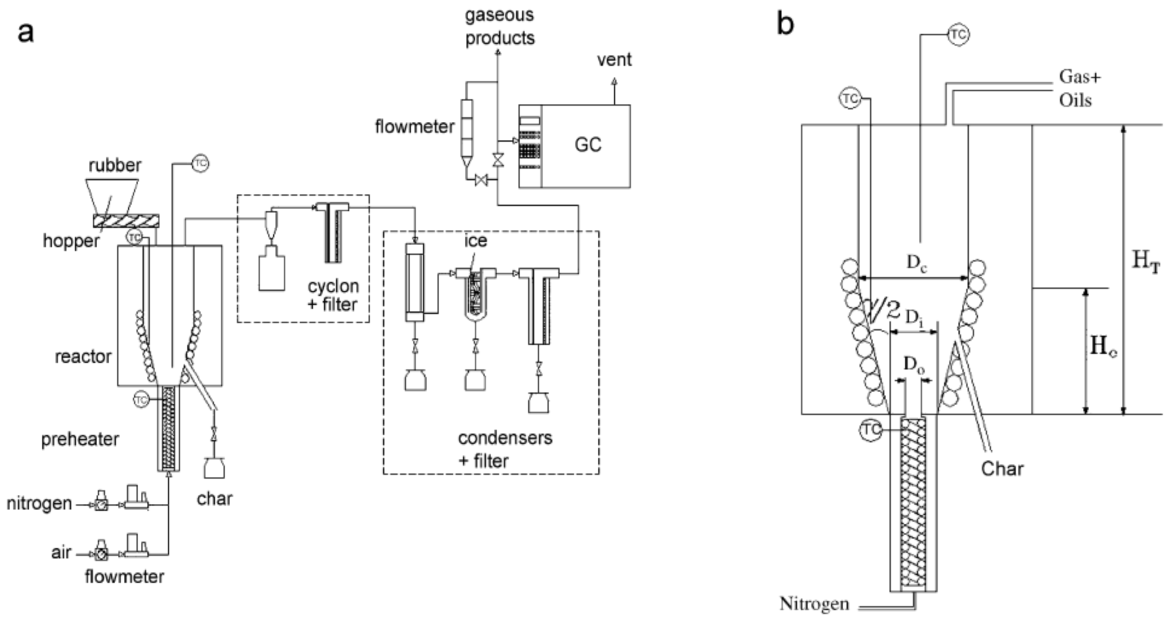

Figure 2.3: (a) Scheme of the pilot plant. (b) Scheme of the spouted bed reactor

Source: Arabiourrutia (1995)

2.3 CHARACTERISTIC OF DIESEL ENGINE

2.3.1 History of Diesel Engine

Bosch (2005) stated that the diesel cycle was invented by Rudolf Diesel and it has the highest thermal efficiency of any internal or external combustion engine, mostly due to its very high compression ratio. Low-speed diesel engines (as used in ships and other applications where overall engine weight is relatively unimportant) often have a thermal efficiency which exceeds 50%.

Diesel engines are manufactured in two stroke and four stroke versions. They were originally used as a more efficient replacement for stationary steam engines. Since the 1910s they have been used in submarines and ships. Use in locomotives, large trucks and electric generating plants followed later.

In the 1930s, they slowly began to be used in a few automobiles. Since the 1970s, the use of diesel engines in larger on-road and off-road vehicles in the USA increased. As of 2007, about 50 percent of all new car sales in Europe are diesel.

2.3.2 Basic Principles of the Diesel Engine

Holt D. J (2004) stated that the diesel engine is a four-stroke, compression-ignition engine in which the fuel and air are mixed inside the engine. The air required for combustion is highly compressed inside the combustion chamber. This generates high temperatures which are sufficient for the diesel fuel to spontaneously ignite when it is injected to the cylinder. The diesel engine thus uses heat to release the chemical energy contained within the diesel fuel and convert it into mechanical force.

4 Stroke cycle

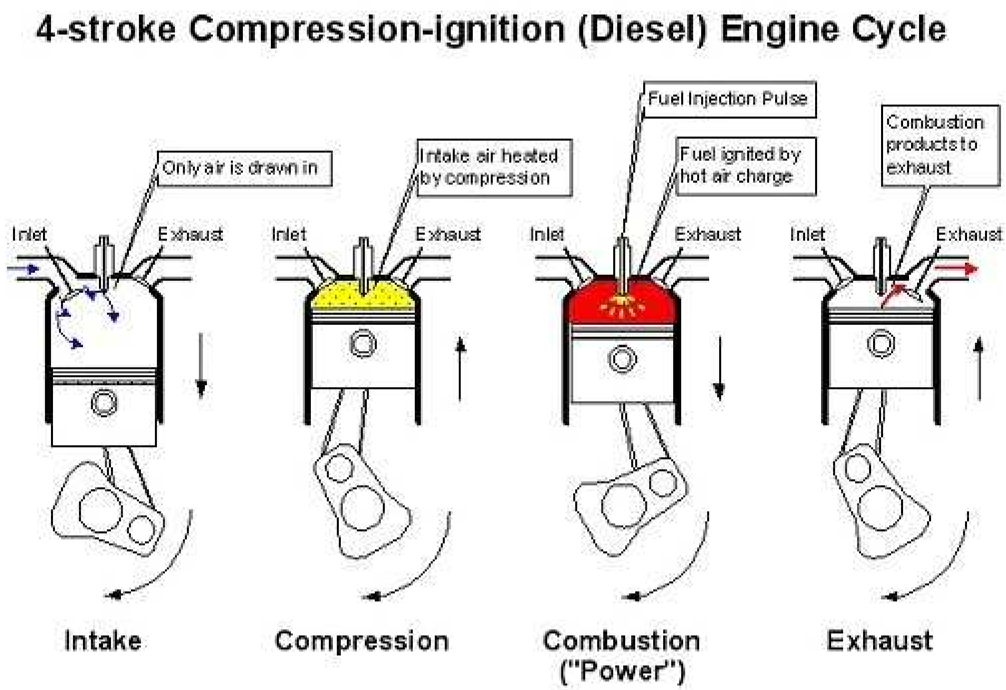

Figure 2.4: Four stroke cycle diagram

Source: Holt D. J (2004)

Stroke 1 of 4 "Intake": On the *intake* or *induction* stroke of the piston, the piston descends from the top of the cylinder to the bottom of the cylinder, reducing the pressure inside the cylinder. Air is forced by atmospheric (or greater) pressure into the cylinder through the intake port. The intake valve(s) then close.

Stroke 2 of 4 "Compression": With both intake and exhaust valves closed, the piston returns to the top of the cylinder compressing the fuel-air mixture. This is known as the *compression* stroke.

Stroke 3 of 4 "Power": While the piston is at or close to Top Dead Center, the fuel is injected into the combustion chamber and ignited by the heat and pressure of compression (for a diesel cycle or compression ignition engine). The resulting massive pressure from the combustion of the compressed fuel-air mixture drives the piston back down toward bottom dead center with tremendous force. This is known as the *power* stroke, which is the main source of the engine's torque and power.

Stroke 4 of 4 "Blow": During the *exhaust* stroke, the piston once again returns to top dead center while the exhaust valve is open. This action evacuates the products of combustion from the cylinder by pushing the spent fuel-air mixture through the exhaust valve(s).

2.3.3 Design and Engineering Principles of Diesel Engine

The design and engineering principle of the diesel engine are explained in the descriptions below (Bosch, 2005):

<u>Fuel octane rating</u>

Internal combustion engine power primarily originates from the expansion of gases in the power stroke. Compressing the fuel and air into a very small space increases the efficiency of the power stroke, but increasing the cylinder compression ratio also increases the heating of the fuel as the mixture is compressed

A highly flammable fuel with a low self-ignition temperature can combust before the cylinder reaches top-dead-center (TDC), potentially forcing the piston backwards against rotation. Alternately, a fuel which self-ignites at TDC but before the cylinder has started downwards can damage the piston and cylinder due to the extreme thermal energy concentrated into a very small space with no relief. This damage is often referred to as engine knocking and can lead to permanent engine damage if it occurs frequently.

The octane rating is a measure of the fuel's resistance to self-ignition, by increasing the temperature at which it will self-ignite. A fuel with a greater octane rating allows for a much higher compression ratio without the risk of damage due to self-ignition.

Diesel engines rely on self-ignition for the engine to function. They solve the engine damage problem by separately injecting high-pressure fuel into the cylinder shortly before the piston has reached TDC. Air without fuel can be compressed to a very high degree without concern for self-ignition, and the highly pressurized fuel in the fuel injection system cannot ignite without the presence of air.

Power output limit

The maximum amount of power generated by an engine is determined by the maximum amount of air ingested. The amount of power generated by a piston engine is related to its size (cylinder volume), whether it is a two-stroke or four-stroke design, volumetric efficiency, losses, air-to-fuel ratio, the calorific value of the fuel, oxygen content of the air and speed (RPM). The speed is ultimately limited by material strength and lubrication. Valves, pistons and connecting rods suffer severe acceleration forces.

At high engine speed, physical breakage and piston ring flutter can occur, resulting in power loss or even engine destruction. Piston ring flutter occurs when the rings oscillate vertically within the piston grooves they reside in. Ring flutter compromises the seal between the ring and the cylinder wall which results in a loss of cylinder pressure and power. If an engine spins too quickly, valve springs cannot act quickly enough to close the valves. This is commonly referred to as 'valve float', and it can result in piston to valve contact, severely damaging the engine. At high speeds the lubrication of piston cylinder wall interface tends to break down. This limits the piston speed for industrial engines to about 10 m/sec.

Intake/exhaust port flow

The output power of an engine is dependent on the ability of intake (air–fuel mixture) and exhaust matter to move quickly through valve ports, typically located in the cylinder head. To increase an engine's output power, irregularities in the intake and exhaust paths, such as casting flaws, can be removed, and, with the aid of an air flow bench, the radii of valve port turns and valve seat configuration can be modified to reduce resistance. This process is called porting, and it can be done by hand or with a CNC machine.

Supercharging

One way to increase engine power is to force more air into the cylinder so that more power can be produced from each power stroke. This was originally done using a type of air compression device known as a Supercharger which is powered by the engine crankshaft.

Supercharging increases the power output limits of four-stroke engine, but the supercharger is always running. Continuous compression of the intake air requires some mechanical energy to accomplish, so the supercharger has a cost of reduced fuel efficiency when the engine is operating at low power levels or when the engine is simply unloaded and idling.

Turbocharging

The Turbocharger was designed as a part-time method of compressing more air into the cylinder head. It consists of a two piece, high-speed turbine assembly with one side that compresses the intake air, and the other side that is powered by the exhaust gas outflow.

When idling, and at low-to-moderate speeds, the turbocharger is not engaged and the engine operates in a naturally-aspirated manner. When much more power output is required, the engine speed is increased until the exhaust gases are sufficient to 'spin up' the turbocharger's turbine to start compressing much more air than normal into the intake manifold.

Turbo charging allows for more efficient engine operation at low-to-moderate speeds, but there is a design limitation known as turbo lag. The increased engine power is not immediately available; due to the need to sharply increase engine RPM to spin up the turbo, before the turbo starts to do any useful air compression.

Rod and piston-to-stroke ratio

The rod-to-stroke ratio is the ratio of the length of the connecting rod to the length of the piston stroke. A longer rod will reduce the sidewise pressure of the piston on the cylinder wall and the stress forces, hence increasing engine life. It also increases cost and engine height and weight.

A "square engine" is an engine with a bore diameter equal to its stroke length. An engine where the bore diameter is larger than its stroke length is an oversquare engine; conversely, an engine with a bore diameter that is smaller than its stroke length is an undersquare engine.

Valve train

The valves are typically operated by a camshaft rotating at half the speed of the crankshaft. It has a series of cams along its length, each designed to open a valve during the appropriate part of an intake or exhaust stroke. A tappet between valve and cam is a contact surface on which the cam slides to open the valve.

Many engines use one or more camshafts “above” a row (or each row) of cylinders, as in the illustration, in which each cam directly actuates a valve through a flat tappet. In other engine designs the camshaft is in the crankcase, in which case each cam contacts a push rod, which contacts a rocker arm which opens a valve. The overhead cam design typically allows higher engine speeds because it provides the most direct path between cam and valve.

Valve clearance

Valve clearance refers to the small gap between a valve lifter and a valve stem that ensures that the valve completely closes. On engines with mechanical valve adjustment excessive clearance will cause noise from the valve train. Typically the clearance has to be readjusted each 20,000 miles with a feeler gauge.

Most modern production engines use hydraulic lifters to automatically compensate for valve train component wear. Dirty engine oil may cause lifter failure.

Energy balance

Otto engines are about 35% efficient – in other words, 35% of the energy generated by combustion is converted into useful rotational energy at the output shaft of the engine, while the remainder appears as waste heat. By contrast, a six-stroke engine may convert more than 50% of the energy of combustion into useful rotational energy.

Modern engines are often intentionally built to be slightly less efficient than they could otherwise be. This is necessary for emission controls such as exhaust gas recirculation and catalytic converters that reduce smog and other atmospheric pollutants. Reductions in efficiency may be counteracted with an engine control unit using lean burn techniques.

Major advantages

Diesel engines have several advantages over other internal combustion engines:

- They burn less fuel than a petrol engine performing the same work, due to the engine's higher temperature of combustion and greater expansion ratio. Gasoline engines are typically 25% efficient while diesel engines can convert over 30% of the fuel energy into mechanical energy.
- They have no high-tension electrical ignition system to attend to, resulting in high reliability and easy adaptation to damp environments. The absence of coils, spark plug wires, etc., also eliminates a source of radio frequency emissions which can interfere with navigation and communication equipment, which is especially important in marine and aircraft applications.
- They can deliver much more of their rated power on a continuous basis than a petrol engine.
- The life of a diesel engine is generally about twice as long as that of a petrol engine due to the increased strength of parts used, also because diesel fuel has better lubrication properties than petrol.

- Diesel fuel is considered safer than petrol in many applications. Although diesel fuel will burn in open air using a wick, it will not explode and does not release a large amount of flammable vapor. The low vapor pressure of diesel is especially advantageous in marine applications, where the accumulation of explosive fuel-air mixtures is a particular hazard.
- For any given partial load the fuel efficiency (mass burned per energy produced) of a diesel engine remains nearly constant, as opposed to petrol and turbine engines which use proportionally more fuel with partial power outputs.
- They generate less waste heat in cooling and exhaust.
- With a diesel, boost pressure is limited only by the strength of the engine components, not predetonation of the fuel charge as in petrol engines.
- The carbon monoxide content of the exhaust is minimal; therefore diesel engines are used in underground mines.
- Biodiesel is an easily synthesized, non-petroleum-based fuel (through the Fischer–Tropsch process) which can run directly in diesel engines, while gasoline engines either need adaptation to run synthetic fuels or else use them as an additive to gasoline (e.g., ethanol added to gasohol), making diesel engines the clearly preferred choice for sustainability.

2.4 DIESEL FUEL CHARACTERISTICS

High-quality diesel fuels are characterized by the following features (Challen and Baranescu, 1999):

- High cetane number
- Relatively low final boiling point
- Narrow density and viscosity spread.
- Low aromatic compounds (particularly polyaromatic compounds) content
- Low sulfur content.

In addition, the following characteristic are particularly important for the service life and constant function of fuel-injection systems.

- Good lubricity
- Absence of free water
- Limited pollution with particulate.

The most important criteria are explained in detail:

<u>Cetane Number/ Cetane Index</u>

Cetane number (CN) expressed the ignition quality of the diesel fuel. The higher the cetane number, the greater the fuel's tendency to ignite. As the diesel engine dispenses with an externally supplied ignition spark, the fuel must ignite spontaneously (auto-ignition) and with minimum delay (ignition lag) when injected into the hot, compressed air in the combustion chamber.

Boiling Range

The boiling range of a fuel is the temperature range at which the fuel vaporizes, depends on its composition.

A low initial boiling point makes a fuel suitable for use in cold weather, but also means a lower cetane number and poor lubricant properties. This raises the wear risk for central injection units.

On the other hand, if the final boiling point is situated at high temperatures, this can result in increased soot production and nozzle coking (deposit caused by chemical decomposition of not easily volatized fuel constituent on the nozzle cone, and deposits of combustion residues. For this reason, the final boiling point should not be too high.

Filtration Limit (Cold-flow Properties)

Precipitation of paraffin crystals at low temperature can result in fuel-filter blockage, ultimately leading to interruption of fuel flow. In worst-case scenarios, paraffin particles can start to form at temperatures of 0˚C or even higher. The cold-flow properties of a fuel are assessed by means of the “filtration limit” (Cold Filter Plugging Point (CFPP)).

European Standard EN 590 (Bosch, 2005) defines the CFPP for various classes, and can be defined by individual member states depending on the prevailing geographical and climatic conditions.

Flash Point

The flash point is the temperature at which the quantities of vapor which a combustible fluid emits to the atmosphere are sufficient to allow a spark to ignite the air/vapor mixture above the fluid.

Density

The energy content of diesel fuel per unit of volume increases with density. Assuming constant fuel-injection-pump settings (i.e. constant injected fuel quantity) the use of fuels with widely different densities causes variations in mixture ratios due to fluctuation in calorific value.

When an engine runs on fuel that has a high type–dependent density, engine performance and soot emissions increases; as fuel density decreases, these parameter drop. As a result, the requirements call for a diesel fuel that has a low type-dependent density spread.

Viscosity

Viscosity is a measure of a fuel's resistance to flow due to internal friction. Leakage losses in the fuel-injection pump result if diesel-fuel viscosity is too low, and this in turn results in performance loss.

Much higher viscosity 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. High viscosity also changes the spray pattern due to the formation of larger droplets.

Lubricity

In order to reduce the sulfur content of diesel fuel, it is hydrogenated. In addition to removing sulfur, the hydrogenation process also removes the ionic fuel components that aid lubrication. After the introduction of desulfurized diesel fuels, wear-related problems started to occur on distributor fuel-injection pumps due to the lack of lubricity. As a result, they were replaced by diesel fuels containing lubricity enhancers. Lubricity is measured in a High-Frequency Reciprocating Rig (HFRR method). A fixed, clamped steel ball is ground on a plate by fuel at high frequency. The magnitude of the resulting flattening, i.e. the Wear Scar Diameter (WSD) measured in µm, specifies the amount of wear, and thus a measure of fuel lubricity. Diesel fuels complying with EN 590 must have a WSD of ≤ 460 µm.

Sulfur Content

Diesel fuels contain chemically bonded sulfur, and the actual quantities depend on the quality of the crude petroleum and the components added at the refinery. In particular, crack components mostly have high sulfur contents.

To desulfurize fuel, sulfur is removed from the middle distillate by hydrogenation at high pressure and temperature in the presence of a catalyst. The initial by product of this process is hydrogen sulfide (H_2S) which is subsequently converted into pure sulfur.

Exhaust gas treatment systems for NO_x and particulate filters use catalysts. They must run on sulfur-free fuel since sulfur poisons the active catalyst surface.

Alternative Fuels

Water and alcohols are difficult to dissolve in diesel. Emulsifiers are required to keep the mixture stable and prevent it from demulsification. Wear-and corrosion-inhibiting measures are also necessary. The use of emulsifiers reduces soot and nitrogen-oxide emissions since the combustion mixture is cooler due to the water content.

2.5 EXHAUST EMISSION CHARACTERISTICS

Pulkrabek W.W (2003) has stated that until the middle of the 20th century, the number of internal combustion engines in the world was small enough that the pollution they emitted was tolerable, and the environment, with the help of sunlight, stayed relatively clean. As the world population grew, power plants, factories and an ever increasing number of automobiles began to pollute the air to the extent that it was no longer acceptable. During the 1940s, air pollution was first recognized as a problem in the Los Angeles basin in California. Two causes of this were the large population density and the natural weather conditions of the area. The large population created many factories and the power plants, as well as one of the largest automobile densities in the world. Smoke and other pollutants from the many factories and automobiles combined with the fog that was common in this ocean area, and smog resulted.

During the 1950s, the smog problem increased along with the population density and automobile density. It was recognized that the automobile was one of the major contributors to the problem, and by the 1960s emission standards were beginning to be enforced in California. During the next decades, emission standards were adopted in the rest of the United States and in Europe and Japan. By making engines more fuel efficient, and with the use of exhaust aftertreatment, emissions per vehicle of HC, CO and NO_x were reduced by about 95% during the 1970s and 1980s. Lead, one of the major air pollutants, was phased out as a fuel additive during the 1980s. More fuel-efficient engines were developed, and by the 1990s the average automobile consumed less than half the fuel used in 1970s. However, during this time, the number of automobiles greatly increased, resulting in no overall decrease in fuel usage. In 1999, petroleum consumption in the Unites States amounted to 16500 L/sec, a large percentage of which was fuel for internal combustion engine.

Carbon Monoxide (CO)

Carbon monoxide, a colorless, odorless, poisonous gas, is generated in an engine when it is operated with a fuel-rich equivalent ratio. When there is not enough oxygen to convert all carbon to CO_2, some fuel does not get burned and some ends up as CO. Typically, the exhaust of a spark ignition engine will be about 0.2% to 5% carbon monoxide. Not only is CO considered an undesirable emission, but it also represents lost chemical energy that was not fully utilized in the engine. CO is a fuel that can be combusted to supply additional thermal energy:

$$CO + \frac{1}{2} O_2 \longrightarrow CO_2 + \text{heat}$$

Maximum CO is generated when an engine runs rich, such as when starting or when accelerating. Even when the intake air-fuel mixture is stoichiometric or lean, some CO will be generated in the engine. Poor mixing, local rich regions, and incomplete combustion will create some CO.

A well-designed SI engine operating under ideal conditions can have an exhaust mole fraction of CO as low as 10^{-3}. CI engines that operate in a lean manner overall generally have very low CO emissions. (Refer to figure 2.6)

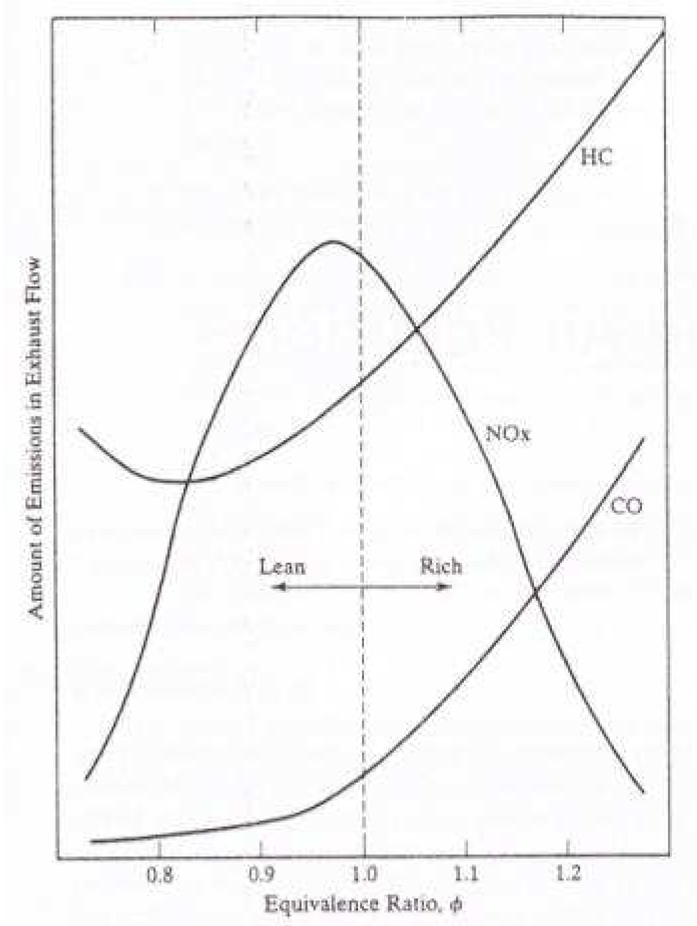

Figure 2.5: Emissions from SI engine as a function of equivalence ratio

Source: Pulkrabek W.W (2003)

Oxides of Nitrogen (NO_x)

Exhaust gases of an engine can have up to 2000ppm of oxides of nitrogen. Most of this will be nitrogen oxide (NO), with a small amount of nitrogen dioxide (NO_2), and traces of other nitrogen-oxygen combinations. These are all grouped together as NO_x which x representing some suitable numbers. NO_x is a very undesirable emission, and regulations that restrict the allowable amount continue to become more stringent. Released NO_x reacts in the atmosphere to form ozone and is one of the major causes of photochemical smog.

NO_x is created mostly from nitrogen in the air. Nitrogen can also be found in fuel blends, which may contain trace amounts on NH_3, NC, and HCN, but this would contribute only to a minor degree. There are number of possible reactions that form NO, all of which are probably occurring during the combustion process and immediately after. These include but are not limited to,

$$O + N_2 \longrightarrow NO + N$$

$$N + O_2 \longrightarrow NO + O$$

$$N + OH \longrightarrow NO + H$$

NO, in turn, can then further react to form NO_2 by various means, including the following:

$$NO + H_2O \longrightarrow NO_2 + H_2$$

$$NO + O_2 \longrightarrow NO_2 + O$$

Atmospheric nitrogen exists as a stable diatomic molecule at low temperatures, and only very small trace amounts of oxides are found. However, at the very high temperatures that occurs in the combustion chamber of an engine, some diatomic nitrogen (N), which is reactive:

$$N_2 \longrightarrow 2\,N$$

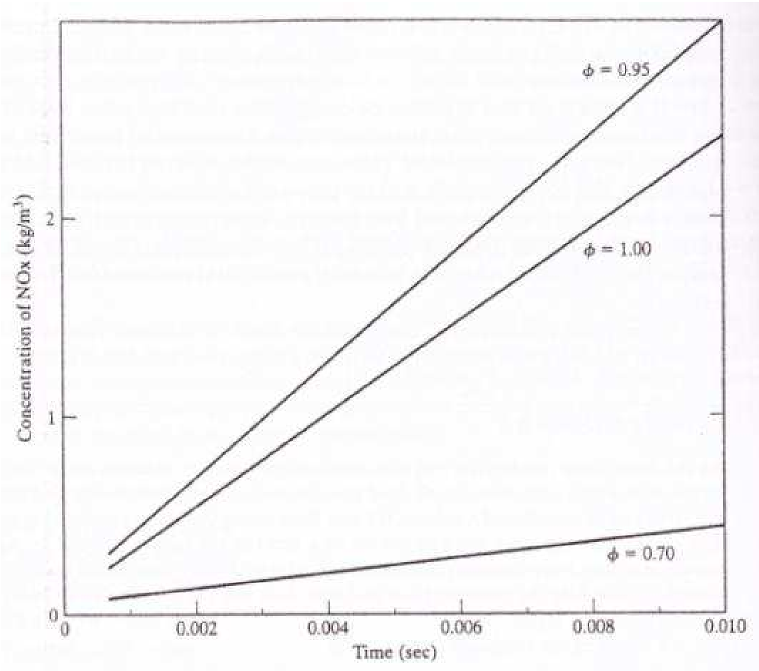

Figure 2.6: Generation of NO_x in an engine as a function of combustion time

Source: Pulkrabek W. W (2003)

Particulates

The exhaust of CI engines contains solid carbon soot particles that are generated in the fuel-rich zones within the cylinder during the combustion. These are seen as exhaust smoke and are an undesirable odorous pollution. Maximum density of particulate emissions occurs when the engine is under load at WOT. At this condition, maximum fuel is injected to supply maximum power, resulting in a rich mixture and poor fuel economy. This can be seen in the heavy exhaust smoke emitted when a truck or railroad locomotive accelerates up a hill from a stop.

Soot particles are clusters of solid carbon spheres. These spheres have diameters from 10nm to 80nm (1nm = 10^{-9} m), with most within the range of 15-30 nm. The spheres are solid carbon with NC and traces of other components absorbed on the surface. A single soot particle will contain up to 4000 carbon spheres.

Carbon spheres are generated in the combustion chamber in the fuel rich-rich zones where there is not enough oxygen to convert all carbon to CO_2:

$$C_xH_y + z\ O_2 \longrightarrow a\ CO_2 + b\ H_2O + c\ CO + d\ C\ (s)$$

Then, as turbulence and mass motion continue to mix the components in the combustion chamber, most of these carbon particles find sufficient oxygen to further react and consumed to CO_2:

$$C\ (s) + O_2 \longrightarrow CO_2$$

Over 90% of carbon particles originally generates within an engine are thus consumed and never get exhausted. If CI engines were to operate with an overall stoichiometric air-fuel mixture, instead of the overall lean mixture they do operate with, particulate emissions in the exhaust would far exceed acceptable levels.

Up to about 25% of the carbon in soot comes from lubricating-oil components, which vaporize and then react during combustion. The rest comes from the fuel and amounts to 0.2-0.5% of the fuel. Because of the high compression ratios of CI engines, a large expansion occurs during the power stroke, and the gases within the cylinder are cooled by expansion cooling to a relatively low temperature. This causes the remaining high-boiling components found in the fuel and lubricating oil to condense on the surface of the carbon soot particles. This absorbed portion of the soot particles is called the soluble organic fraction (SOF), and the amount is highly dependent on cylinder temperature.

At light loads, cylinder temperatures are reduced and can drop to as low as 200°C during final expansion and exhaust blowdown. Under these conditions, SOF can be as high as 50% of the total mass of soot. Under other operating conditions when the temperatures are not so low, very little condensing occurs and SOF can be as low as 3% of total soot mass. SOF consists mostly of hydrocarbon components with some hydrogen, SO_2, NO, NO_2 and trace amounts of sulfur, calcium, iron, silicon and chromium, while lubricating-oil additives contain zinc, phosphorus and calcium.

Particulate generation can be reduced by engine design and control of operating conditions, but quite often this will create other adverse results. If the combustion time is extended by combustion chamber design and timing control, particulate amounts in the exhaust can be reduced. Soot particles originally generated will have a greater time to be mixed with oxygen and combusted to CO_2. However, a longer combustion time means a high cylinder temperature and more NO_x generated. Dilution with EGR lowers NO_x emissions, but increase particulate and HC emissions. Higher injection pressure gives a finer droplet size, which reduces HC and particulate emission, but increases cylinder temperature and NO_x emissions. Engine management systems are programmed to minimize NO_x, HC CO and particulate emissions by controlling ignition timing, injection pressure, injection timing and/or valve timing. Obviously compromise is necessary. In most engines, exhaust particulate amounts cannot be reduced to acceptable levels solely by engine design and control.

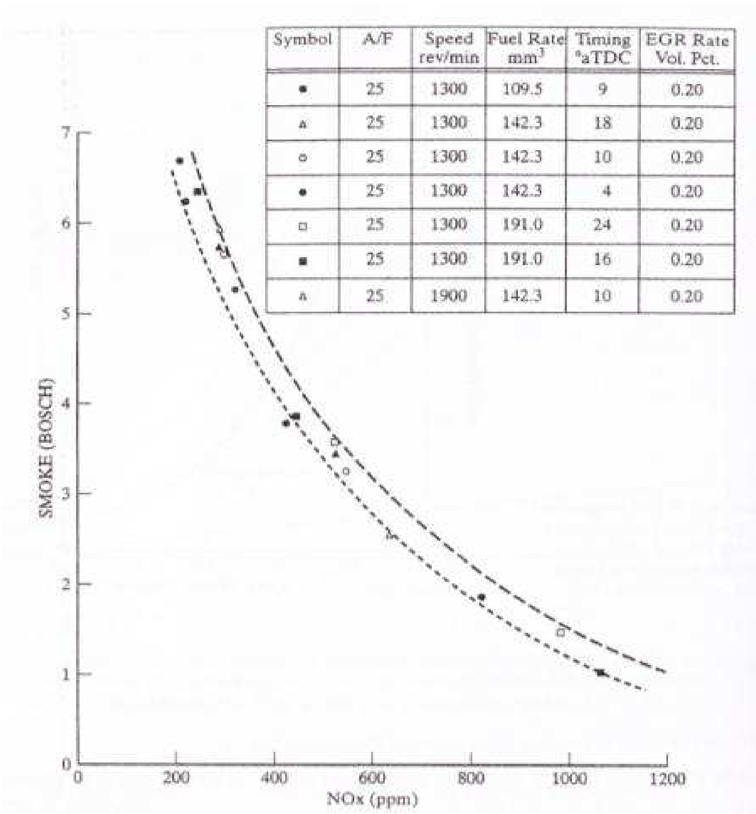

Figure 2.7: Nitrogen oxide (NO_x)-smoke (particulates) trade-off at various engine operating conditions

Source: Pulkrabek W.W (2003)

Carbon Dioxides (CO_2)

At moderate levels of concentration, carbon dioxide is not considered an air pollutant. However, it is considered a major greenhouse gas and, at higher concentrations, is a major contributor to global warming. CO_2 is a major component of the exhaust in the combustion of any hydrocarbon fuel. Because of the growing number of motor vehicles, along with more factories and other sources, the amount of carbon dioxide in the atmosphere continues to grow. At upper elevations in the atmosphere, this higher concentration of carbon dioxide, along with other greenhouse gases, creates a thermal radiation shield. This shield reduces the amount of thermal radiation energy allowed to escape from the earth, raising slightly the average earth temperature. The most efficient way of reducing the amount of CO_2 is to burn less fuel (i.e., use engines with higher thermal efficiency)

Formation of Sulfur

Many fuels used in CI engines contain small amounts of sulfur, which, when exhausted contributes to the acid rain problem of the world. Unleaded gasoline generally contains 150-600 ppm sulfur by weight. Some diesel fuels contain up to 5000 ppm by weight, but in United States and some other countries sulfur content is restricted by law to a tenth of this value or less.

At high temperature, sulfur combines with hydrogen to form H_2S and with oxygen to form SO_2:

$$H_2 + S \longrightarrow H_2S$$

$$O_2 + S \longrightarrow SO_2$$

Engine exhaust can contain up to 20 ppm of SO_2 then combines with oxygen in the air to form SO_3:

$$2\ SO_2 + O_2 \longrightarrow 2\ SO_3$$

These molecules combine with water vapor in the atmosphere to form sulfuric acid (H_2SO_4) and sulfurous acid (H_2SO_3), which are ingredients in acid rain:

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

$$SO_2 + H_2O \longrightarrow H_2SO_3$$

Many countries have laws restricting the amount of sulfur allowed in fuel, and these laws are continuously being made more stringent. During the 1990s, the United States reduced acceptable sulfur levels in diesel fuel from 0.05% by weight to 0.01%. The amount of sulfur in natural gas can range from small (sweet) to large (sour) amounts. This can be a major emissions problem when this fuel is used in an IC engine or any other combustion system.

When the allowable sulfur level in diesel fuel was lowered, a new problem surfaced in CI engines. It was found that the fuel with very low levels of sulfur lost its lubricating ability, resulting in sticking fuel pumps and injectors. In addition, there was abnormal wear on cylinder surfaces and rapid pressure buildup in some particulate traps. To overcome these problems, additives are put into low-sulfur fuels. These additives include aliphatic ester derivatives and carboxylic acids.

A more serious effect of sulfur, in addition to being harmful emission, is that it poisons most emissions aftertreatment systems. Catalyst materials in catalytic converters and regenerating particulate traps deteriorate in the presence of sulfur, lead of phosphorus.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will describe further on the study about this project which is the emission characteristics from the usage of tire scrap fuel for diesel engine. In order to complete the experiment, the methodology of the project is one of the most important things that need to be considered. The objective of methodology is to ensure that the flow of the project is according to the schedule.

In this chapter, all the details and related discussions on the process that involved in the project will be described. There will be a flow chart that shows the process timeline. The chart will explain every single step that is followed to ensure that the objective of the project will be successfully achieved. The steps will start from the literature review until the complete report is submitted.

3.2 FLOW CHART

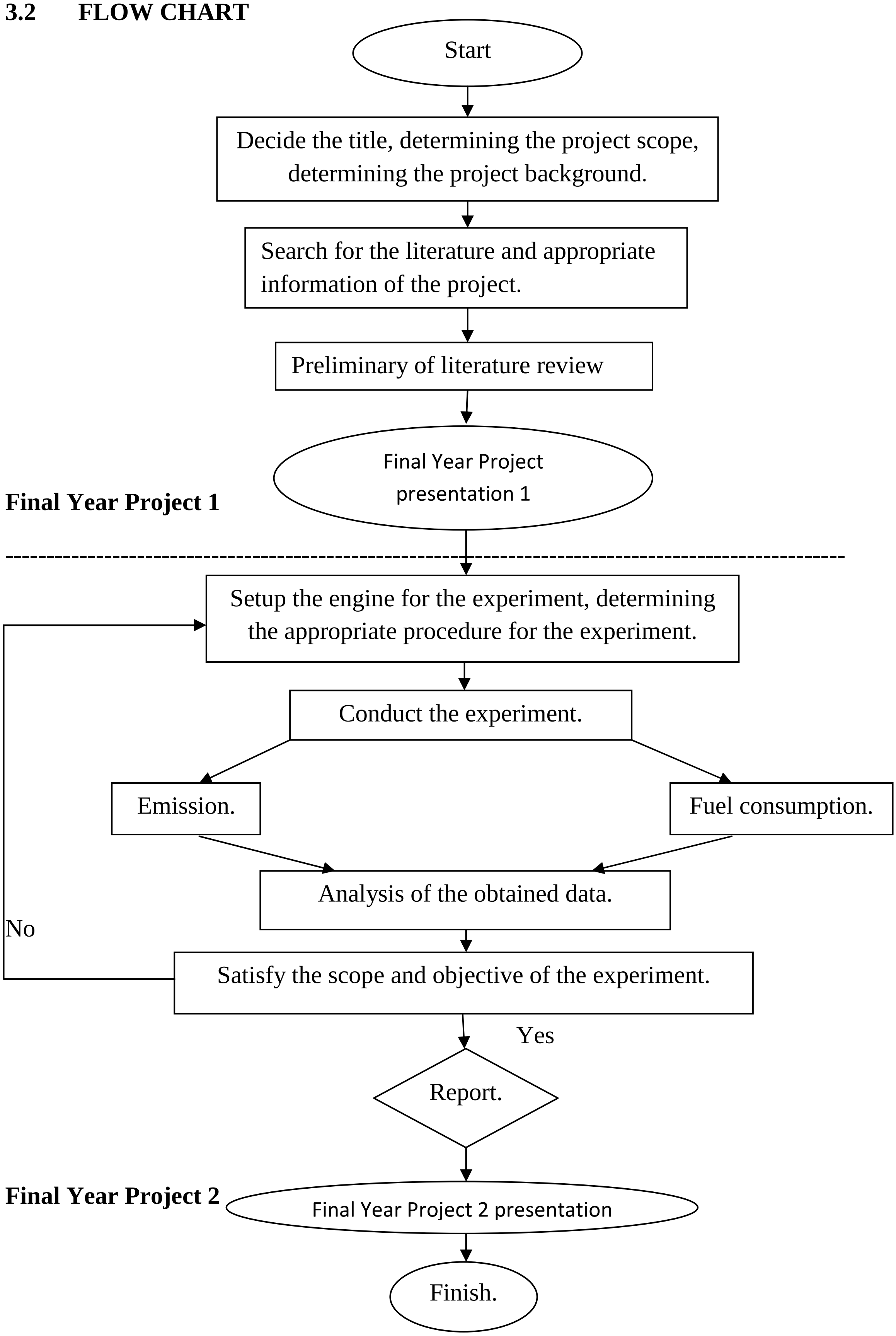

Figure 3.1: Project flow chart

3.3 FLOW CHART DESCRIPTION

The flow chart shows overall steps that are taken in completion the project. At the beginning, the project starts with determine and understanding the title of the project. The next step is determining the project scopes and objectives. Then the project background is determined.

The project is continued by searching the literature and gathering all the information needed for this project. The source of information includes the information from supervisors, books, journals and others. The data that are collected are analyzed to gain more understanding about the project.

The next step is preliminary of literature review. The general methodology of the project also planned during this step. The last step in the Final Year Project 1 is Final Year Project 1 Presentation.

Final Year Project 2 starts with the setup for the experiment. In this phase, the engine rig is fabricated, and also the custom exhaust manifold, the exhaust particle trap, fuel tanks and others. The next step begins with determining the appropriate procedures for the experiment. The methods to measure the fuel consumption and emission due to usage of diesel fuel and tire scrap fuel are determined.

The experiment is conducted based on the experiment procedures that are determined. There are two factors that are analyzed, that are fuel consumption and emission. The available data then analyzed according to the project objectives. If the data satisfy the project scopes, the project proceed to report writing and if not, the experiment will be repeated.

The report writing starts when all the required data have been analyzed. All the information starts from the beginning is written and divided into five chapters. The last step in Final Year Project 2 is Final Year Project 2 Presentation and also the final report submission.

3.4 LITERATURE ANALYSIS

Literature analysis is a combination and elaboration of the literature review that have been collected from various sources like journals, books, and also the analysis results from the previous research. Before the project is started, it is important to understand the project objectives which are analyzing the fuel consumption and emission due to usage of diesel fuel and tire scrap fuel. In order to understand that, the best and precise information must be gathered from the right source. So, there are several ways or methods of source to obtain all the information required such as books, journals, previous researches and information from Project Supervisor.

3.4.1 Books

Books provide the good information about the project. It is because it is been written by a good author which is commonly have deep knowledge and experiences in the related field. To look for this kind of source, library or book shop is suitable place. All the required information such as analysis, concept and calculation method can be found in the book.

3.4.2 Journals

Journals also a good source of information. There are several of journals which are commonly published by Society of Automotive Engineers (SAE) and other publishers that can be referred. Journals may provide the data that can be a comparison and guidelines when conducting the experiment.

3.4.3 Previous Researches

There are several researches that are related to this title. The data that are available in the researches can be compared to this project. Many of the researches are conducted by the institution outside from Malaysia. The research papers are published in the internet and can be downloaded in (.pdf) format.

3.4.5 Project Supervisor

Not all the information that obtained from the books, journals and previous researches can be easily understood and precise to the project. So, project supervisor's advice is very important to finalize the information obtained and make sure that all the information are relevant to be written in the project report. So, discussion with supervisor which is specifically expert in the related field will give more information especially when the required information is hard to obtain. Furthermore, discussion with supervisor can generate new idea for the project research and also make the research more clear and understandable.

3.5 ENGINE RIG DESIGN

Before the experiment is started, the engine that is used must be attached to a rig. For that purpose, a rig is designed before starting the fabrication process. For that design, SOLIDWORK software is used. The dimension must be larger than size of YANMAR single piston engine because it will be use as a base for that engine.

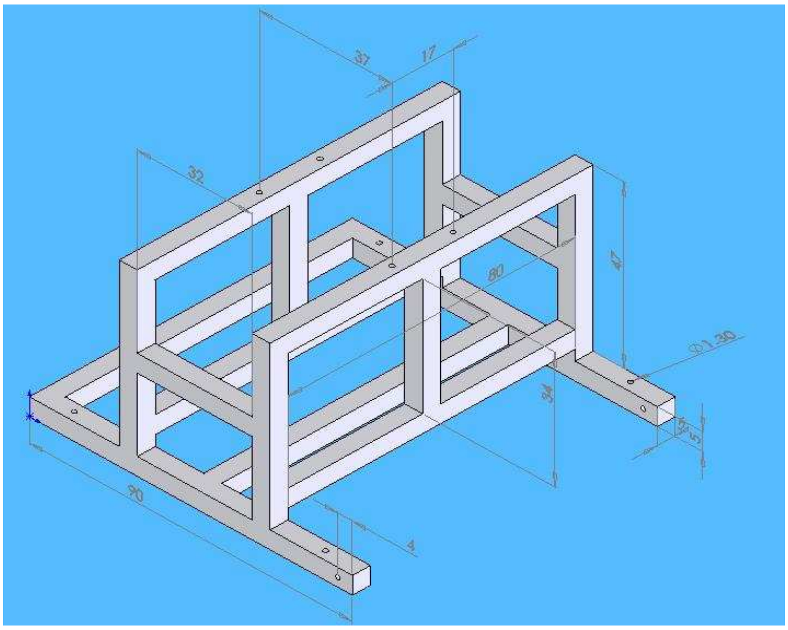

Figure 3.2: Engine rig design

3.6 TOOLS

This project based on experimenting method. For that purpose, many of the experiment apparatus must be self-fabricated. There are many tools that have been used in order complete the fabrication process such as disk cutter, Metal Inert Gas (MIG) welding, hand drill and hand grinder. Disk cutter is used to cut all the materials such as hollow mild steel into desired size while MIG welding is used to assemble all the part that will be used in the experiment, hand drill is used to make a hole and hand grinder is used to remove the burr after cutting process.

Figure 3.3: Disk cutter

Figure 3.4: MIG welding

Figure 3.5: Hand grinder

Figure 3.6: Hand drill

3.7 FABRICATION

Fabrication is the important process that needs to be finished before preceding the experiment. There are several parts that need to be fabricated in order to start the experiment such as engine rig, display panel table, rack, and exhaust manifold.

3.7.1 Engine rig

After the engine rig design is finished, the fabrication process can be started. The material used to fabricate the engine rig is hollow mild steel which the size is 5 cm x 5 cm.

Figure 3.7: Engine Rig

3.7.2 Exhaust manifold

Exhaust manifold have been modified to make sure a thermocouple hole and a valve can be installed, so that the exhaust gasses can be analyzed from the hole and valve.

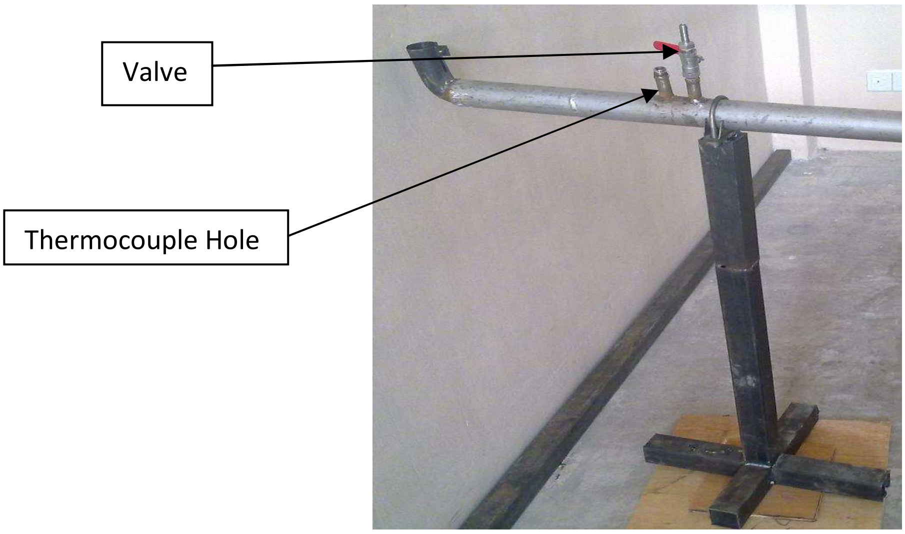

Figure 3.8: Exhaust manifold

3.8 APPARATUS

3.8.1 The Diesel Engine

The engine that is used for this experiment is YANMAR TF 120. This is water cooled, single cylinder diesel engine.

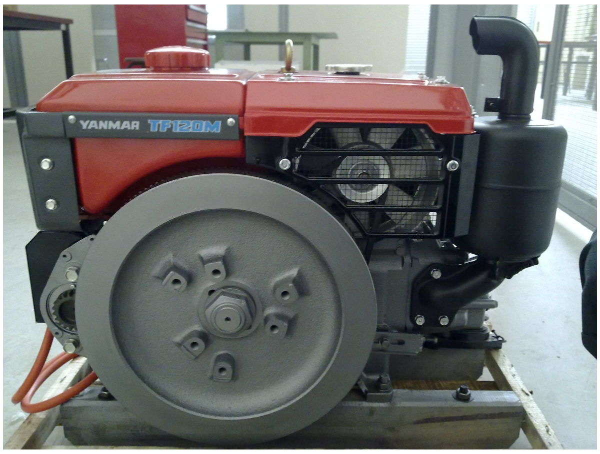

Figure 3.9: Engine side view

Figure 3.10: Engine side view

3.8.2 Exhaust gas particle trap

Diesel engine produces soot as a product of combustion. If this soot enters the exhaust analyzer, it will cause the exhaust analyzer to be damage. The exhaust gas particle trap functioned to avoid the soot from reaching the exhaust analyzer. It worked by cooling the exhaust gas through the “water jacket” along the tube that the exhaust gas going through, causing the particle in the exhaust gas loosing energy and become heavier, and the particle will drop to the bottom of the beaker that act as a trap. The picture of the exhaust gas particle trap is shown next:

Figure 3.11: Water reservoir tank

Figure 3.12: Exhaust gas particle trap

3.8.3 Fuel Flow Rate Analyzer

The fuel flow meter that is used in this experiment is from AIC – 1204 HR 2000 model, with board computer from BC 3033 model. The picture for both apparatus is shown below:

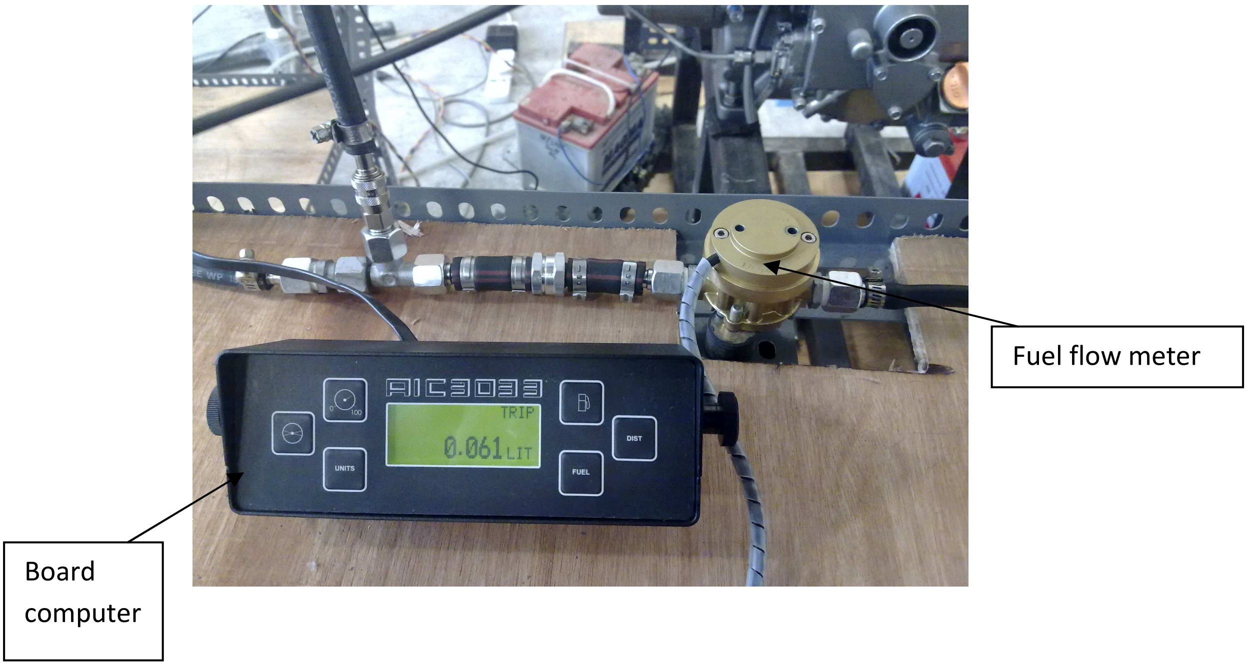

Figure 3.13: Fuel Flow Rate Meter and Board Computer.

3.8.4 Engine speed sensor

The engine speed sensor is used to measure the current engine speed. The model used for engine speed sensor is from 461957 photoelectric sensor models and the display unit is from 461950 panel tachometer model. Photoelectric sensor is attached to the engine rig to enable the speed of the engine to be measured. A marking have been made to the engine's flywheel to enable the engine speed sensor to detect the engine speed. The picture of the RPM sensor and the panel tachometer unit are shown below:

Figure 3.14: Photoelectric sensor

Figure 3.15: Panel tachometer

3.8.5 Exhaust gas analyzer

The exhaust gas is analyzed using exhaust analyzer. The model that is used is Hand Held 4 & 5 Gas Analyzer Auto 4-2 & Auto 5-2 model. The picture of the exhaust gas analyzer is shown next:

Figure 3.16: Exhaust gas analyzer

3.8.6 Exhaust gas temperature sensor

The exhaust gas temperature is measured using thermocouple and the temperature is shown by the display unit. Thermocouple is placed at the exhaust manifold as shown below:

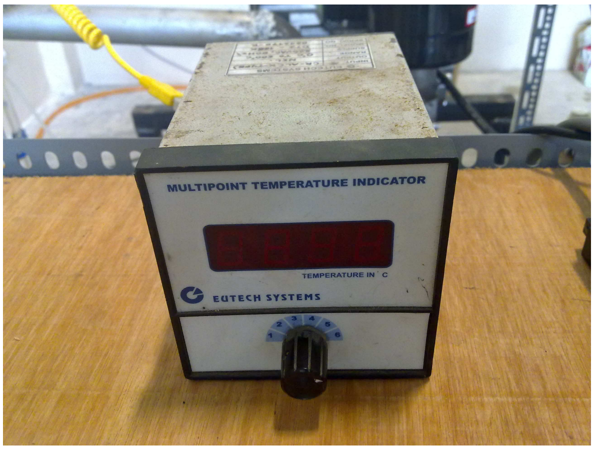

Figure 3.17: Thermocouple

Figure 3.18: Temperature display unit

3.9 EXPERIMENTAL PROCEDURE

3.9.1 Fuel consumption analysis

At the beginning, the engine speed is set to be 1100 revolution per minute (rpm). The time taken for the engine to consume 100mL of fuel is taken and the fuel consumption can be determined manually by dividing the 100mL of fuel by the time taken to consume 100mL of fuel. Using flow rate meter, the amount of fuel consumed for 5 minutes can be determined directly from the board computer unit that displays the amount. The fuel consumption also can be determined by dividing the amount of fuel consumed by 5 minutes of time taken. The value that is obtained through both methods can be compared. The unit for the fuel consumption is liter/hour (L/hr)

The engine speeds then are variable to 1500rpm, 1700rpm, 1900rpm and 2100 rpm and the same procedures are repeated. The experiment then is continued with tire disposal fuel. All the data obtained are filled in the table. The graph of fuel consumptions for both fuel usages are plotted and compared.

3.9.2 Emission analysis

At the beginning, the engine speed let to be 1100rpm. The exhaust gas that is come out from the exhaust valve is collected using pipe and the smoke is let through the exhaust particle trap. The water jacket around the exhaust pipe will cause the particle to fall at the bottom of the trap. The “clean” exhaust gas then will enter the exhaust analyzer and the content of the exhaust gas will be analyzed. The amount of the content can be measured directly from the exhaust analyzer display unit.

The engine speeds then are variable to 1500rpm, 1700rpm, 1900rpm and 2100rpm and the same procedures are repeated. The experiment then is continued with tire disposal fuel. All the data obtained are filled in the table. The graph of exhaust gas emissions for both usages of fuel are plotted and compared.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

In this chapter, the results from the experiment will be analyzed. The comparison between the usage of tire scrap fuel and diesel fuel is made in term of emission and fuel consumption. All the data obtained are represented in form of graph.

4.2 FUEL CONSUMPTION

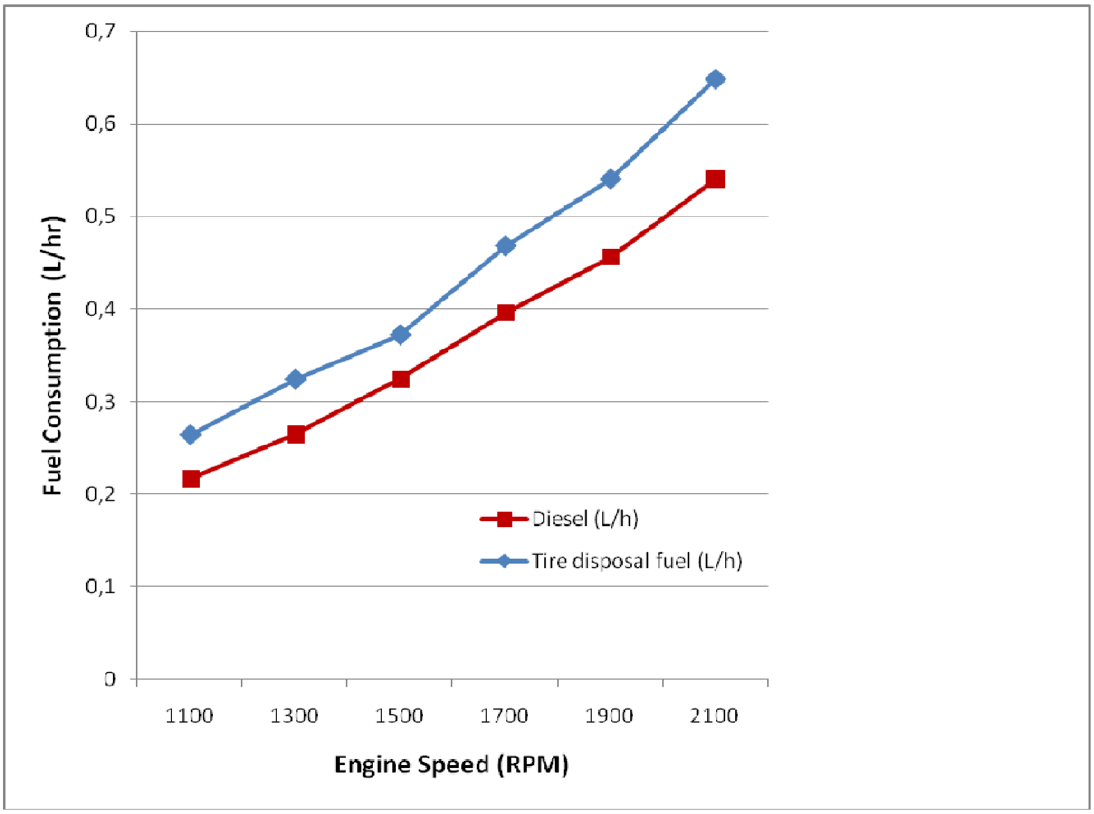

Figure 4.1: Fuel consumption comparison

Figure 4.1 shows the comparison of fuel consumption between tested fuels. It is clearly shown that the fuel consumption due to tire disposal fuel usages is higher than diesel fuel. The average fuel consumption for tire disposal fuel usage is higher than diesel fuel by 19.13%. The fuel consumption when the tire disposal fuel is used is higher probably because the time taken for all the tire disposal fuel that injected into the combustion chamber is longer to completely burned compared to same amount diesel fuel. At the end of power stroke of the engine, there are probably still remaining some tire disposal fuels that are still not burned. When the exhaust gas is pushed out during scavenging process, the unburned tire disposal fuel also pushed out and wasted. This may cause the fuel consumption due to usage of tire disposal fuel is higher. This can be seen when some liquid that is probably tire disposal fuel but more dense that are leaking out at the exhaust manifold.

4.3 EMISSION

4.3.1 NO_x Emission

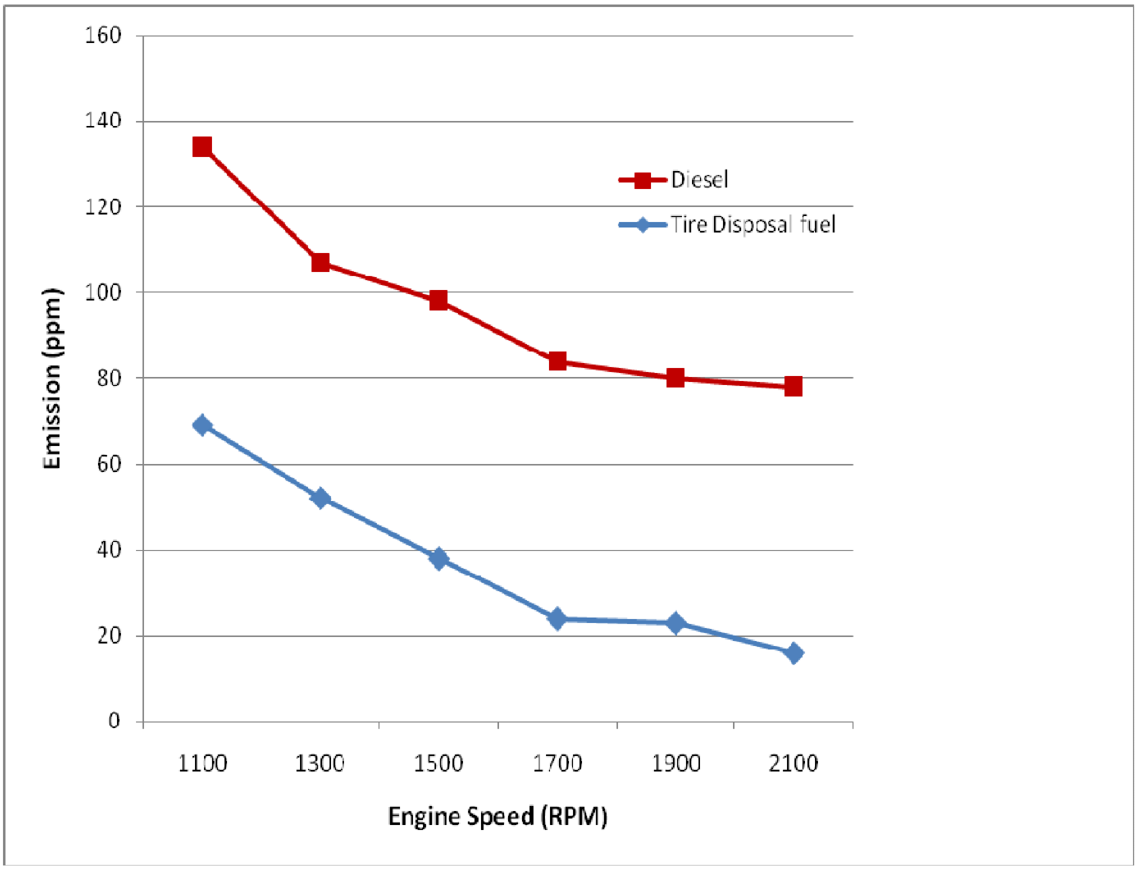

Figure 4.2: Graph of composition of NO_x versus Engine Speed

Figure 4.2 shows the comparison of NO_x emission for the tested fuels. The value of NO_x due to usage of tire disposal fuel is lower than diesel fuel. At the minimum engine speed which is 1100 rpm, the value of NO_x for diesel fuel is 134 parts per million (ppm) while the tire disposal fuel is 69ppm. At the maximum speed which is 2100rpm, the value of NO_x for diesel fuel is 78ppm and for tire disposal fuel is 16ppm. The average of NO_x emission from the usage of tire disposal fuel is lower than diesel fuel by 62.08%. The trend of the graph shows that when the engine speed increased, the emission of NO_x for both fuel usages is decreasing. This may caused by the condition of the engine that is running without load exerted to it. The air-fuel ratio of the engine is lean and caused the composition of the NO_x decreasing as the engine speed is increased.

4.3.2 NO Emission

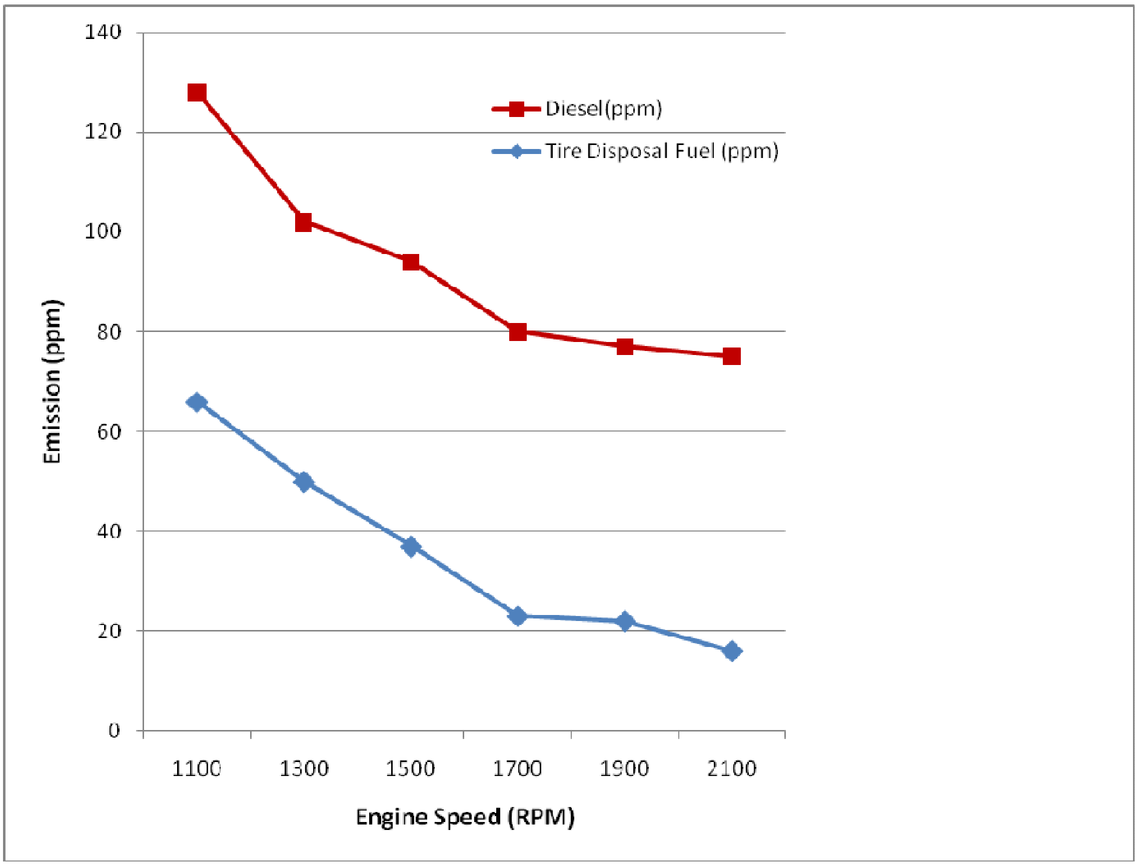

Figure 4.3: Graph of NO emission versus Engine Speed

Figure 4.3 shows the comparison of NO emission for the tested fuels. The value of NO due to usage of tire disposal fuel is lower than diesel fuel. At the minimum engine speed which is 1100rpm, the value of NO for diesel fuel usage is 128ppm and for tire disposal fuel usage is 66ppm. At the engine maximum speed which is 2100rpm, the value of No for diesel fuel usage is 75ppm and for tire disposal fuel usage is 16ppm. The average of NO emission due to usage of tire disposal fuel is lower than diesel fuel by 61.51%. The graph shows decreasing value of NO for both fuels with increasing of engine speed. This may caused by the condition of the experiment where the engine runs with no load exerted on it. The air-fuel ratio of the mixture is lean and causes the NO that produced is lower.

4.3.3 CO Emission

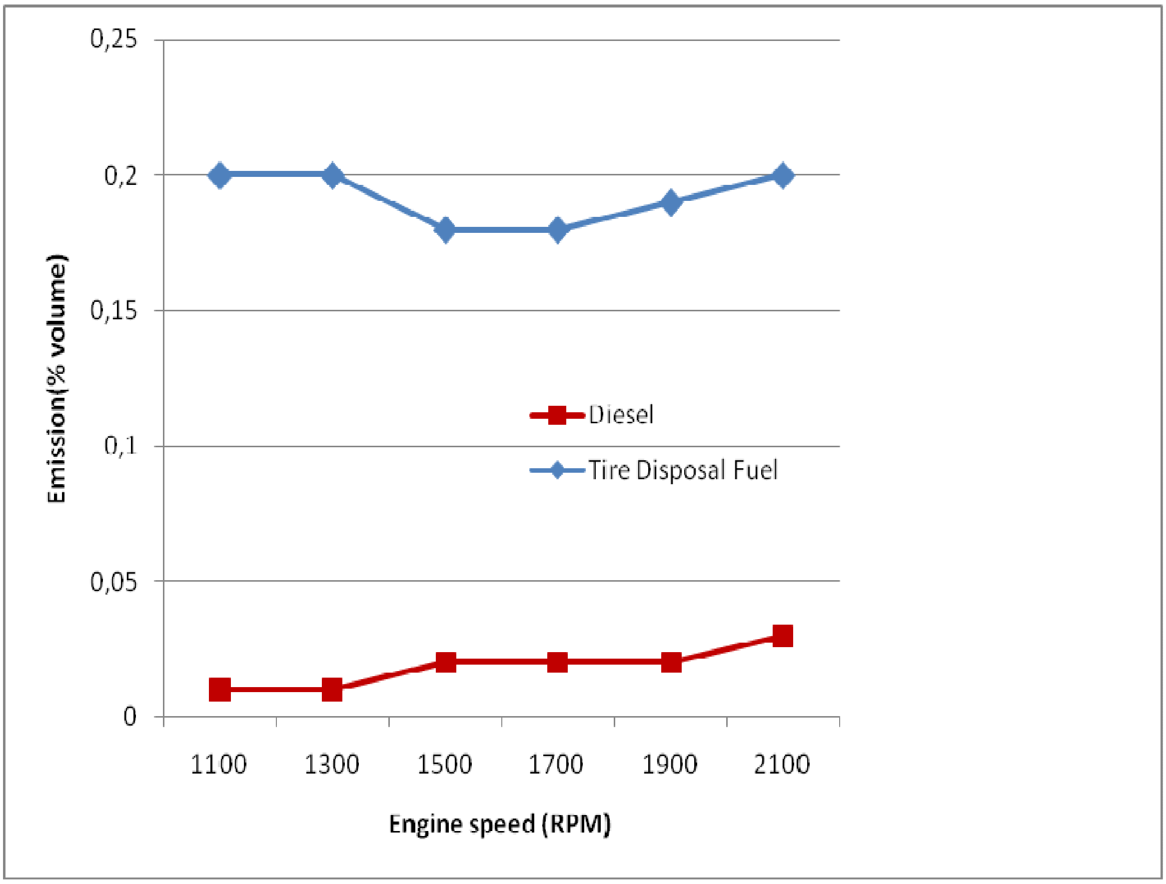

Figure 4.4: Graph of CO emission versus engine speed

Figure 4.4 shows the comparison of CO emission for the tested fuels. The value of CO due to usage of diesel fuel is lower than tire disposal fuel. At the minimum engine speed which is 1100rpm, the value of CO for diesel fuel usage is 0.01% volume and for tire disposal fuel usage is 0.20% volume. At the maximum speed which is 2100rpm, the value of CO for diesel fuel usage is 0.03% volume and for tire disposal fuel usage is 0.20% volume. The average of CO emission for tire disposal fuel is higher than diesel fuel by 945.66%. The fuel air mixture fills inside the cylinder is lean and some of the mixtures nearer to the wall and crevice volume, the flame will not propagate. Therefore, they do not find time to undergo combustion which results higher CO emission for tire disposal fuel than diesel fuel. However, the CO emissions for tire disposal fuel lie below 0.9 % volume which is a maximum value of CO emission from diesel engines.

4.3.4 CO_2 Emission

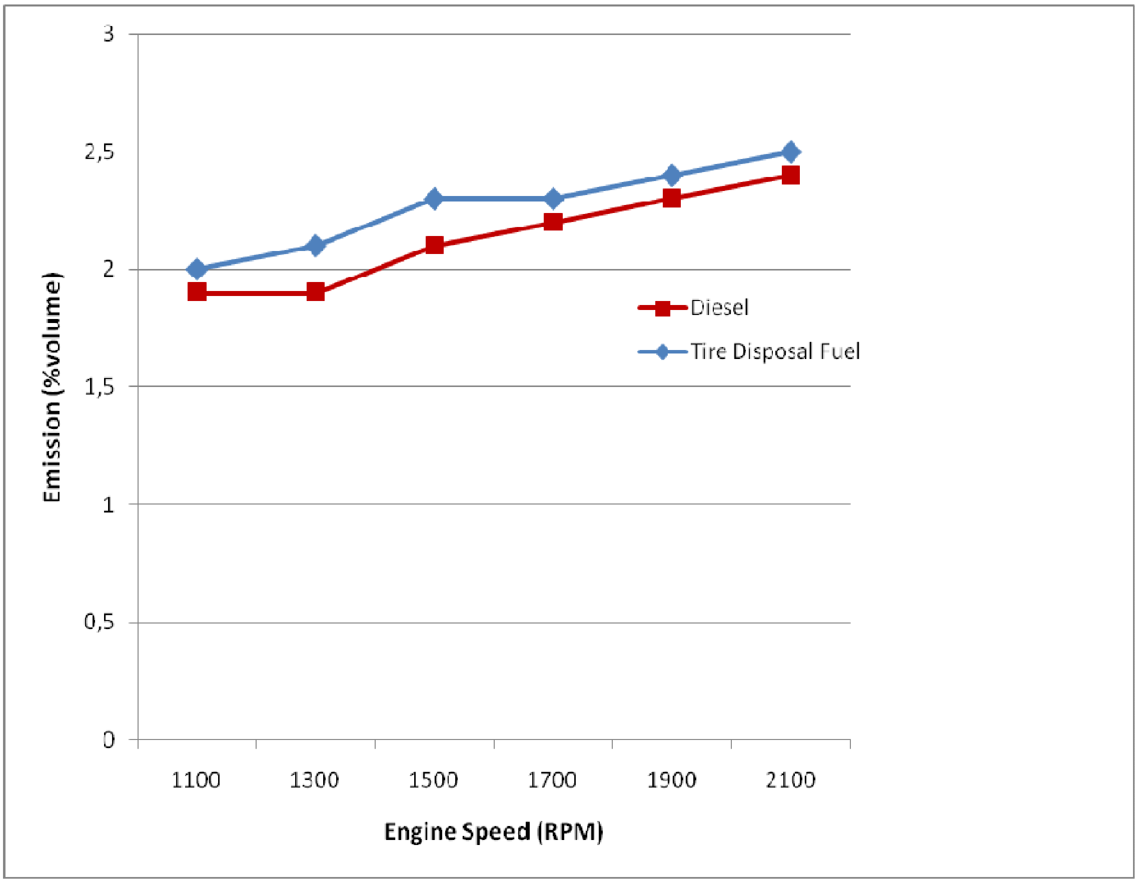

Figure 4.5: Graph of CO_2 emission versus engine speed

Figure 4.5 shows the comparison of CO_2 emission for tested fuels. The value of CO_2 due to usage of diesel fuel is lower than tire disposal fuel. At the minimum engine speed which is 1100rpm, the value of CO_2 for diesel fuel usage is 1.9% percent volume while for tire disposal fuel usage is 2.0% percent volume. At the maximum speed which is 2100rpm, the value of CO_2 for diesel fuel usage is 1.9% volume and for tire disposal fuel usage is 2.5% volume. The average of CO_2 emission for tire disposal fuel is higher than diesel fuel by 6.28%. The CO_2 emission for tire disposal fuel is higher than diesel fuel probably because the presences of carbon black contents in the tire scrap fuel. The combustion of carbon black in the tire disposal fuel may cause the exhaust gas temperature for this fuel is higher than diesel fuel.

4.3.5 O_2 Emission

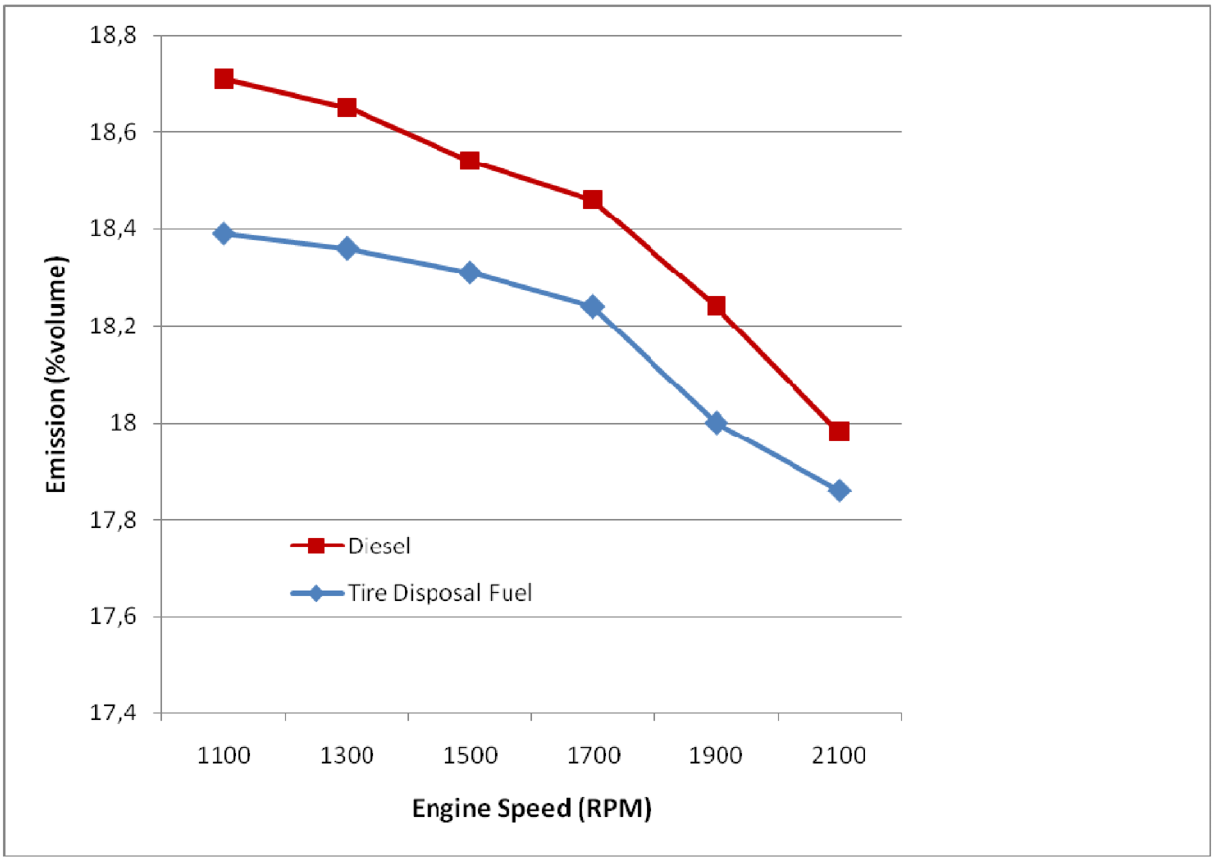

Figure 4.6: Graph of O_2 emission versus engine speed

Figure 4.6 shows the comparison of O_2 emission for tested fuels. The value of O_2 due to usage of tire scrap fuel is lower than diesel fuel. At the minimum engine speed which is 1100 rpm, the value of O_2 due to diesel fuel usage is 18.71% volume and for tire disposal fuel usage is 18.39% volume. At the maximum speed which is 2100rpm, the value of O_2 due to usage of diesel fuel is 17.98% volume and for tire disposal fuel usage is 17.86% volume. The average of O_2 emission for diesel fuel is higher than tire disposal fuel by 1.30%. The value of O_2 become lower when the engine speed increased probably because when the engine speed increased, more O_2 combines with the fuel to enable the combustion to occur.

4.4 EXHAUST GAS TEMPERATURE

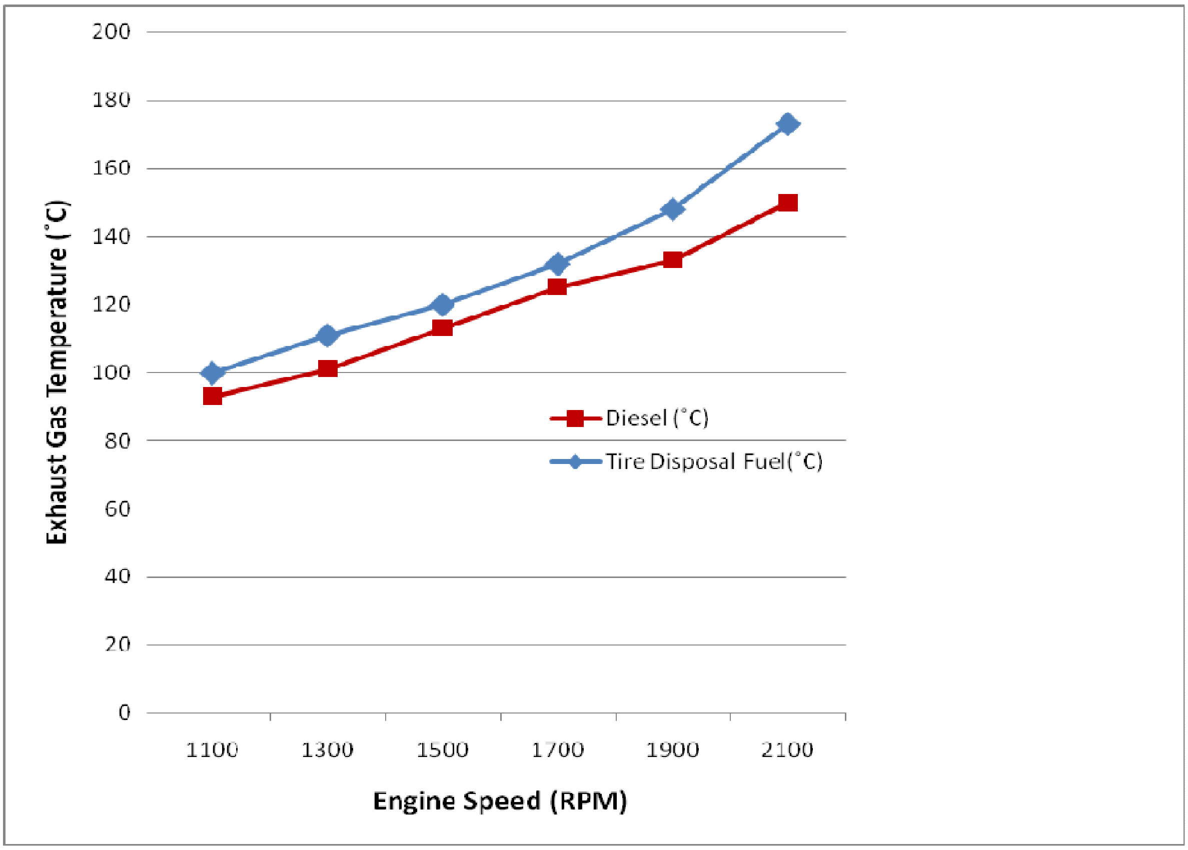

Figure 4.7: Graph of Exhaust Gas Temperature versus Engine Speed

Figure 4.7 shows the comparison between exhaust gas temperatures between tested fuels. At the minimum speed which is 1100rpm, the temperature of exhaust gas for diesel fuel usage is 93°C and for tire disposal fuel usage is 100°C. At the maximum speed which is 2100rpm, the exhaust gas temperature for diesel fuel usage is 150°C and for tire disposal fuel usage is 173°C. The average of exhaust gas temperature for diesel fuel usage is lower than tire disposal fuel usage by 9.65%. The exhaust gas temperature due to usage of tire disposal fuel is higher compared to diesel fuel because tire disposal fuel has higher kinematic viscosity from diesel fuel. Higher kinematic viscosity cause more penetration of the fuel into the combustion chamber and the more amount of heat is developed during combustion.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The main objective of this project is to analyze the emission characteristics of a single cylinder diesel engine that are using tire scrap fuel compared to diesel fuel. The second objective is to analyze the fuel consumption of the engine due to usage of tire scrap fuel compared to diesel fuel. For the first objective, the experiment is conducted to analyze the emission of the engine using both type of fuel. The emission of the engine is analyzed using the exhaust analyzer and the results are plotted on the graph. The emission of both fuel usages is compared and analyzed. From the experiment, the average of NO_x emission from the usage of tire scrap fuel is lower than diesel fuel by 61.78%. For NO emission, the average amount due to usage of tire scrap fuel is lower than diesel fuel by 61.52% while the average of CO emission for tire disposal fuel is higher than diesel fuel by 1173%. Furthermore, the average of CO_2 emission for tire disposal fuel is higher than diesel fuel by 4.65% and lastly the average of O_2 emission for diesel fuel is higher than tire scrap fuel by 1.30%.

The second objective is achieved by measuring the fuel consumption for both fuel usages. The fuel consumption can be measured directly using flow rate meter and the results are plotted in the graph and analyzed. The fuel consumption for both fuel usages is compared. From the experiment, the fuel consumption for tire disposal fuel usage is higher than diesel fuel by 19.13%.

Based on the results obtained, the usage of 100% tire disposal fuel blends for diesel engine is not suitable. This is because the results shows higher emission due to usage of tire disposal fuel compared to diesel fuel. The fuel consumption tire disposal fuel usage also higher compared to diesel fuel.

During the experiment, the view that can be seen is when the tire disposal fuel is used; the engine is not running smoothly. The engine speed is also not stable.

Furthermore, when the engine speed is increased, the thick, white smoke can be seen at the exhaust manifold as it become thicker when the engine speed is increased. But at the 1900 rpm and 2100 rpm the white smoke reduce. The emission emitted when tire disposal fuel is used causes irritation to the eyes as well as breathing difficulty. This also shows that the usage of 100% blends of tire disposal fuel for diesel engine is not suitable.

5.2 RECOMMENDATIONS FOR FUTURE RESEARCH

After all process done in completing the project, there is a recommendation that can be done for the future research. The recommendation is the hydraulic dynamometer can be installed in the apparatus setup. By installing the dynamometer, the performance of the engine such as torque can be measured and give more information about the engine performance when tire disposal fuel is used.

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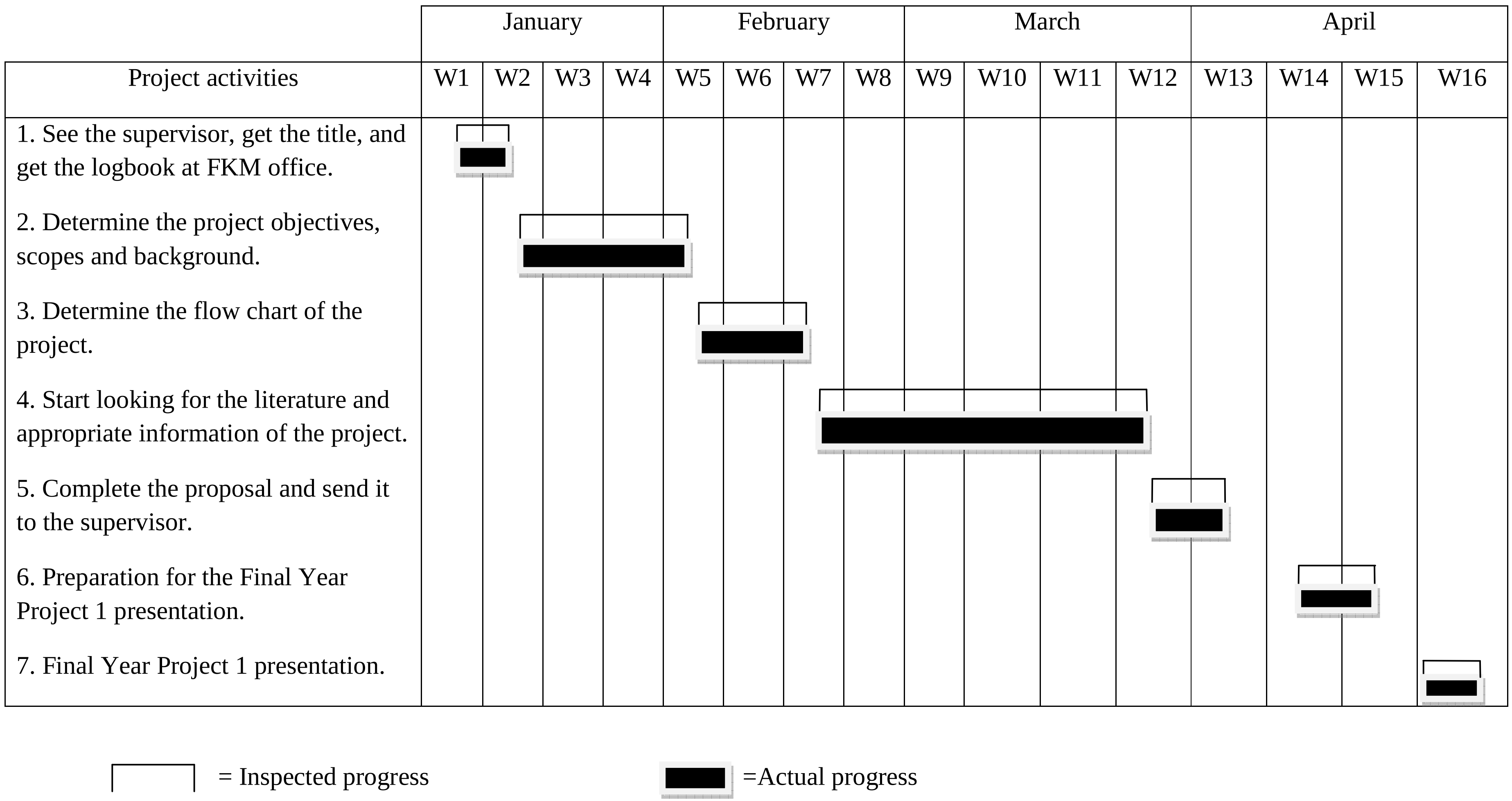
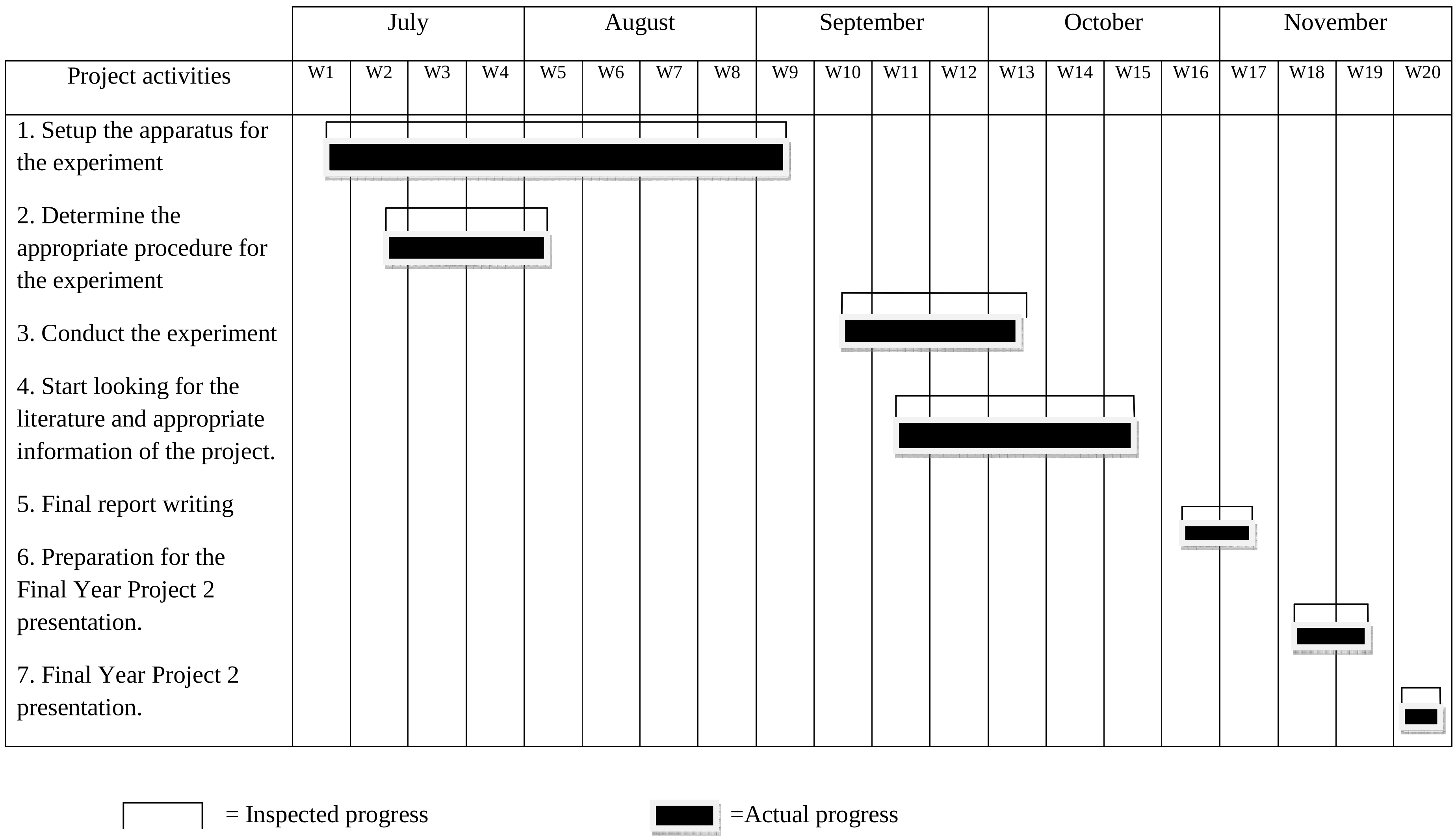
APPENDIX A

FINAL YEAR PROJECT 1 GANTT CHART



APPENDIX B

FINAL YEAR PROJECT 2 GANTT CHART



APPENDIX C

DIESEL FUEL DATA

Engine speed (RPM)	Time taken to consume 100 mL (minute)	5 minute average fuel consumption (L)	Exhaust gas temperature (°C)	Emission					Ambient Temperature (°C)	Throttle Opening (cm)
				NO_x (ppm)	NO (ppm)	CO (% volume)	CO_2 (% volume)	O_2 (% volume)		
1100	26	0.018	93	134	128	0.01	1.9	18.71	30.6	2.1
1300	22	0.022	101	107	102	0.01	1.9	18.65	30.6	2.3
1500	18	0.027	113	98	94	0.02	2.1	18.54	29.2	2.6
1700	15	0.033	125	84	80	0.02	2.2	18.46	29.2	2.9
1900	14	0.038	133	80	77	0.02	2.3	18.24	29.8	3.2
2100	12	0.045	150	78	75	0.03	2.4	17.98	29.8	3.7

APPENDIX D

TIRE DISPOSAL FUEL DATA

Engine speed (RPM)	Time taken to consume 100 mL (minute)	5 minute average fuel consumption (L)	Exhaust gas temperature (°C)	Emission					Ambient Temperature (°C)	Throttle Opening (cm)
				NO_x (ppm)	NO (ppm)	CO (% volume)	CO_2 (% volume)	O_2 (% volume)		
1100	24	0.022	100	69	66	0.20	2.0	18.39	29.3	2.0
1300	17	0.027	111	52	50	0.20	2.1	18.36	29.3	2.3
1500	15	0.031	120	38	37	0.18	2.3	18.31	30.1	2.6
1700	14	0.039	132	24	23	0.18	2.3	18.24	30.2	2.9
1900	12	0.045	148	23	22	0.19	2.4	18.00	30.6	3.3
2100	10	0.054	173	16	16	0.20	2.5	17.86	30.4	3.7

APPENDIX E

ENGINE SPECIFICATION

Brand	: YANMAR
Model	: TF 120
Displacement	: 636 cc
Max Output	: 12 Bhp @ 2400rpm
Continuous output	: 10 Bhp @ 2400rpm
Fuel tank capacity	: 11 liter
Cooling system	: Water cooled, radiator
Starting system	: Starter or manual cranking
Dimensions (L/W/H)	: 685cm/350cm/530cm
Weight	: 102 kg

APPENDIX F

BOARD COMPUTER AND FUEL FLOW METER SPECIFICATION

For board computer:

Voltage supply	: 11 to 30 VDC
Current consumption of system (U in = 24 V)	
- Normal operation and standby	: 40 MA
- With illumination	: 60 mA
- With sensors connected	: 100mA
- Supply for sensors	: U out 7 V
	I max 40 mA

For fuel flow meter:

- Dimensions	: 115 × 55 ×55 mm (incl. non-return valve)
-Weight	: 0.600 kg
- Measuring range	: 1 to 80 l/h
- Pulse rate	: 2000 ppm

APPENDIX G

TECHNICAL SPECIFICATION OF PANEL TACHOMETER AND PHOTOELECTRIC SENSOR

Model 461950 Panel Tachometer:

Range : 5 to 99 990 RPM

Accuracy : 0.1 (5 to 999.9); 1 (1000 to 9999); 10 (10.000 to 99.990)

Display : 0.5 “(13mm) 4 digit (9999 count) LED display

Display update rate: Once per second

Power : 110/220 VAC; 50/ 60 Hz $\pm$ 15%

Panel cutout dimensions: 3.62 × 1.77” (92 × 45mm)

Bezel dimensions : 3.78 × 1.89 × 2.36” (96 × 48 ×60mm)

Model 461957 Photoelectric sensor:

Range : Up to 6000 RPM (100 Hz)

Power : 12- 24 VDC $\pm$ 10%; Consumption: 40 mA max

Response time : < 1 ms

Output : NPN transistor; Max load 80 mA

Photo beam color : Green

Photo beam wavelength : 5500 Angstroms

Cable length : 1.8 meters

APPENDIX H

SPECIFICATION OF EXHAUST ANALYZER

Parameter	Resolution	Accuracy	Range
Carbon Monoxide	0.01%	±5% of reading	0-10%
Oxygen	0.01%	±5% of reading	0-21%
Hydrocarbon	1 ppm	±5% of reading	0-5000ppm
Carbon Dioxide	0.1%	±5% of reading	0-16%
Nitric Oxide	1 ppm	±4% of reading	0-5000ppm