Effect of Fuel Additives on the Performance and Emissions of an Internal Combustion Engine

By

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Project dissertation submitted in partial fulfillment of

The requirements for the

Bachelor of engineering (Hons)

(Mechanical Engineering)

September 2011

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Approved by,

_____

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TRONOH, PERAK

SEPTEMBER 2011

CERTIFICATION OF ORIGINALITY

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

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Marwan Mohamed Fathi Sayed Khatab

Abstract

Internal combustion engines fuel additives producers claim that with the addition of some additives to diesel fuel, an engine can function better in terms of performance and efficiency and decrease the emissions due to the combustion process as well. The diesel engine thermal efficiency ranges from about 35 to 40 percent. The diesel fuel price in Malaysia is about RM 1.80 per liter. The emissions due to the combustion of diesel fuel include mostly CO_x and NO_x emissions. A study must be carried out in order to validate the claims of the fuel additives producers and find out the effect of the additives on the performance and the emissions of the diesel engine. The objective of this project is to carry out the experiment needed to validate the claims throughout running an engine using an additive free diesel fuel and an additive on diesel fuel. This experiment is conducted through using two fuel additives. After testing the fuel with the additives and without the additives the results of the experiment are tabulated, comparing torque, power, specific fuel consumption and exhaust temperature with respect to the engine's speed. A single cylinder two strokes diesel engine is used in this experiment with and without the additives. The parameters of interest in this study would be (Torque, Fuel consumption, power and exhaust temperature) According to recent researches made by few researchers some additives validated the claims of the fuel additives producers. Some of these research results is included with further details in this report.

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Chapter 1

Introduction

1.1 Background

Diesel engines are widely used in oil and gas industry in order to generate electricity through connecting it to generators in the oil field. The generators produce electricity for the operation of the different equipments in the oil and gas fields.

Unlike gasoline engines; diesel engines are self ignition engines that depends on the compression ratio so that the combustion process can start. Diesel engines are also used in vehicles like the SUVs which require high torque. The compression ratio of the diesel engine ranges from 14:1 to 25:1. This means that the diesel cycle has higher thermal efficiency than the Otto cycle because the compression ratio of the Otto cycle ranges from 8:1 to 12:1. So in comparison due to the higher compression ratio the diesel engine's thermal efficiency will be higher that the gasoline engine's thermal efficiency at a lower RPM.

According to the geological studies; the earth will run out of petroleum reservoirs within the coming 40-50 years according to energy anabolic website, thus there will be a problem with the fossil fuel operated equipments. So in order to solve this problem, different researches were made in order to find alternatives to these fossil fuels. Some alternatives were found like the biomass fuel according to how stuff works website, yet they are not feasible yet due to their prices compared to the current used fuels. One of those alternatives is the biodiesel.

Engines manufacturers claim that with the usage of suitable additives the fuel consumption can decrease and at the mean time increase the thermal efficiency can be achieved. The challenges facing the usage of additives include the ability to affect the different mechanical parts through rusting and wearing, the possible need to increase the capacity of the engine and the ability to produce the additive itself. Another problem facing the environment due to the usage of diesel fuels is the resulting emissions due to the combustion process. Those emissions include CO which causes laziness' and death

due to its reaction with the body's hemoglobin. The emissions also include CO_2 which causes green house effect leading to global warming which leads to the change in the world's climate and temperatures. Other emissions like NO_x are produced too. So one of the important motives is to improve the usages of diesel fuel is decreasing the negative effect on the environment.

1.2 Problems Statement

Fuel additives have been claimed to enable increase in performance of internal combustion engines. The truthiness of this claim can be questionable. Thus a systematic study would be required.

1.3 Objective and Scope of Study

The objective of this project is to study the effect of the fuel additives on the engine in terms of thermal efficiency, fuel consumption, exhaust temperature and validate the claims of the manufacturers.

The scope of study will include experimental work on a single cylinder engine in order to find the effect of the additives of the fuel on the performance and emissions of the engine. The primary interest would be the variation of torque, power, specific fuel consumption and the exhaust temperature at a constant RPM for a constant time interval

Chapter 2

Literature Review

2.1 Effect of Iron-Based Fuel Additives on Diesel Engine Emissions

This research was carried out by Centers for disease control and prevention. To evaluate the potential of the two iron based fuel additives; laboratory tests were conducted. Ferrous picrate did not affect the engine exhaust properties and it did not affect diesel particulate matter as well. The ferrocence-treated fuel produced red deposits in the engine's main combustion chamber. In conclusion this is the red coating of ferric oxide which acts as oxidation catalyst. By measuring the concentration of exahaust emissions (CO, CO_2, O_2, GPHC, NO_x and diesel particulate matter); it was found that they were affected by the presence of the ferrocence-treated fuel. The diesel particulate matter reductions ranged between 4 to 45 percent for six steady-state engine operating conditions. The diesel particulate matter reduction for an 8 minute transient cycle reached up to 37%. The reduced level of VDPM caused the change in the DPM at low and moderate fuel-air ratios, and this was found out through measurements. However, at high load conditions; an analysis of the results showed that the carbon levels were reduced as well. The major opposing effect was the increment in the NO_x which reached up to 12%.

2.2 Effects of Di-Methyl Carbonate Fuel Additive on Diesel Engine Performances

The physical and chemical properties of some oxygenated compounds are discussed, including dimethoxymethane (methylal, or DMM), dimethyl carbonate (DMC), and ethyl acetate. In particular, DMC may be a promising additive for diesel fuel owing to its high oxygen content, no carbon-carbon atomic bonds, suitable boiling point, and solubility in diesel fuel. The aim of this research was to study the combustion characteristics and performance of diesel engines operating on diesel fuel mixed with DMC. The experimental results have shown that particulate matter (PM) emissions can be reduced using the DMC oxygenated compound. The combustion analysis indicated that the ignition delay of the engine fuelled with DMC-diesel blended fuel is longer, but combustion duration is much shorter, and the thermal efficiency is increased compared with that of a base diesel engine. Further, if injection is also delayed, NO_x emissions can be reduced while PM emissions are still reduced significantly. The experimental study

found that diesel engines fuelled with DMC additive had improved combustion and emission performances. Journal of Automobile engineering (2005).

2.3 Effect of H_2o_2 Addition in Increasing the Thermal Efficiency of A Diesel Engine

The impacts of using a small amount of H_2O_2 mixture as an additive on the performance of a four-cylinder diesel engine were evaluated. The required amount of the mixture was generated using electrolysis of water considering on-board production of H_2O_2 mixture. Hydrogen which has about nine times higher flame speed than diesel has the ability to enhance overall combustion generating higher peak pressure closer to TDC resulting in more work. The experimental results showed that with the introduction of 6.1% total diesel equivalent H_2O_2 mixture into diesel, the brake thermal efficiency increased by 2.6% at 19 kW, 2.9% at 22 kW, and 1.6% at 28 kW. The brake specific fuel consumption of the engine reduced by 7.3%, 8.1%, and 4.8% at 19 kW, 22 kW, and 28 kW, respectively. However, adding H_2O_2 beyond 5% does not have significant effect in enhancing the engine performance. The emissions of HC, CO_2 and CO were found to be reduced due to better combustion while NOx increased due to the higher temperature reached during the combustion. This research was carried out by Bari and Esmaeil (2009).

Chapter 3
Theories

3.1 Gasoline Engine versus Diesel Engine

The diesel cycle is the ideal cycle of a self ignition engine. This means that the combustion doesn't require ignition. Unlike the gasoline engines, diesel engines only depend on the compression ratio of the fuel to start ignition. The diesel engine was first proposed by Rudolph Diesel in 1890s. The working mechanism of the diesel engine depends on the compression of air to a temperature that is above the auto ignition temperature of the fuel. The fuel is then injected to the combustion chamber and once a contact between the fuel and the hot air occurs; combustion takes place. In other words, both the spark plug and the carburetor are replaced by a fuel injector diesel engine.
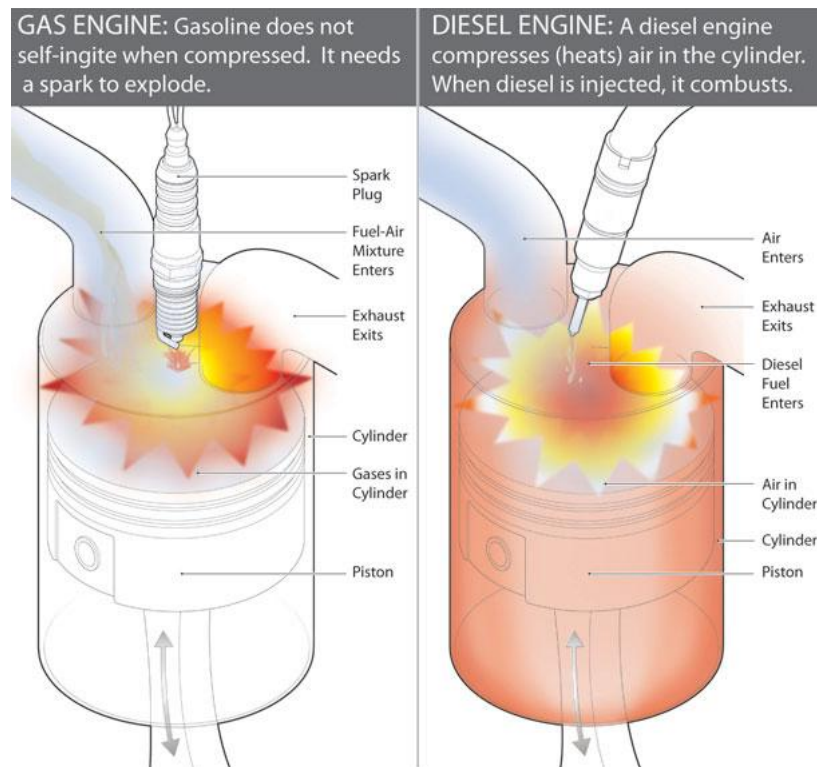
Fig. 3.1 Gasoline Engine Vs Diesel Engine …. www.hybridcars.com

In the diesel engines during the induction stroke only air is drawn to the combustion chamber. The charge of air is compressed leading to an increase in its temperature. The temperature of the air rises to a level higher than the temperature at which the fuel self ignites. The specific fuel consumption of a diesel engine is lower than that of gasoline engine. The diesel engines operate at higher compression ratios because they are heavier than gasoline.

3.2 The Diesel Cycle

During the compression stroke, air is compressed, thus preventing auto ignition; and this is the reason behind the ability of the diesel engine to normally operate with compression ratios of 12 to 24. This also gives the ability to remove the stringent requirements placed on the gasoline allowing the ability to use less refined fuels (which will be less expensive) in diesel engines.

The diesel cycle starts with an isentropic compression 1-2, the process 2-3 is heat addition process in an approximated constant pressure, process 3-4 is an isentropic expansion and 4-1 process is a constant volume heat rejection.

The ignition takes place when the fuel is injected when the piston reaches the top dead center and continues during the first part of the power stroke allowing the combustion process to take place over a longer interval.

Fig. 3.2 P-V and T-S diagrams of diesel cycle

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3.3 Four Strokes Engine versus Two Strokes Engine

The four stroke engine (Fig. 3.3) is called Four stroke because of the working principle used the four strokes of the engine are separated.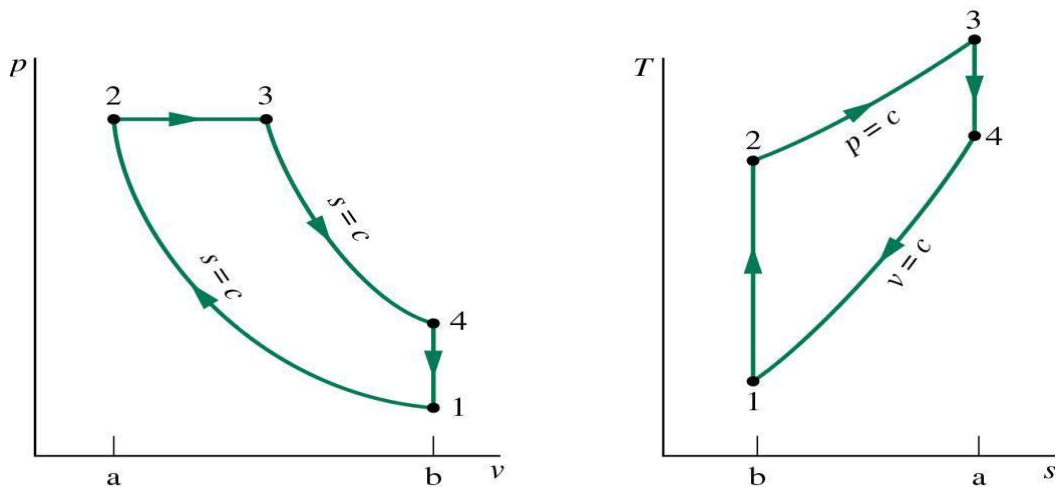 In a rotation two strokes occur. Air is drawn in through the carburetor. The butterfly valve in the carburetor controls the flow of air to the engine. The throttle is connected to the valve thus it can control it. The speed of the engine is changed by moving the throttle which by its turn moves the valve leading to more air drawn by the carburetor. The carburetor also controls the flow of the fuel. The fuel and the air are mixed in the correct proportions.

The fuel evaporates in the induction manifold and the mixture of air fuel is drawn into the cylinder. During compression self ignition occurs.

Induction stroke: the process of drawing the fuel and the air to the cylinder. Air is drawn into the cylinder through the inlet valve by the downward movement of the piston. Induction pressure is slightly below atmospheric pressure.

Compression stroke: The piston reaches the bottom dead center "BDC" and the inlet valves close. Air is compressed by the upward motion of the piston and diesel is injected just before the piston reaches top dead center "TDC", then self ignition of the mixture occurs

Power stroke: The piston is pushed downwards as an effect of the expansion of the gases as their pressure increases dude to the heat generated by combustion process during the compression stroke. Exhaust valves open during the end of the power stroke in order for the gas to blow down the exhaust duct. The pressure now falls to approximately the atmospheric pressure.

Exhaust stroke: the rest of the exhaust gas is pushed out of the cylinder through the exhaust valve. This process occurs when the piston moves again upwards. Exhaust valve closes and inlet valves opens for the next stroke at the end of the stroke.
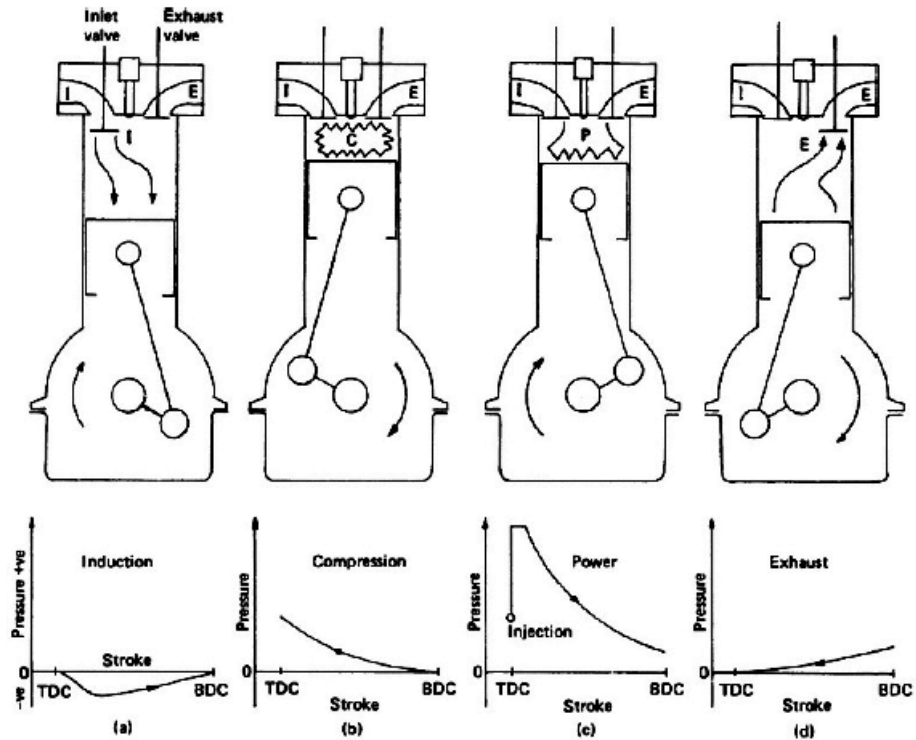
Fig. 3.3 Four Strokes Engine

The work is done by the gas to drive the piston downwards during each power stroke (this is the reason why it is called power stroke). The connecting rod transmits the force on the piston to an offset crank which turns the crankshaft. The energy produced is averaged over the four strokes by the flywheel and an average torque is produced at the engine output shaft.

The two strokes engine is called two strokes because in this engine two strokes take place simultaneously, thus the two strokes engine completes the same cycle of events like the four strokes in only two strokes. Unlike the four stroke engine, power is produced twice the power strokes for a given engine speed, while on the other hand the four strokes engine has only one power stroke. Piston is used to cover and uncover the passage in cylinder and crankcase; therefore the inlet and the exhaust valves are eliminated.
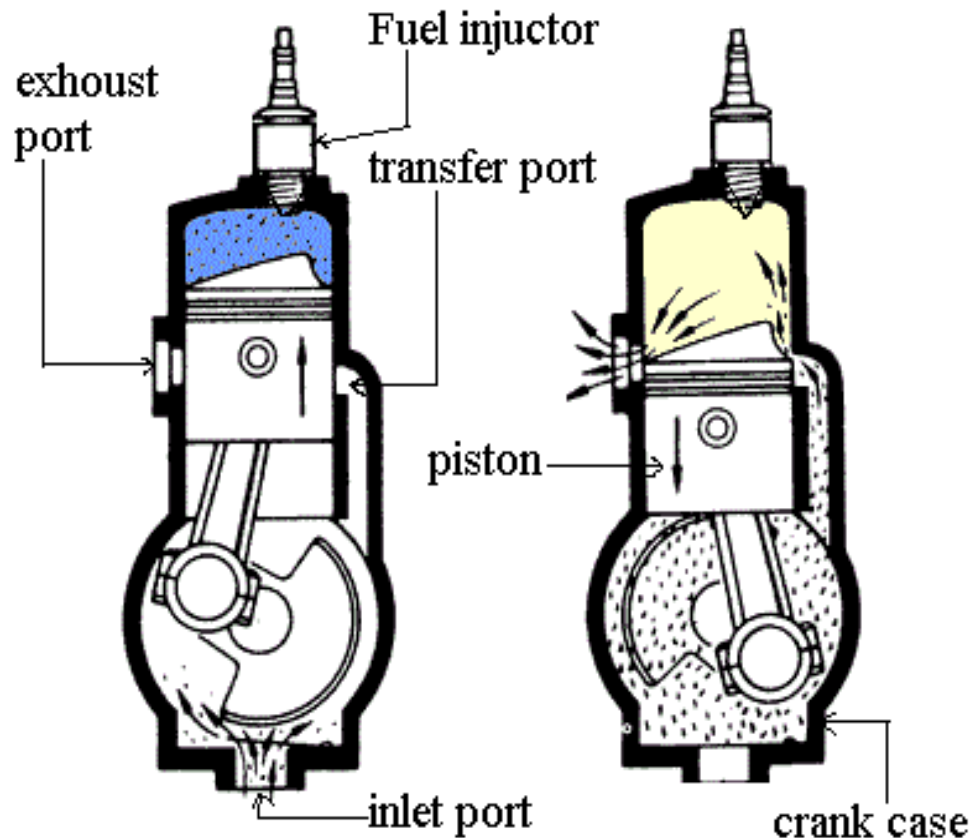
Fig. 3.4 Two Strokes Engine

In the two strokes engine (Fig. 3.4), the cycle begins where the piston is about halfway through its compression stroke and all the three ports (passages) are covered. Inside the combustion chamber fresh charge of the mixture is compressed due to the upward movement of the piston. The pressure in the crankshaft is reduced below atmospheric pressure at the same time. Near the top of the stroke the lower edge of the piston uncovers the inlet port; this allows the pressure of the atmosphere to fill the crankcase of the engine with fresh mixture from the carburetor.

Ignition takes place near the top of the stroke (similar to the four strokes engine). The piston is driven down by the high pressure of the burned gases. The inlet port is covered by the piston just below the top dead center, when the piston moves further downward

the mixture is compressed to the crankcase. The piston uncovers the exhaust port near the bottom of the stroke; this allows the burnt gases to flow out of the cylinder under their own pressure.

Slightly further down, the piston uncovers the transfer port and the compressed mixture in the crankcase flows into the cylinder above the piston. The mixture is deflected upwards by the shaped piston, this prevents it from flowing straight across the cylinder and out through the exhaust port. The cycle operation begins again as the piston rises on its next stroke.

3.4 Engine RPM

The engine used to conduct this experiment is a Robin DY23-2D diesel engine. This engine is a single cylinder two stroke engine which can operate to a maximum RPM of 3750. The RPM of this engine is controlled by using a mechanical throttle. The maximum power output is 3.5 KW / 3600 RPM. The starting system of the engine is a recoil starter.

The engine RPM is measured electronically by a pulse counting system. An optical head mounted on the dynamometer chassis contains an infrared transmitter and receiver. A rotating disc with radial slots is situated between the optical source and sensor. As the engine and slotted disc rotate the beam is interrupted. The resulting pulse train is electronically processed to provide a read out of engine RPM.

The engine RPM is the varying parameter in this experiment. This means that the output parameters of this experiment will be in variance with the RPM. The RPMs used in this experiment are 1000 RPM, 1500 RPM and 2000 RPM. The variation of the RPM is a decrement of 500 RPM starting from 2000 RPM as the max and the lowest is 1000 RPM.

Fig. 3.5 (Ribon DY23-2D engine)

The RPM of the engine is to be converted to the unit of rad/sec by using this formula:

$$V = 2\pi \frac{\omega}{60}$$ (3.1)

where W is the engine RPM and V is the speed of the engine in rad/sec. This formula will give us the speed of engine in the units of rad/sec which can be used later on to find the power of the engine.

3.5 Engine Torque

The torque of this engine is determined by using a dynamometer. The dynamometer load is exerted by the pressure of water, thus we have to make sure that the dynamometer is filled with water before carrying out the experiment. The torque will be used later on to find the power of the engine using the formula:

$$P = \tau * V$$ (3.2)

3.6 Exhaust Temperature

The temperature of the exhaust is measured by using the thermocouple. The thermocouple is connected to the exhaust pipe as well as the instrumentation unit

3.7 Diesel fuel flow rate

The engine fuel rate is determined by calculating the time needed by the engine to fully consume 8 ml of fuel. The timing is kept by a stop watch and then this equation is used to find the fuel flow rate:

$$\dot{m}_f = \frac{SG_f * 8 * 10^{-3}}{t} \tag{3.3}$$

where SG_f is the specific gravity of the fuel used, and t is the time taken by the engine to consume the fuel.

Chapter 4

Methodology

4.1 Research Methodology

The research methodology started by literature review in order to find the up to date results of research papers related to the topic of this project. After the literature review a research is made in order to find the suitable additives that can be used in this experimental project. The criteria of the additive are the availability and the price as well. An extra research was made in order to find other additives and compare it to the additives used in the experimental work..

4.2 Project Activities

Project activities will include experimental work using a single cylinder diesel engine. The engine was run first with the diesel fuel without any additives. This test was run in order to find the preliminary results needed to compare it with the further results during the experiment. After that another test run will be done but this time the additives will be added to the fuel. The results found then will be compared to the preliminary results of the experiment. The experiment was repeated three times using three different RPMs (2000, 1500, and 1000) for the engine. After running the experiment tabulated results was presented on a graph. The graphs include torque, power, exhaust temperature and fuel consumption relative to the engine RPM. The graph is used to compare the performances of the pure diesel together with the fuel mixed with the additives.

4.3 Tools

A single cylinder diesel engine was used in order to test the effect of the additives on the diesel will be used. Readings was taken throughout monitoring the temperature of the emission, the fuel consumption, the torque and the RPM of the engine.

4.4 Project Methodology Flow Chart

The project starts with a research on the current research results, including all the possible research carried out in order to validate the claim of the fuel additives producers.

The fuel additives are identified. Two additives will be used in this experiment. These additives are (STP diesel fuel treatment and X-1R diesel system treatment).

The third step in this project is the base fuel test, where the diesel is used without any additives to come up with the parameters needed in this study which are (power, exhaust temperature and fuel consumption) with variance of the RPM of the engine.

The next step is a testing experiment for the diesel fuel, but this time each additive was used to run the experiment and find the same parameters used in the base fuel test.

After carrying out both experiments, the results were tabulated showing the relation between the parameters of this experiment with the RPM of the engine and show the difference in the performance of the fuel which is additives free and the one that has the additives.

```
┌──────────────────┐
│ Research the     │
│ current research │
│ results          │
└────────┬─────────┘
         ↓
┌──────────────────┐
│ Finding the      │
│ suitable         │
│ Fuel additives   │
└────────┬─────────┘
         ↓
┌──────────────────┐
│ Experimenting on │
│ the engine with  │
│ the additives    │
└────────┬─────────┘
         ↓
┌──────────────────┐
│ Experimenting on │
│ the engine       │
│ without the      │
│ additives        │
└────────┬─────────┘
         ↓
┌──────────────────┐
│ Tabulating the   │
│ results of       │
│ consumption      │
│ relative to RPM  │
│ of the engine    │
└────────┬─────────┘
         ↓
┌──────────────────┐
│ Tabulate the     │
│ results of       │
│ emission         │
│ temperatures     │
│ relative to the  │
│ RPM of the engine│
└────────┬─────────┘
         ↓
┌──────────────────┐
│ The physical and │
│ the chemical     │
│ changes in the   │
│ fuel will be     │
│ experimented     │
└──────────────────┘
```

Fig. 4.1 Project flowchart

4.5 Project Gantt charts

Table 4.1 FYPI Gantt chart:

No.	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of project	▓	▓													
2	Selection of project title			▓												
3	Approval of purchase and usage of resources and services				▓											
4	Preliminary research work				▓	▓	▓									
5	Submission of extended proposal defense						▓									
6	Meeting Mr. Fahmi and Mr. Sani to discuss with them about the project							▓								
7	Proposal Defense									▓	▓					
8	Project work continues in Block N											▓	▓	▓		
9	Submission of interim draft report														▓	
10	Submission of interim report															▓

Table 4.2 FYPII Gantt chart:

No.	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project work continues in Block N	▓	▓													
2	Meeting with Mr. Fahmi and Mr. Sani to discuss about the results			▓												
3	Project work continues in Block N				▓	▓										
4	Meeting with Dr. Shahrin do discuss the results of the project						▓									
5	Project work continues in block N							▓								
6	Submission of progress report									▓						
7	Project work continues in block N										▓					
6	Meeting with Dr. Shahrin, Mr. Fahmi and Mr. Sani to show the updated results											▓				
7	Pre-EDX												▓			
8	Submission of draft report													▓		
9	Submission of technical paper														▓	
10	Submission of dissertation (soft bound)														▓	
11	Viva															▓
12	Submission of hard-bound copy of project dissertation															▓
13	Grading of project															▓

4.6 Experiment activity

4.6.1 Apparatus

The basic test rig for each engine consists of engine, hydraulic dynamometer and instrumentation unit. The engine used (Fig 4.2) is a Robin DY23-2D diesel engine. The engine is a single cylinder two stroke engine with mechanical throttle and maximum power output of 3.5 KW / 3600 RPM. The starting system of the engine is a recoil starter. The engine throttle (B) is used to adjust the RPM of the engine, the bleed hex screw (A) is used to make sure that the air is totally removed from the system, The priming plunger (C) is removed in order to fill the plunger chamber with the fuel. The instrumentation unit (Fig 4.3) is used to measure and display the engine performance; it contains fuel system, air flow meter, torque gauge, RPM gauge and temperature gauge. The hydraulic dynamometer (Fig 4.4) is used to measure the torque of the engine. The flow is controlled by a needle valve (A), water is supplied to the top of the dynamometer and out through the bottom, the water is then discharged through a tap (C). Needle (A) controls the flow through the dynamo meter, hence it controls the load applied controlling power absorbed from the engine.   The fuel system (Fig 4.5) is fed from a 4.5 liter tank mounted on the top of the instrumentation unit. The fuel consumption is determined by measuring the time taken for the engine to consume a given volume, a graded pipette can be used to do this, and the pipette is marked on 8mL, 16mL and 32mL. The complete small engine test rig (Fig 4.6) shows the schematic diagram of the whole system together. The parts of the system are; bench (1), water supply (2), drain (3), exhaust system (4) and electric power point (5). The engine is the connected the exhaust system, engine air intake is connected to the instrumentation unit Airbox using a short flexible pipe (6). The torque transducer, tachometer optical head and exhaust thermocouple are connected to the correct inputs on the instrumentation unit (A, B, C). The water supply is connected to the inlet of the needle valve.
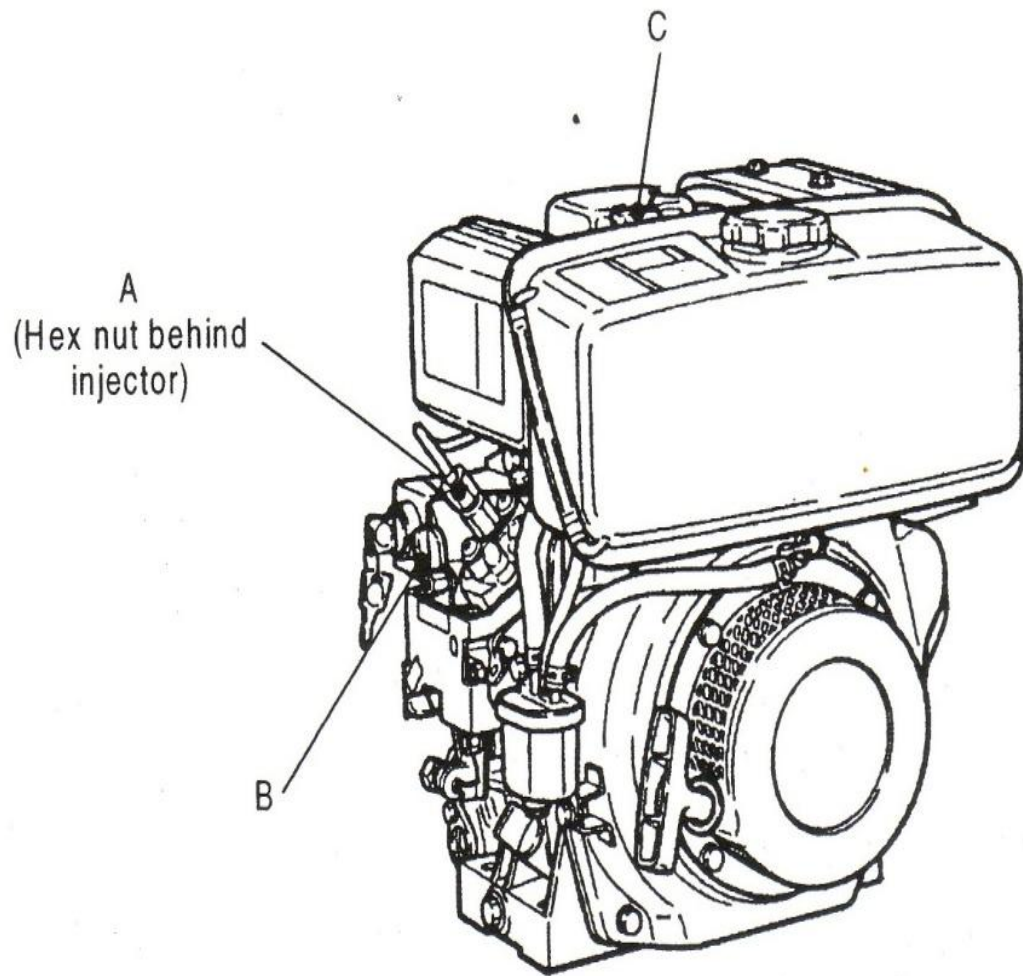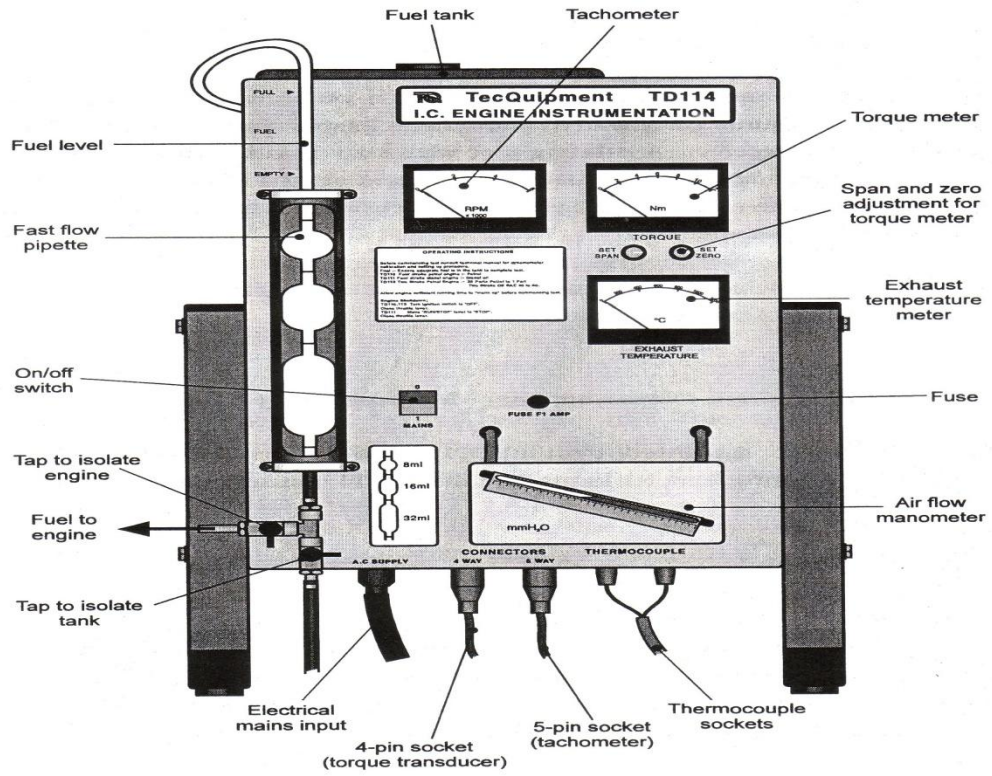
Fig. 4.2 Diesel Engine Controls
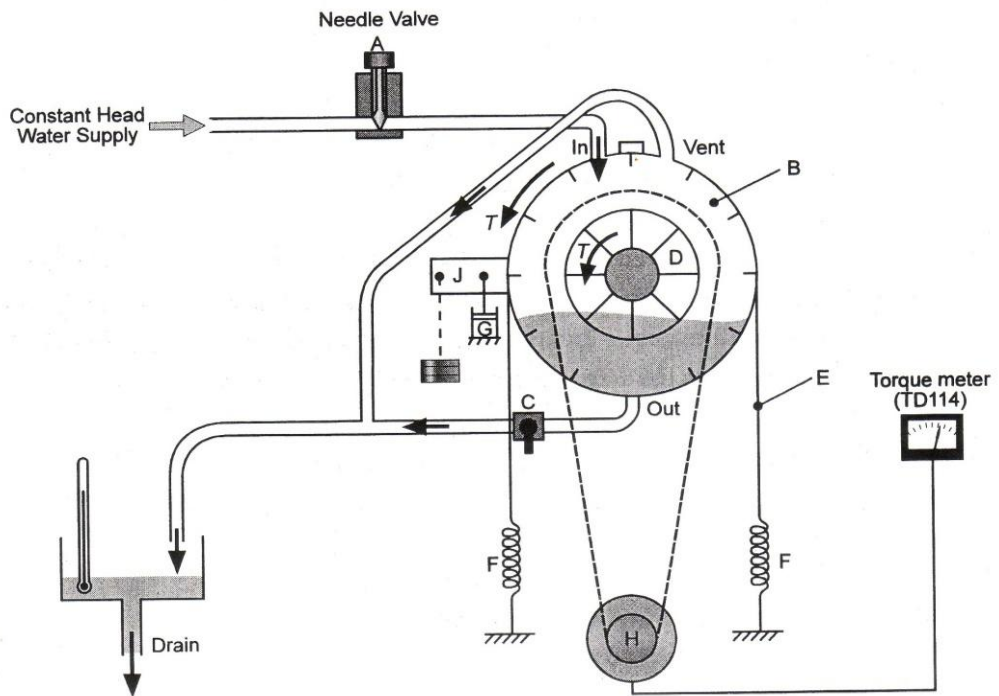
Fig. 4.3 Instrumentation Unit

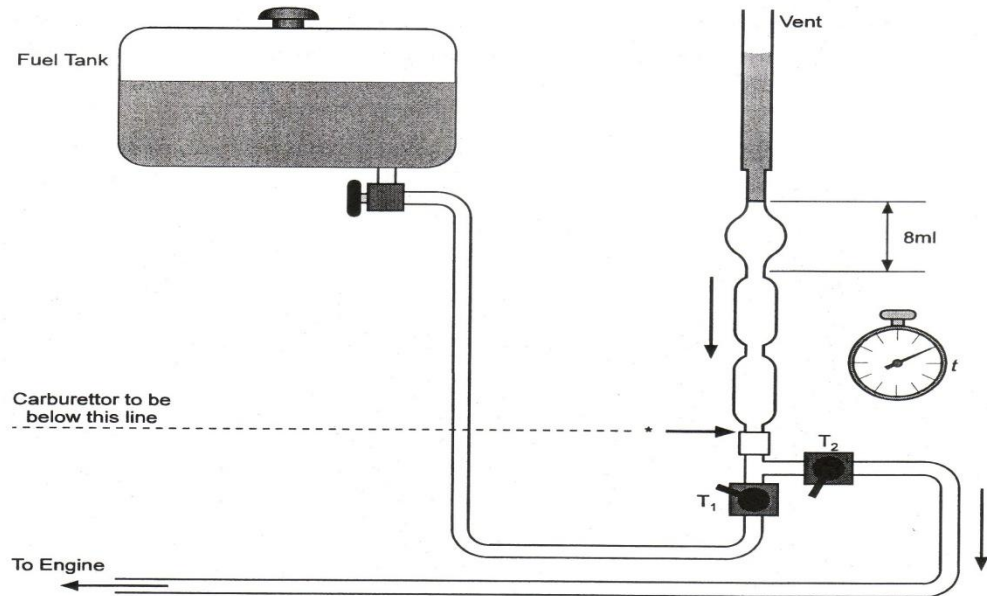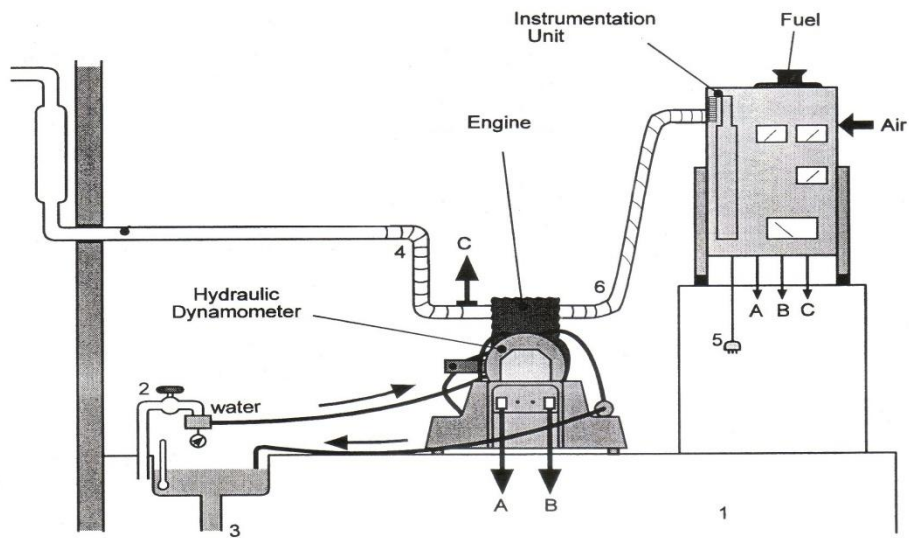Fig. 4.4 Hydraulic Dynamometer

Fig. 4.5 Fuel System

Fig. 4.6 The complete Small Engine Test Rig

4.6.2 Procedures

The instrumentation unit is connected to the electric source; connection of the thermocouple is checked. Water tap and water valve are opened to a half turn, engine mechanical throttle is set to half throttle. Fuel as added to the tank, water drain valve is opened. Valve T1 (Fig 4.5) is closed in case of the availability of fuel in the fuel meter and vice versa while valve T2 is always opened. The engine is started and left to warm up for 10 minutes before taking the readings. The experiment is carried out starting by the highest RPM (2000 RPM), follow by 1500 RPM and then to the lowest RPM (1000 RPM). Data is recorded. The experiment is carried on first by using a pure diesel engine. The experiment is then carried out twice using the two different fuel additives. The ratio STP diesel fuel treatment to fuel is 2.4 mL for every 1 liter of diesel, the ratio of X-1R diesel system treatment is 3.7 mL for every 1 liter of diesel. After running the experiment with pure diesel the fuel was totally flushed from the engine. The engine was run until it stopped by itself to make sure that the engine is totally free from fuel. The fuel mixed with STP diesel fuel treatment is then poured into the fuel tank. After recording the data for 2000 RPM, 1500 RPM and 1000 RPM again the fuel is totally flushed and the engine is run until it stops by itself to make sure it is totally free from the fuel. The X-1R diesel system treatment is then poured to the fuel tank, experiment is run again and the data for 2000 RPM, 1500 RPM and 1000 RPM is recorded.

Chapter 5

Results and Discussion

5.2 Results

After running the experiment the results were all brought together in one table. The results of this experiment are all taken after a constant time interval of 4 minutes. For the highest RPM the readings were taken after 14 minutes, 10 of those were for the engine warm up and another 4 minutes for the instrumentation unit to be in a stable state. After changing the RPM 4 minutes were taken by engine in order to assure the stability of the instrumentation unit. The tables below show the results of the experiment after running it using pure diesel (Table 5.1), STP diesel fuel treatment (Table 5.2) and X-1R diesel fuel treatment (Table 5.3). All the results were then tabulated in graphical representation in order to show the difference between pure diesel and diesel mixed with additives.

Table 5.1 Experiment Results for pure diesel

RPM	Torque (N.m)	Exhaust Temperature (T^oC)	Air Flow (mmH_2O)	Fuel consumption (ml/sec)	Power (hp)
1000	4.5	200	4.5	0.05	0.60
1000	4.75	200	4.5	0.05	0.64
1000	4.75	200	4.5	0.05	0.64
1500	8.5	250	7	0.09	1.71
1500	8.75	260	7	0.09	1.76
1500	9	260	7	0.09	1.81
2000	8.5	250	10	0.13	2.28
2000	9	270	10	0.13	2.42
2000	9.5	310	10	0.13	2.55

Table 5.2 Experiment Results for diesel mixed with STP diesel fuel treatment

RPM	Torque (N.m)	Exhaust Temperature (T^oC)	Air Flow (mmH_2O)	Fuel consumption (ml/sec)	Power (hp)
1000	4.75	190	3	0.06	0.64
1000	5	190	3	0.06	0.67
1000	5.25	190	3	0.06	0.70
1500	8.5	260	6	0.11	1.71
1500	8.75	260	6	0.11	1.76
1500	9	260	6	0.11	1.81
2000	8.5	250	9	0.17	2.28
2000	9	290	9	0.17	2.42
2000	9.5	300	9	0.17	2.55

Table 5.3 Experiment Results for diesel mixed with X-1R diesel system treatment

RPM	Torque (N.m)	Exhaust Temperature (T^oC)	Air Flow (mmH_2O)	Fuel consumption (ml/sec)	Power (hp)
1000	5.25	210	3	0.07	0.70
1000	5.5	210	3	0.07	0.74
1000	5.75	200	3	0.07	0.77
1500	9	270	6	0.13	1.81
1500	9.25	270	6	0.13	1.86
1500	10	260	6	0.13	2.01
2000	10	270	9	0.19	2.68
2000	10.5	300	9	0.19	2.82
2000	11	340	9	0.19	2.95

Table 5.4 Average of experiment Results for pure diesel

RPM	Torque (N.m)	Exhaust Temperature (T^{o}C)	Air Flow (mmH$_2$O)	Fuel consumption (ml/sec)	Power (hp)
1000	4.67	200	4.5	0.05	0.63
1500	8.75	256.67	7	0.09	1.76
2000	9.25	276.67	10	0.13	2.48

Table 5.5 Average of experiment Results for diesel mixed with STP diesel fuel treatment

RPM	Torque (N.m)	Exhaust Temperature (T^{o}C)	Air Flow (mm H$_2$O)	Fuel consumption (ml/sec)	Power (hp)
1000	5	190	3	0.06	0.67
1500	8.75	260	6	0.11	1.76
2000	9.25	280	9	0.17	2.482

Table 5.6 Average of experiment Results for diesel mixed with X-1R diesel system treatment

RPM	Torque (N.m)	Exhaust Temperature (T^{0}C)	Air Flow (mm H$_2$O)	Fuel consumption (ml/sec)	Power (hp)
1000	5.5	206.67	3	0.07	0.74
1500	9.42	266.67	6	0.13	1.90
2000	10.75	303.33	9	0.19	2.89

5.3 Discussion

The results of the experiment were all expressed in a graph. The pure diesel together with the mixed diesel was all put together in one graph in order to compare the different results. There are five graphs tabulated below. These graphs shows the relation between the experiment parameters (power, air flow, fuel consumption, torque and exhaust temperature) relative to the engine RPM.
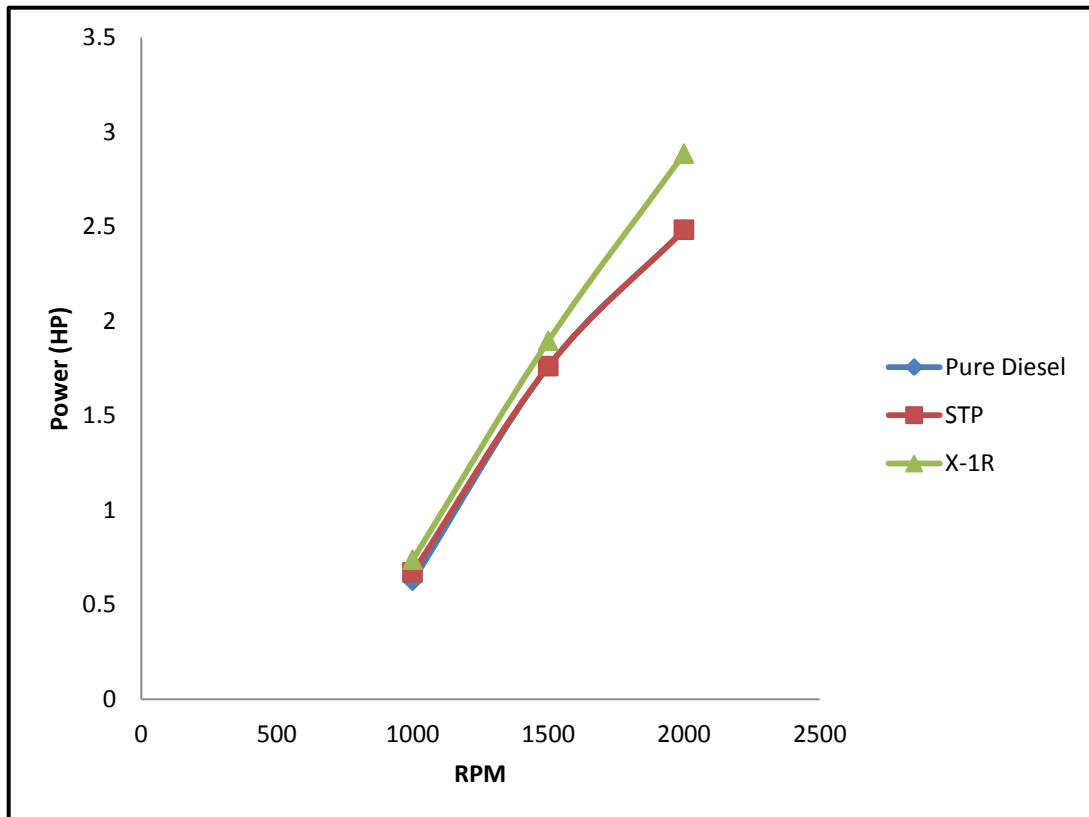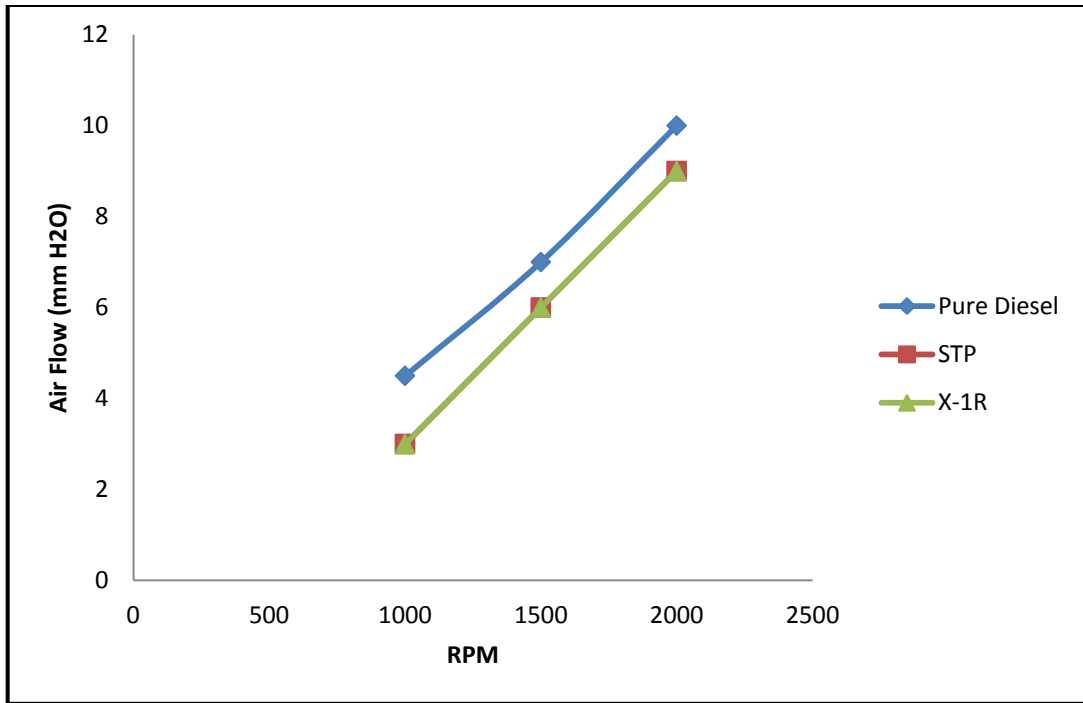

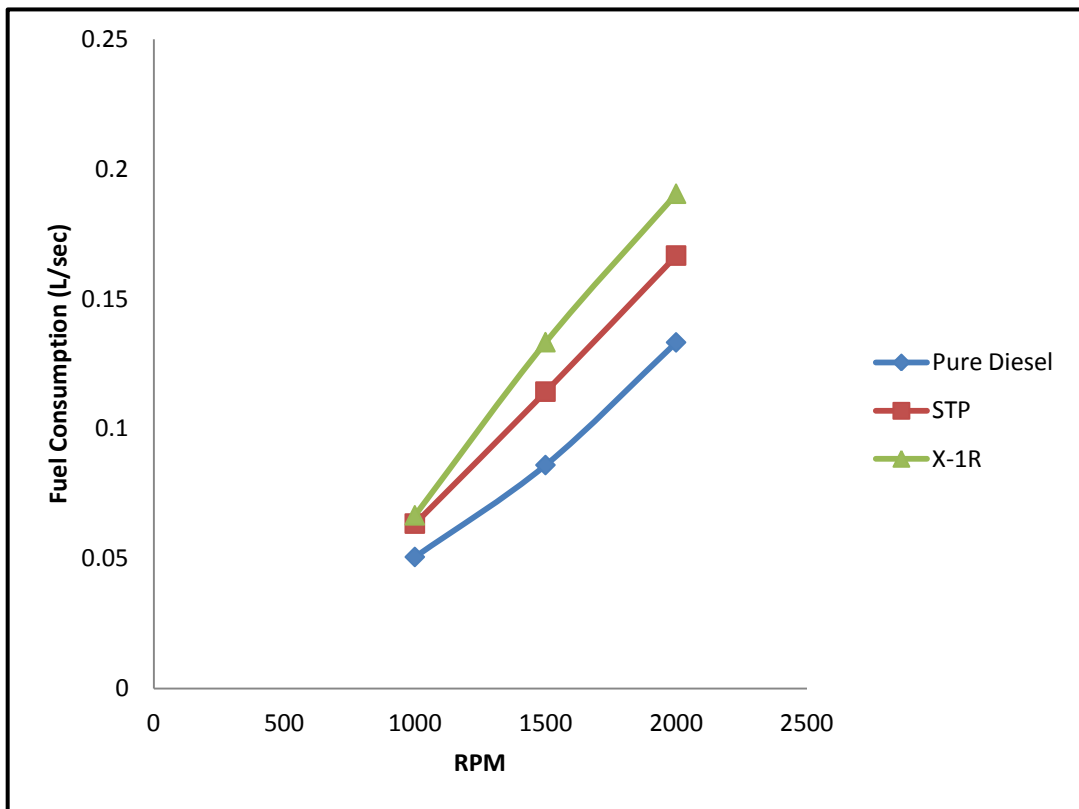Fig. 5.1 Power Vs RPM

Fig. 5.2 Air Flow Vs RPM
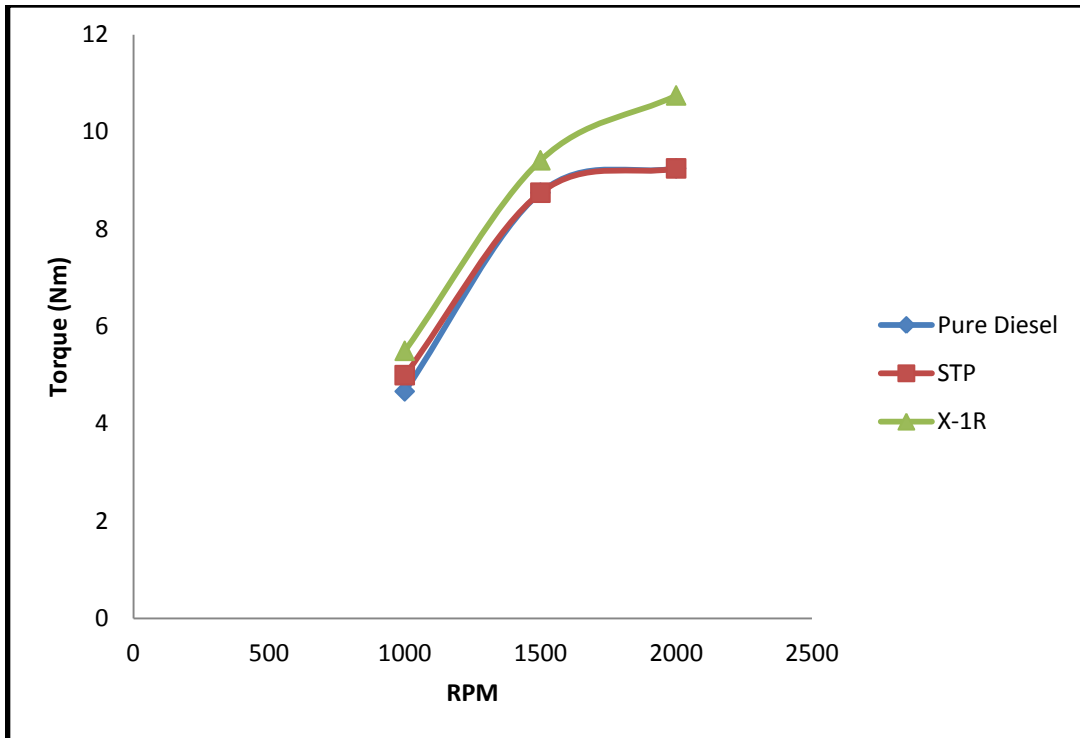

Fig. 5.3 Fuel consumption Vs RPM
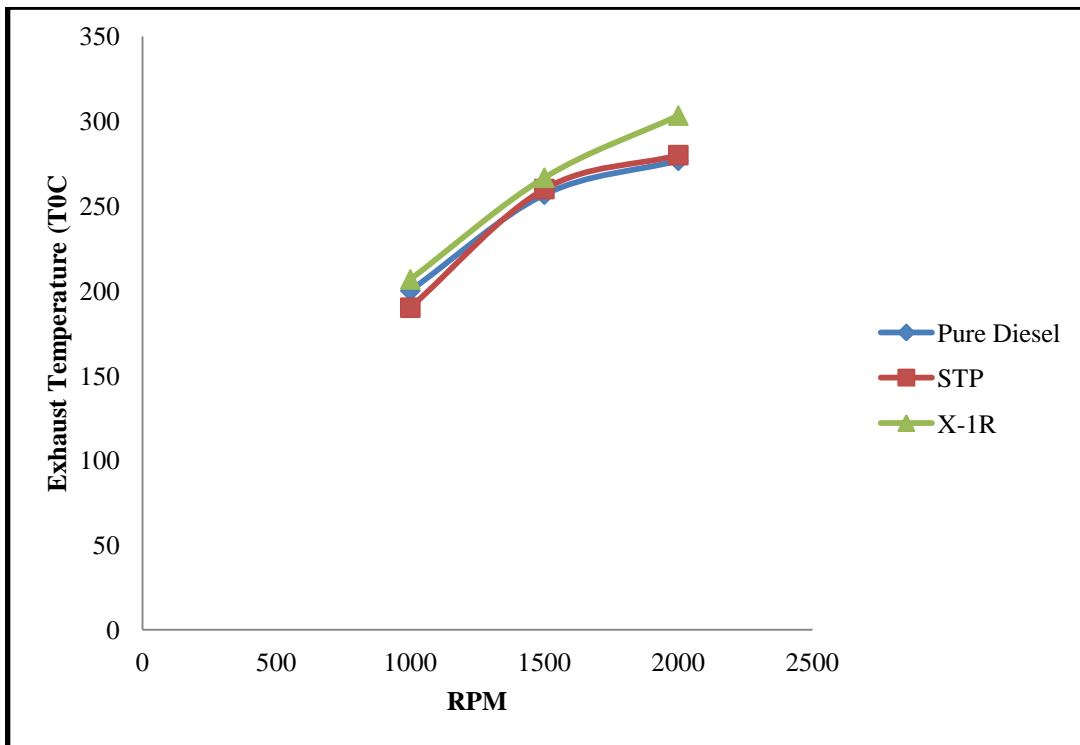
25

Fig. 5.4 Torque Vs RPM

Fig. 5.5 Exhaust Temperature Vs RPM

Results showed that both additives have effect on the diesel engine. For the STP diesel fuel treatment; there is an increase in the consumption, a decrease in the air flow, results also showed that it has no effect on engine torque, power and exhaust temperature. This is due to the nature of the STP diesel fuel treatment which is more of a cleaner than a fuel booster, it can have effect on the long run. For the X-1R diesel fuel treatment; there is an increase in fuel consumption as well, a decrease in the air flow, results showed an increase in engine torque, power and exhaust temperature. This is due to the effect of the X-1R diesel system treatment which works on both cleaning of the system as well as better fuel consumption leading to a boost in the engine performance. The effect of X-1R diesel system treatment can be better on the long run; however the difference can still be noticed in a short run as well. From the Figures above we can see that all the five parameters increase by increasing the RPM (which is expected from the experiment).

There was only one problem with the engine which was the very high vibration that occurred during running the experiment. This very high vibration caused error in the readings dude to the unstable condition of the engine. The suggested solution is the replacement of the engine by a new one as this engine is old and was used in so many researches before.

Form the aspect of HSE the lab is considered in an unsafe unhealthy condition. The chemicals in the lab are not labeled and safety precautions weren't fulfilled (safety gloves and safety mask weren't found in the lab, yet the safety mask arrived to the lab in the last half four of the experiment). The lack of ventilation system is another HSE problem in this lab because the increased volume of fumes is harmful for the experiment conductor because diesel fumes contain carbon which is extremely dangerous on health.

Chapter 6

Conclusions and recommendations

6.1 Conclusions

In conclusion, the project objectives were achieved throughout experiment work. The claims of the manufactures are found to be true, because there is an effect on the fuel due to the usage of the additives, however the additives producers recommend the usage of the whole additive in the car tank and then reuse again after certain mileage coverage. For STP diesel treatment, it is advised by the treatment producer to use the whole amount of the bottle (236mL) for every 14 gallons (around 53 liters). For X-1R diesel system treatment, it is advised by the treatment producer to use the whole amount of the container (240mL) for every 100 liters. Due to the cleaning effect of the additives carbon remains are cleaned, this lead to better performance and on the long run will lead to longer life time for engine parts.

6.2 Recommendations

It is recommended that the fuel additives should be used due to their cleaning effect which can increase the life time of engine parts. It is also recommended to make sure to choose the suitable additive, the experiment showed that an additive meant for cleaning is different than the one mean for boosting the performance. Recommendation for the project is to take it to further experimental to find better additives if possible. And finding the better additives is not the end of this project; it is also recommended to be able to find the suitable marketing plan to market the additives that were found to have a positive effect on fuel consumption and emissions. It is also recommended to solve the engine vibration problem for more precise results, because due to the vibration the readings of the RPM changes due to the vibration of the throttle arm. The readings of the RPM have a tolerance of about ±300 RPM. The problem can be used by using a clip for the throttle or use another engine that is controlled by a computer unit which will be more precise.

Chapter 7
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