COMPARATIVE STUDY OF I.C. ENGINE PERFORMANCE USING DIFFERENT FUELS

A thesis submitted to the department of Mechanical and Chemical Engineering (MCE), Islamic University of Technology (IUT), in the partial fulfillment of the requirement for the degree of Bachelor in Science in Mechanical Engineering.

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CERTIFICATE OF RESEARCH:

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DECLARATION:

This is to certify that the work presented in this thesis is an outcome of experiment and research carried out by the authors under the supervision of **Dr. Md. Faisal Kader**.

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Acknowledgement

We state our heartiest gratefulness to almighty Allah for His kindness, which enables us to finish our project on ''Comparative study of I.C. engine performance using different fuels'' and provides us an opportunity to start our thesis on this very project.

Firstly, it is our pleasure to express our sincere gratitude to the project supervisor **Dr. Md. Faisal Kader** for his support, helpful suggestions and supervision at all stages on the progress of this thesis work. His guidance, encouragement & enthusiasm influenced us to carry out the thesis up to this point.

We are also grateful to **Mr. Robiul Hasan**, who is our automobile Lab in charge for assisting us with his vast practical experience in this field.

We are highly indebted to the above mentioned persons & corporation, without their association it would have been impossible to bring out this report. We seek excuse for any error that might have in the report although we have tried our best.

ABSTRACT

Comparative study of I.C. engine using different fuels is the test of engine performances for different properties of engine as well as comparing these properties using different fuels. The processes involved measuring exhaust temperature, torque, R.P.M. of a small engine with the help of a small engine test bed (TD110-115) and instrumentation unit (TD114). Applying the output value from the previous method and with the help of mathematical formula brake power, specific fuel consumption, fuel mass flow rate, and brake thermal efficiency can be measured. A comparative analysis is introduced by repeating the last two steps to obtain the data analysis table and plotting the curves with the respective values. As conventional fuel petrol, octane and diesel were the common selections. But comparative analysis was aspired to comprehensiveness with the introduction of alternative fuels. The relative analysis with alternate fuels like bio-ethanol came out as a tremendous significance to our whole endeavor. Running the same engine with the same set up instrumentation but different fuels, was an ultimate analysis not only for the engine performance test but also a solution of best possible fuel for the engine. In our experiment we got the maximum torque (7Nm), brake power (2.31kW) and specific fuel consumption at maximum torque speed (418.18 g/kWh) for diesel that's why it is used for high load. For small capacity engine like automotive vehicle bio-ethanol is a much better choice than petrol as it has lower exhaust temperature (300°C max) and higher brake thermal efficiency(24%). CNG is cost effective and good for environment but it gave the maximum exhaust temperature (490°C max) and less torque (5.8 Nm max) and brake power (1.98 kW max). Thus, our comparative study for output torque, efficiency, temperature was an indisputable approach for our targeted data analysis and fuel solution.

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Chapter 1: Introduction & Objectives

1.1 Introduction

The small internal combustion engine is widely used as a convenient and compact source of power. Lawn mowers, cultivators, pumps, cement mixers and motor cycles are just a few of the many applications. The TQ (TecQuipment) small engine with the companion of TD114 instrumentation unit and TD110-115 Engine test bed provide an ideal introduction to the operation of small internal combustion engine to us. It provides information on the efficiency with which the engine converts the chemical energy contained in fuel to useful mechanical energy. Here, we are introduced to the scope of data presented by engine manufacturers and selection of the engine for particular sector for a particular application with reference to performance and economy. The operation can be extended by using different types of fuel and their comparative analysis. The purpose of using different types of fuel for the same engine is to find out the best possible fuel for a running engine. Firstly, particular method should be followed to find out the exhaust temperature, torque and R.P.M. of a 4 stroke small engine which will be shown as output value in instrumentation unit. Applying simple mathematical formulas other properties of the engine like break power, specific fuel consumption, and brake thermal efficiency from the above parameters can easily be found out. The methods are to be repeated for three conventional fuels petrol and diesel and two alternative fuels bio-ethanol and CNG Plotting the curves R.P.M Vs Different parameters in the same page will give us a comparative analysis among the fuels.

1.2 Objectives of the Project

- To test a engine performances by using a small engine test bed and Instrumentation Unit.
- To find out engine's functionality by comparing engine performances result with standard result value given by the manufacturer of the engine.
- For the selection of the engine for particular sector for a particular application with reference to performance and economy
- To run the engine performance test for different fuels for comparative analysis to find out the best possible fuel for a particular engine.

1.3 Steps we followed to analyze the performances of an Engine

- To find out the Exhaust Temperature, Torque, R.P.M of a small engine.
- To find out Brake power, Specific fuel consumption, Brake thermal efficiency from the above parameters.
- To plot curves between different parameters Vs R.P.M using the values we found out from first two processes.
- To run the same operations for different fuels to compose a comparative data analysis table and curves.

Chapter 2: Literature Review & Our Present Scope

2.1 Literature Review

Engine test bed is a very common instrument at present to measure engine performances. It became very common in different industry as well as project purposes after it came out on market in 2000. There has been several projects attempted so far using engine test bed. As far we know the first attempt regarding this engine test bed was done in 2006 by department of Mechanical Engineering Faculty of Engineering, University of North Sumatra. The project was about 'experimental analysis of supercharger and the catalytic converter to improve diesel engine performance'. In the experiment the parameters for observation were torque, power, specific fuel consumption, and exhaust gas emission. The research result showed the torque and power increased with using a supercharger and a catalytic converter for diesel engine stationary. But specific fuel consumption decreased with using supercharger and a catalytic converter. The emission of exhaust gas such as CO, SO_2 and UHC decreased with using of the catalytic converter.

The second project was entitled, 'performance and exhaust gas emission analysis of direct injection CNG-Diesel dual fuel engine'. It was done in University of Delhi, Delhi, INDIA. The project was carried out on a laboratory single cylinder, four-stroke variable compression ratio, direct injection diesel engine converted to CNG-Diesel dual fuel mode to analyze the performance and emission characteristics of pure diesel first and then CNG-Diesel dual fuel mode. The measurements were recorded for the compression ratio of 15 and 17.5 at CNG substitution rates of 30% and 60% and varying the load from idle to rated load of 3.5kW in steps of 1 up to 3kW and then to 3.5kW. The results revealed that brake thermal efficiency of dual fuel engine is in the range of 30%-40% at the rated load of 3.5 kW which is 11%-13% higher than pure diesel engine for 30% and 60% CNG substitution rates. This trend was observed irrespective of the compression ratio of the engine. Brake specific fuel consumption of dual fuel engine was found better than pure diesel engine at all engine loads and for both CNG substitution rates. It was found that there is drastic reduction in CO, CO2, HC, NOx and smoke emissions in the exhaust of dual fuel engine at all loads and for 30% and 60% CNG substitution rates by employing some optimum operating conditions set forth for experimental investigations in this study.

The third research was done in Nigeria in 2012. It was entitled, 'Simulation of performance characteristics of a four-stroke petrol engine'. It was done by Dept of Mechanical & Production Engineering, Nnamdi Azikiwe University, Awka, Nigeria.

The project was about a four-stroke petrol engine mounted in a heat engine laboratory of Enugu State University of Science and Technology as an engine test bed was used for the exercise. A dynamometer was attached to the engine with which a number of load tests were carried out and consequently the engine torque was determined. Several tests were carried out to determine a number of parameters including: rate of fuel consumption at various loads and at different gears, variation of torque and engine speed, brake power developed in relation to engine speed, brake thermal efficiency, specific fuel consumption, and brake mean effective pressure. Measurements were taken of shaft diameter, cylinder stroke and bore, volume of fuel consumed, engine speed, load etc. The data so obtained were used to analyze other parameters and tabulated. Plots of various engine parameters were also done against engine speed. Results show that: the fuel consumption rate increases with engine speed but decreases with increasing gear and also decreases with load; thermal efficiency increases with brake power and also increases with increasing gear and load; less amount of fuel were consumed at no load and also decreases with increasing gear; the specific fuel consumption decreases with increasing engine speed, decreases with increasing load and decreases with increasing gear; brake mean effective pressure is a function of the load and is independent of the gear and engine speed.

2.2 Our Present Scope

We have seen there are different projects have been undertaken by different university regarding this engine test bed. The first one in Indonesia was about improving diesel performance by using turbocharger and catalytic converter.

The second one in India was about performance and exhaust gas emission in CNG-Diesel dual fuel engine. And the last one was about simulation of performance characteristics of 4 stroke petrol engine. Now, if we consider what we our objectives were then we can easily differentiate the differences between their project and ours. Though some thought of the previous projects were common but our project is totally unique as it will be used to find out its performances for four different fuels.

So that we can say we have the opportunity to fulfill our objectives of our project as it is innovative and has never done before and we can also take some useful ideas from the similar type project or research work to us which were done before.

Chapter 3: Installation method

3.1 Engine Specifications

Name of characteristics	Specifications
Number of strokes	4 strokes
Fuel type	Petrol , Octane
Fuel injection system	Carburetor
Number of Cylinder	1cylinder
Engine power range	2.5-7.5 kW
Maximum Torque	15 Nm
Maximum Speed	6000 rev/min
Swept volume	195cc
Cooling system	Air cooling

3.2. The Small Engine Test Rigs

The basic test rig for each engine consists of the engine (TD110, TD111 or TD113), TD115 Hydraulic Dynamometer and TD114 Instrumentation unit. A stop watch, thermometer and barometer are also used for the experiment.

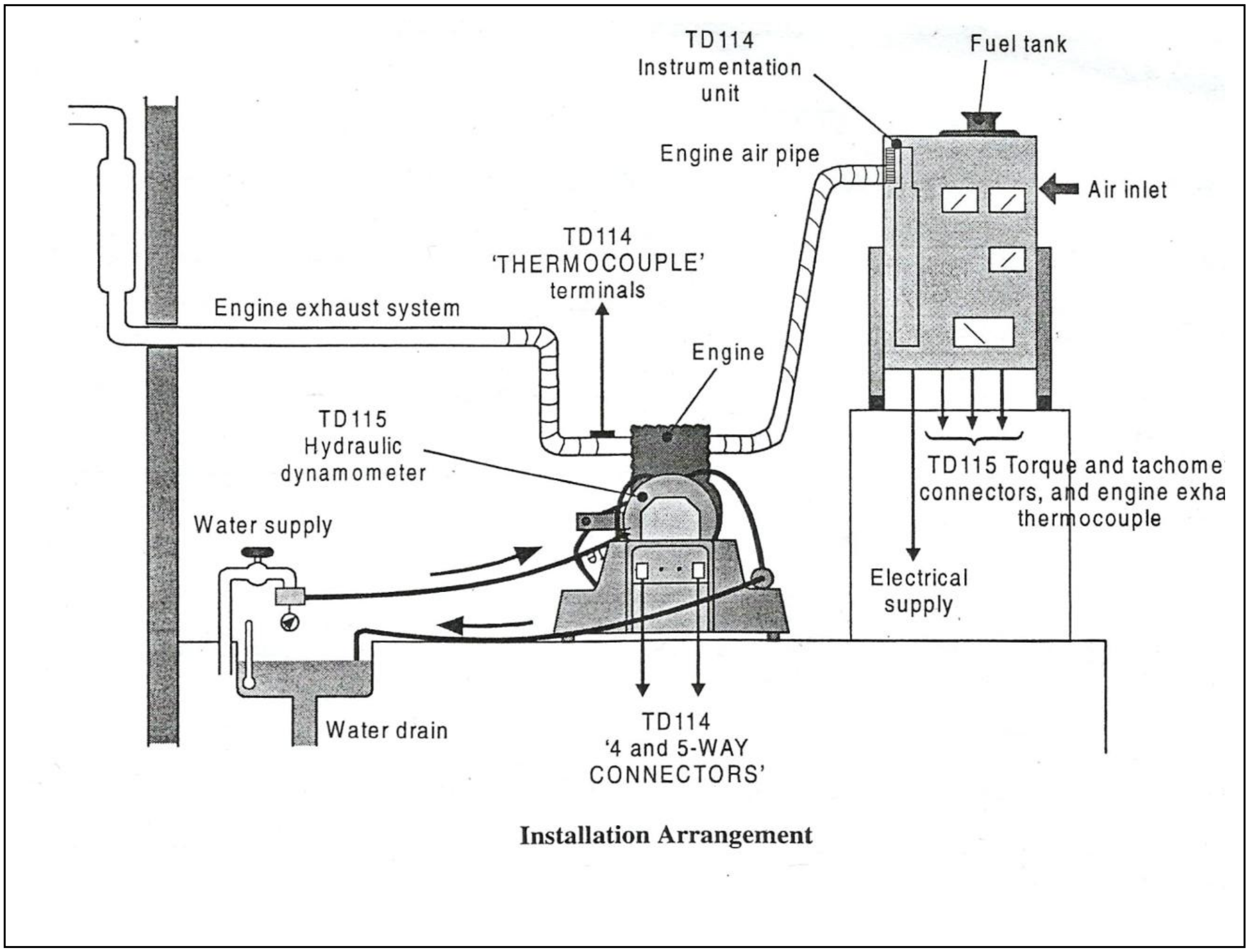


Fig 3.2: Engine test bed installation arrangement

3.3 TD114 Instrumentation Unit

The Instrumentation Unit is designed to beside the engine under test. In addition to housing the instruments necessary for measuring the engine performance, it contains the fuel system and the air box/viscous flow meter used to measure the consumption of air. A front view of the Instrumentation Unit is shown in figure 3.3

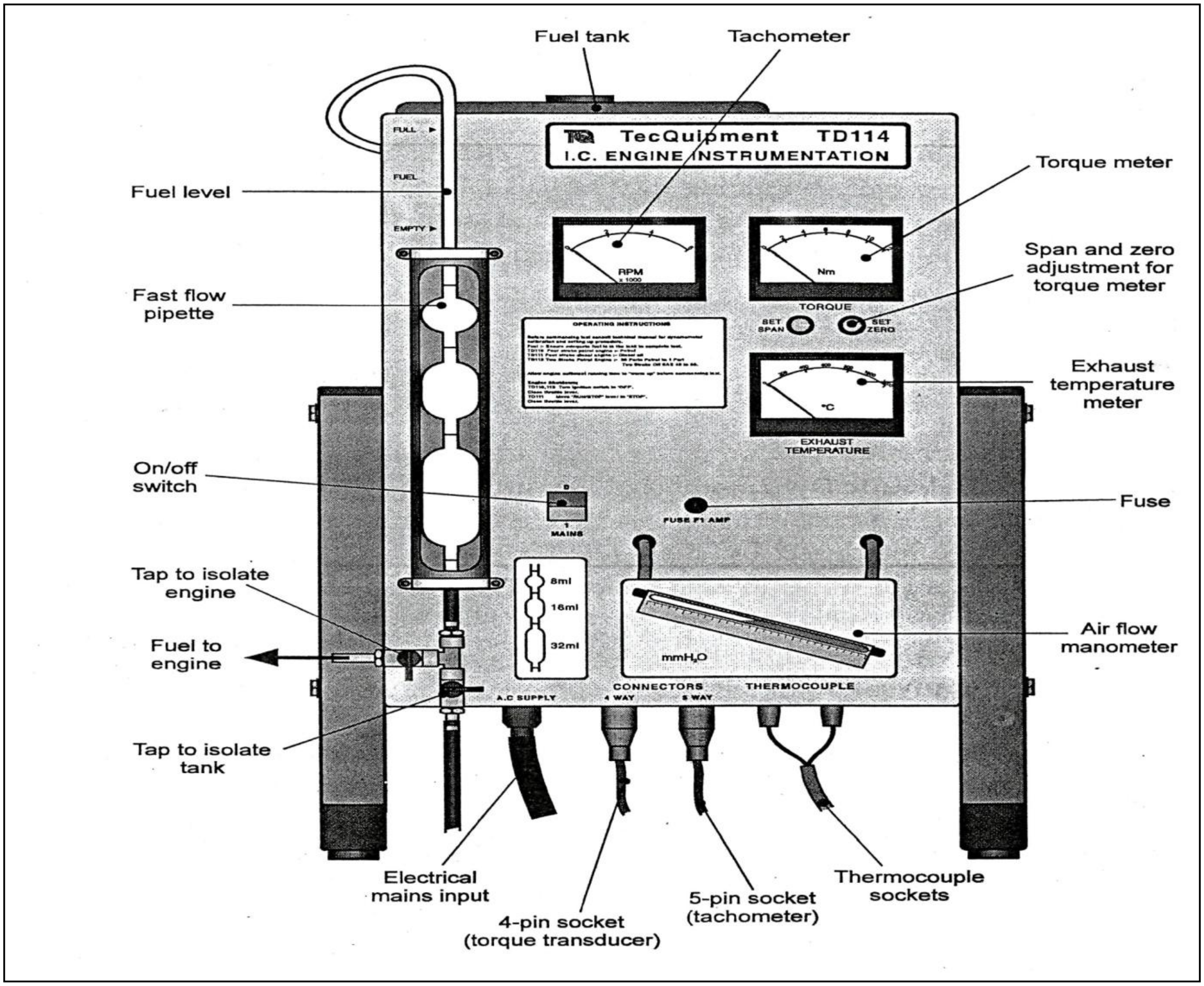


Fig 3.3: TD114 Instrumentation Unit

3.4 Measurement of Speed

The speed 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 readout of engine speed. The electronic tachometer is calibrated against a signal generator at the factory and should not need adjusting.

3.5 TD115 Hydraulic dynamometer- Measurement of Torque

Engine torque is measured by the TD115 Hydraulic Dynamometer and transmitted to a torque meter located on the TD114 Instrumentation Unit.

3.5.1 Water Supply

A constant supply of clean water is required, which can be from a header tank; pressure regulated mains taps, or a pump/sump system. The delivery pressure is not too critical as long as it is between 6 to 12 m head (0.6 to 1.2 X 10^5 pa). The figure quoted is not an exact conversion. Typically, the flow rate is 4 liters/min at a head of 6 m, using 10mm bore flexible plastic tubing.

3.5.2 Description of TD115 Dynamometer

Figure 3.5.2 shows the principle and layout of the dynamometer. The flow of water is controlled by a needle valve (A) mounted on the engine bed. Water flows into the top of the dynamometer casing (B) and out through the bottom, discharging into a drain or sump through a tap (C). The dynamometer also has an air vent. The quantity if water in the dynamometer, and hence the power absorbed from the engine, depends on the settings of the needle valve (A) and (C).

The dynamometer drain pipe should be as short as possible and run Downwards into an open drain or collection tank. The eng of the drain pipe must not be submerged.

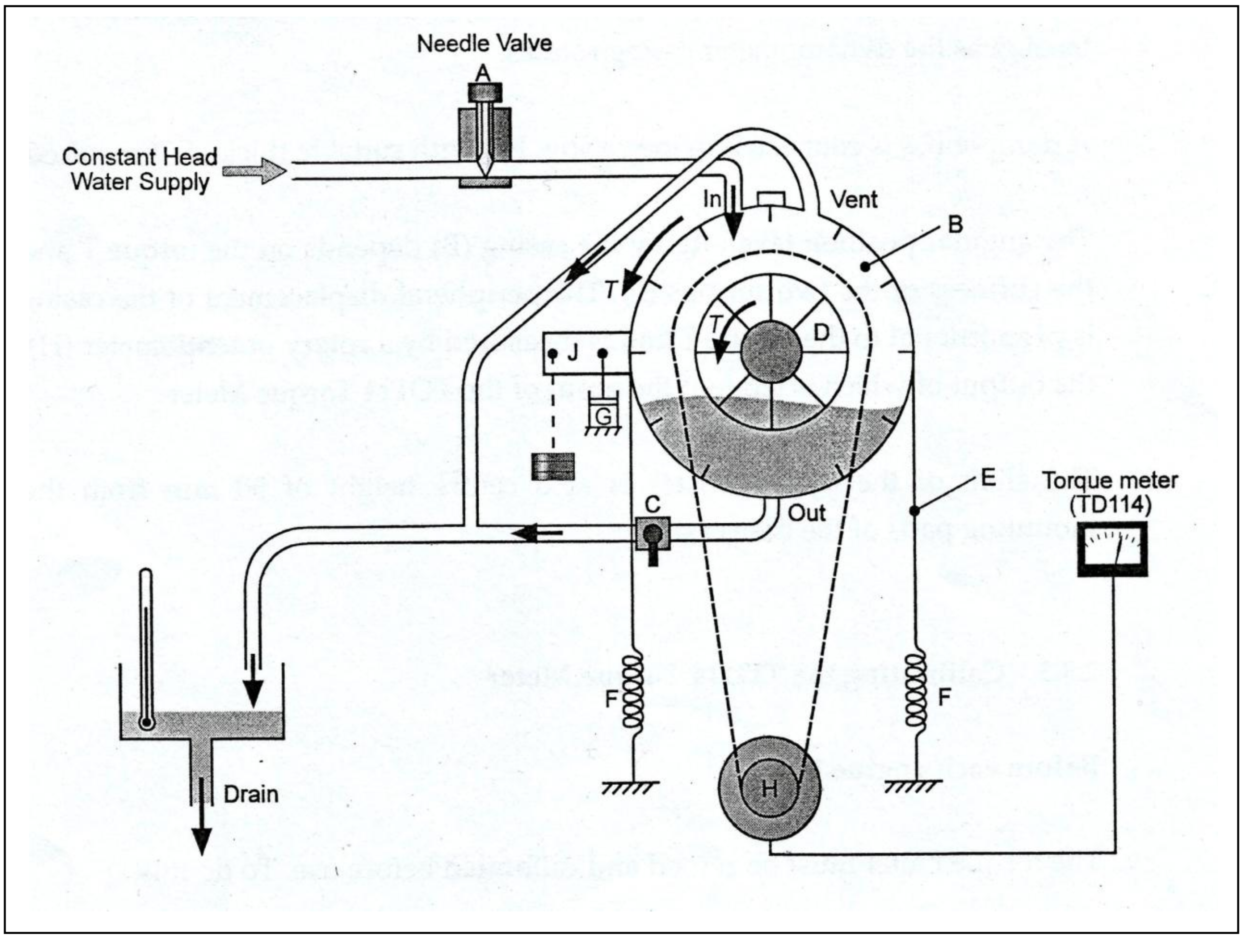


Fig3.5.2: Hydraulic Dynamometer

3.5.3 Torque Measurement Process

- We supplied water to the dynamometer by opening needle valve.
- Water was supplied until the engine held at a steady R.P.M.
- The engine shaft drives a paddle (D) inside the vane casing (B) churning up the water insider the dynamo meter.
- The housing attempts to rotate in response to the torque produced, but is restrained by the scale or torque metering cell that measures the torque which we get from the torque meter.
- A damper G is connected to the casing. We need to fill it with the suitable thick oil if required.

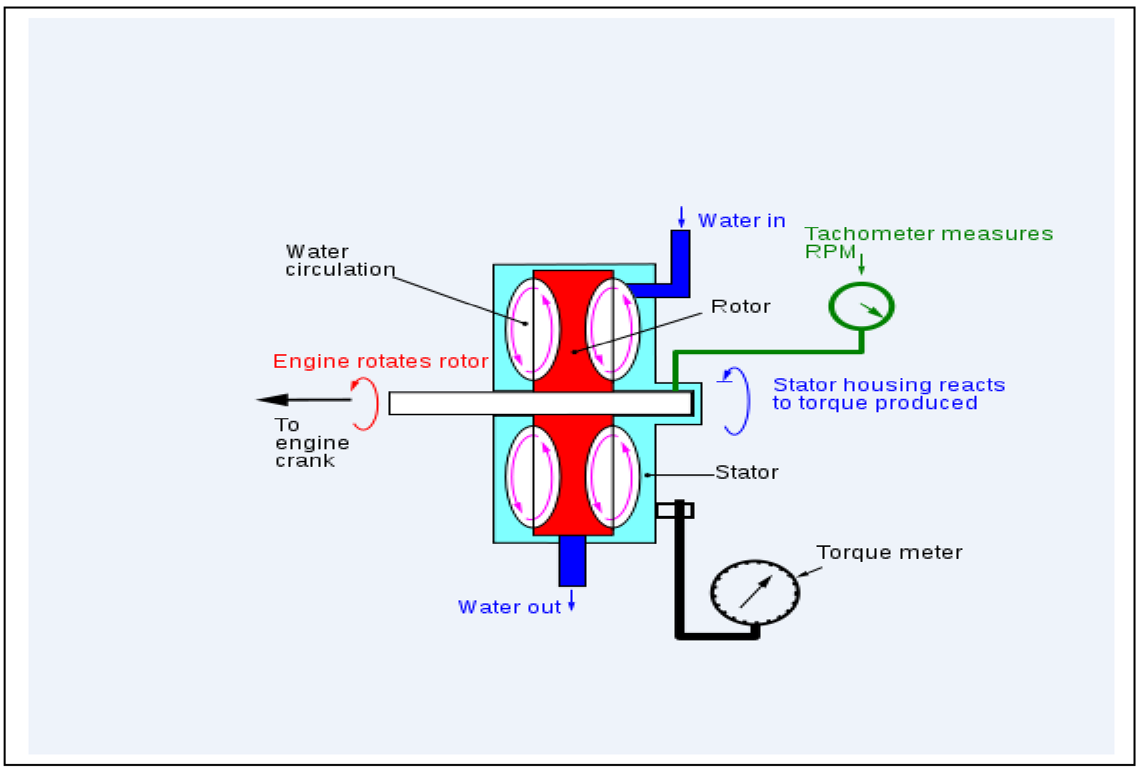


Fig 3.5.3: Torque Measurement process by Hydraulic Dynamometer

3.6 Alternative Fuels We Have Used

Compressed Natural Gas (CNG)

Natural gas, a fossil fuel comprised mostly of methane, is one of the cleanest burning alternative fuels.

Bio-ethanol or Gasohol (E15)

E15 (also called "gasohol") is a blend of 15% ethanol and 85% gasoline sold in many parts of the country. All auto manufacturers approve the use of blends of 15% ethanol or less in their gasoline vehicles

3.7 Advantages of using alternative fuels

- Most of the natural gas used is domestically produced
- Roughly 20% to 45% less smog-producing pollutants
- About 5% to 9% less greenhouse gas emissions
- Less expensive than gasoline

3.8 CNG Conversion of Engine

Equipment required:

- Cylinder (60L, maximum pressure 400 bar)
- Pressure gauge (Gives the reading of cylinder pressure)
- 3-Stage pressure regulator (Convert the high pressure about 300bar to pressure 1.5 bar at 2nd stage and an adjustable pressure at stage 3)

Specifications of three stage pressure regulator:

Characteristics	Specifications
Test pressure	300 bar
Inlet pressure	220 bar
First stage adjustment pressure	4 bar
Second stage adjustment pressure	1.5 bar
Stage 3 Pressure	Adjustable
Power supply	12 V DC
Coil power capacity	20W

- Air-gas mixture input (we had to make this portion according to required dimensions using aluminum metal. This part is to connect air filter and carburetor inlet where the air-gas get mixed)
- Battery (12V DC)

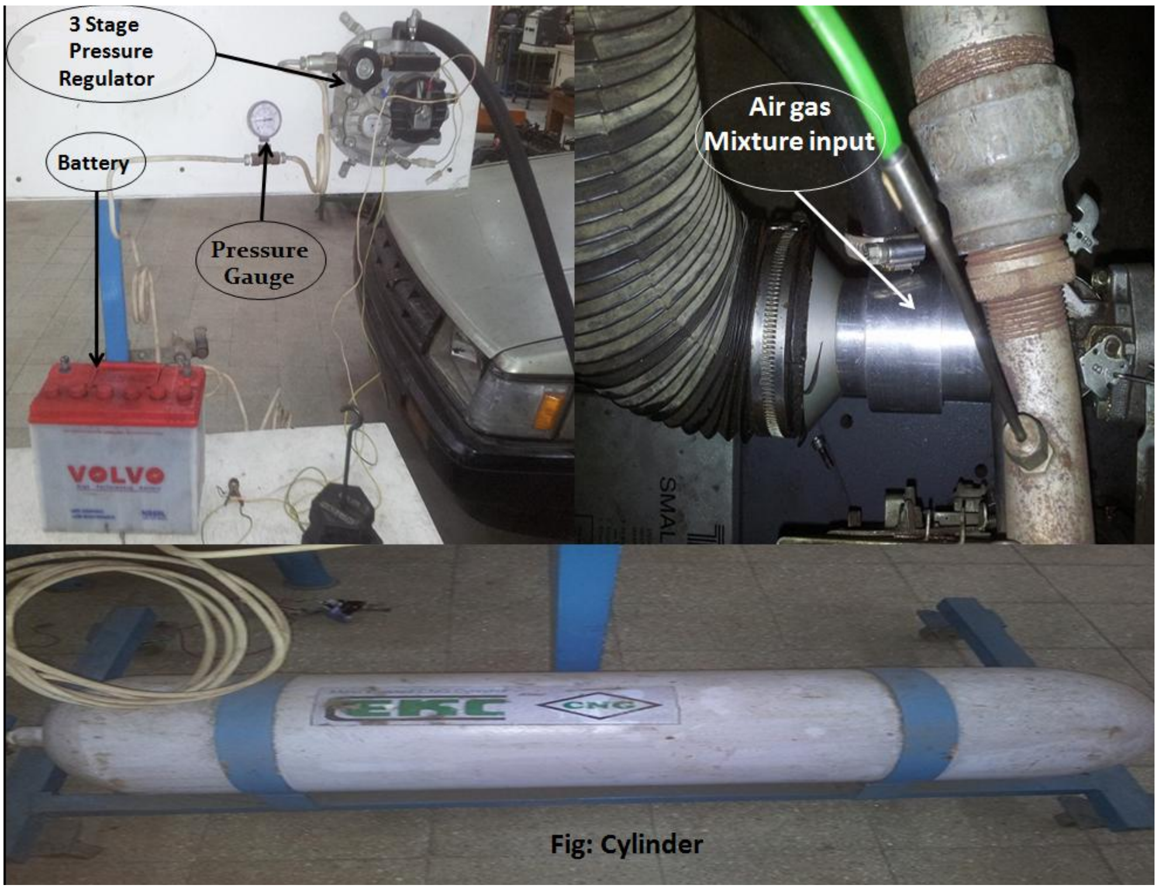


Fig 3.8: Different equipment for CNG conversion

3.9 Whole Experimental set-up

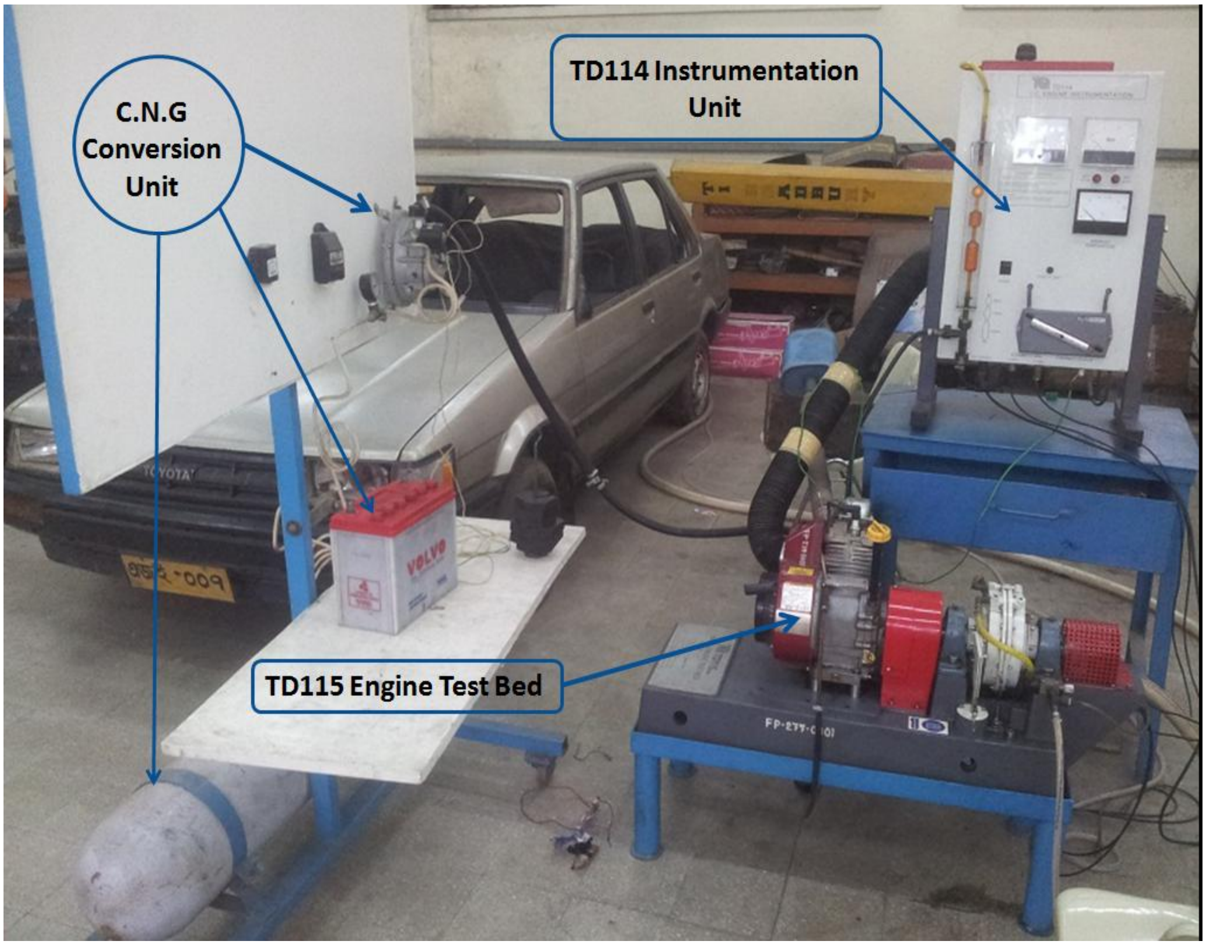
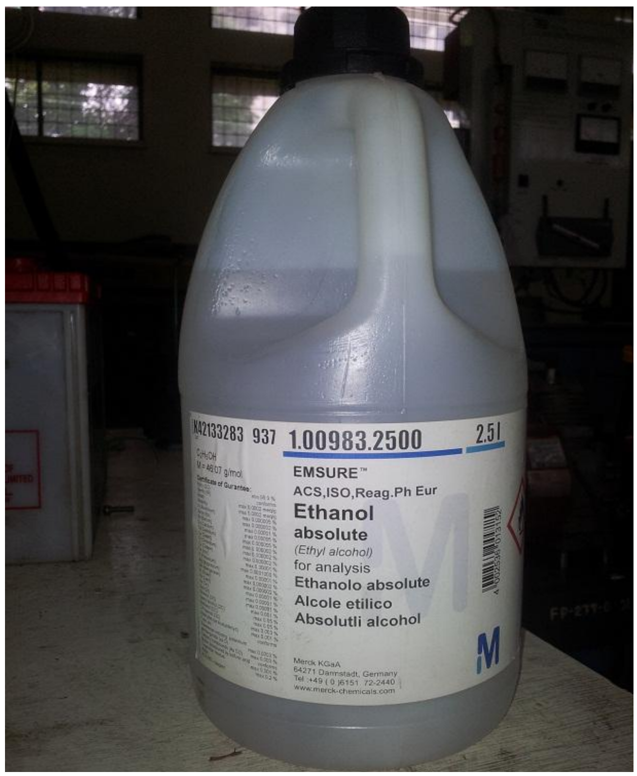


Fig 3.9: Whole experimental set up (With CNG unit)

3.10. Preparing Bio-ethanol E15

- We used 99.96% pure ethanol (manufactured by Merck company, Germany) 15% and 85% petrol to make our bio-ethanol or gasohol E15
- Ethanol is highly corrosive. But change in engine set up was required because manufacturers allow using small amount of ethanol with petrol directly.



3.10 Fig: Ethanol we used to produce bio-ethanol

4. Experimental Procedure

4.1 Setting up the Equipment

It is assumed that an area of the laboratory has been equipped with a bench, water supply, drain, exhaust system and an electrical power point as directed in section 3 ‘Installation method’.

We have to place the engine to be tested and the TD115 Hydraulic Dynamometer on the bench. To prevent the transmission of vibration to the TD114 Instrumentation unit, it is mounted that the TD114 Instrumentation unit is mounted on a separate bench from the engine TD115 Hydraulic dynamometer. The TD114 Instrumentation unit must be higher than the small engine and the TD115 Hydraulic dynamometer.

Then we need to connect the engine to the exhaust system. After that we have to connect torque transducer, tachometer optical head and exhaust thermocouple to the correct inputs on the Instrumentation Unit. Then we have to connect the water supply to the inlet of the needle valve mounted on the engine bed.

Pushing the length of flexible PVC pipe onto the drain pipe we have to ensure that the end discharges into a drain or collection tank and that it is not submerged when the water is flowing.

We have to fill the damper with necessary oil and fill the fuel tank with correct fuel required. After that we have adjust the manometer scale reading to zero.

Then we have to turn on the water supply to adjust the dynamometer. We have to adjust the needle valve also so that we can ensure the maximum flow of water. We reduce the water to a tickle so that the load on the engine is not great when starting.

4.2 Starting the Fuel Tank

4.2.1. Petrol Engine Starting

- At first we need to turn on the tap of the fuel tank.
- We have to ensure that the fuel has reached the carburetor from the fuel tank.
- After that we should open the throttle valve small amount.
- If the ignition is fitted to the engine, we can switch the ignition on.
- We must hold the base and pull the starting handle rapidly outwards. We have to repeat this until the engine runs.
- We have to allow the engine to warm up by running at half throttle for approximate five minutes. Then we can return to choke to the open position as soon as the engine will run smoothly without choke.

4.2.2. Diesel Engine Starting:

- At first we have to tap of the fuel tank.
- If the fuel system has been changed, air will have to enter the fuel pipes and will prevent the injector pump from working. The air must be removed from the system. To do this we have to loosen the hex screw on the top of the fuel pump until clean, bubble free fuel leaks out. Then we have to retighten the screw.
- We have to move the low/high lever to the high position. This sets the injector to pump an excess of fuel into the engine for starting and is analogous to the choke of a petrol engine.

- If the engine is cold it is essential to prime the engine for hand starting. This can be done by removing the priming plunger or filling the chamber with engine oil or replacing the priming plunger and pressing down.

- Then we can pull the starting rope to start the engine.

- The engine should fire and then stop, prime again before attempting to start.

- We should allow the engine to warm up for about 5 minutes. The excess fuel device resets automatically.

4.3 Experimental Test Procedure

- At first we have to advance the throttle or rack control to its maximum position.

- We note the maximum speed of the engine after that.

- We should keep the throttle or rack open and slowly adjust the needle valve to increase the flow of water through the dynamometer until the needle valve is fully open. We have to note the engine speed.

- Engine will be tested over the speed range just established. We have to choose 8 speeds from two extremes at which to take the readings of engine performance.

- We have to keep the throttle open and reduce the water flow to a tickle, so that the engine returns to its maximum speed.

- When the engine is settled down to a steady output, we have to record the speed, torque, exhaust temperature. Then we the fuel tap beneath the pipette so that engine takes is fuel from the pipette to time the consumption of 8ml of fuel.

- We have to check the temperature of water flowing out of the dynamometer is less than 80°C. If the temperature is higher than this we have to increase the water flow to cool the dynamometer bearing seals.

- Then we have to increase the flow of water into the dynamometer until the engine speed drops to the next highest selected value. Because the time response of the dynamometer is fairly slow. So the needle valve has to be operated slowly.

- We should allow the engine to stabilize before taking another set of results. If the dynamometer is too sensitive to obtain the desired speed, it will help if the drain tap is partially closed.

- We have to repeat the process after changing the fuel. And for taking the result of diesel engine, we have to replace the engine with diesel engine also.

- We have to collect all the data and make a table for the calculation to find out different parameters like brake power, specific fuel consumption, brake thermal efficiency.

5. Experimental Data and Result Analysis

5.1. Data Calculation and Mathematical Formulas

- From the tachometer we took the reading of R.P.M, from torque meter we got the value of Torque in Nm and from Exhaust temperature meter we got the Exhaust gas temperature.
- By using the values and mathematical formulas below we calculate different properties-

Barometric pressure = 100 kPa
Ambient temperature = 25°C
Specific gravity of petrol = 0.74
Specific gravity of octane = 0.701
Specific gravity of diesel = 0.840
Calorific value for petrol = 42000 kJ/ kg
Calorific value for diesel = 39400 kJ/kg
Calorific value for bio-ethanol= 40200 kJ/kg

Mathematical formulas

- $\textbf{Brake power} = \frac{(2 \times \pi \times \text{R.P.M.} \times \text{Torque})}{60000}$ kW

- $\textbf{Fuel mass flow rate} = \frac{\text{Specific Gravity} \times 8 \times 3.6}{\text{Time for 8ml fuel consumption}}$ kg/hr

- $\textbf{Specific fuel consumption} = \frac{\text{Fuel mass flow rate} \times 1000}{\text{Brake Power}}$ g/kWh

- $\textbf{Brake thermal efficiency} = \frac{\text{Brake power} \times 3600}{\text{Fuel mass flow} \times \text{C.V.}}$ X 100 %

5.2. Data table for Different Fuels

Data table for Petrol

R.P.M. (Rev/min)	Torque (Nm)	Temperature °C	Brake Power (kW)	Time for 8ml (s)	Fuel Mass Flow Rate (kg/hr)	Specific Fuel Consumption (g/kWh)	Brake Thermal Efficiency %
1200	2.8	220	0.35	61.45	0.35	1000	8
1400	3.2	250	0.47	53.76	0.4	851.06	10
1600	3.7	280	0.61	49.5	0.43	704.91	12
1800	4.1	295	0.77	39.87	0.53	688.31	12
2200	4.9	315	1.13	36.9	0.58	531.27	17
2500	5.5	330	1.43	33.25	0.64	447.53	19
3000	6.4	360	2.01	27.45	0.78	388.06	22
3500	5.9	340	2.16	23.3	0.91	421.3	20

Data Table for Bio-ethanol (E15)

R.P.M. (Rev/min)	Torque (Nm)	Temperature °C	Brake Power (kW)	Time for 8ml (s)	Fuel Mass Flow Rate (kg/hr)	Specific Fuel Consumption (g/kWh)	Brake Thermal Efficiency %
1200	2.6	160	0.33	63.3	0.34	1030.3	9
1400	3.1	180	0.45	57.87	0.37	822.22	11
1600	3.55	215	0.6	52.44	0.41	683.33	13
1800	3.95	230	0.74	44.12	0.49	662.16	14
2200	4.8	250	1.11	40.18	0.53	477.48	19
2500	5.3	280	1.39	38.21	0.56	402.88	22
3000	6.1	300	1.92	30.14	0.71	369.79	24
3500	5.7	295	2.09	25.66	0.84	401.91	22

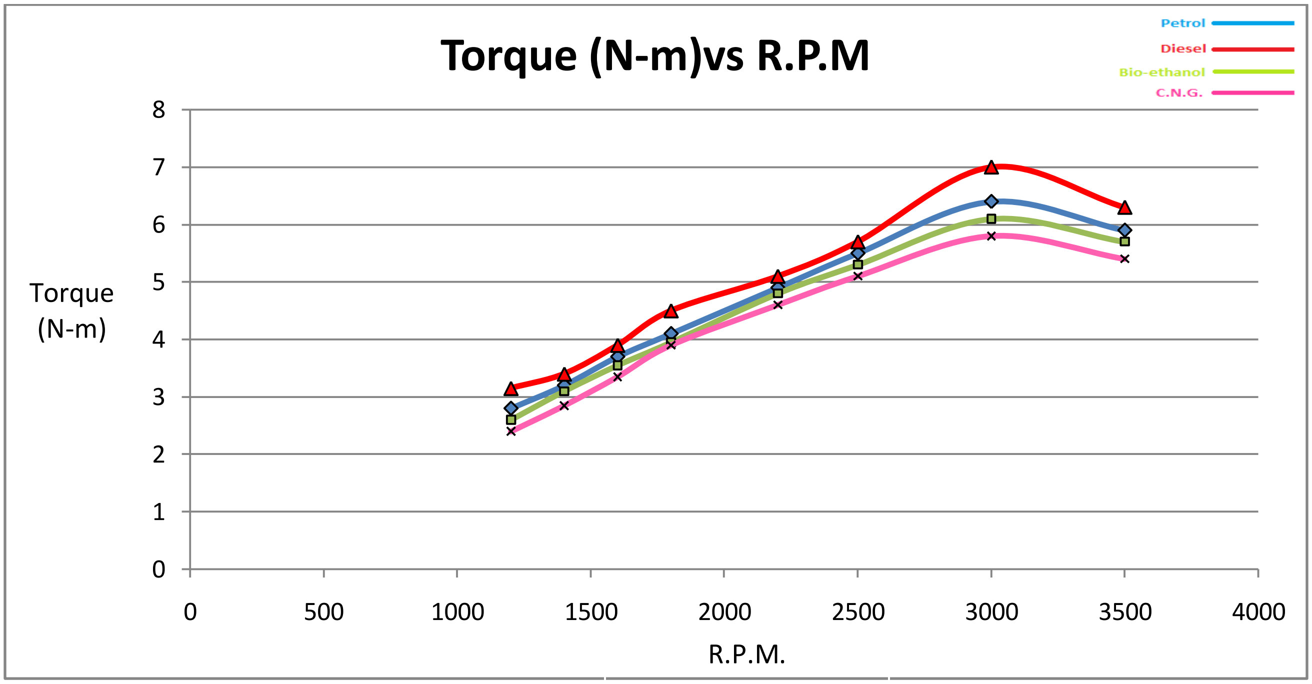
Data Table for Diesel

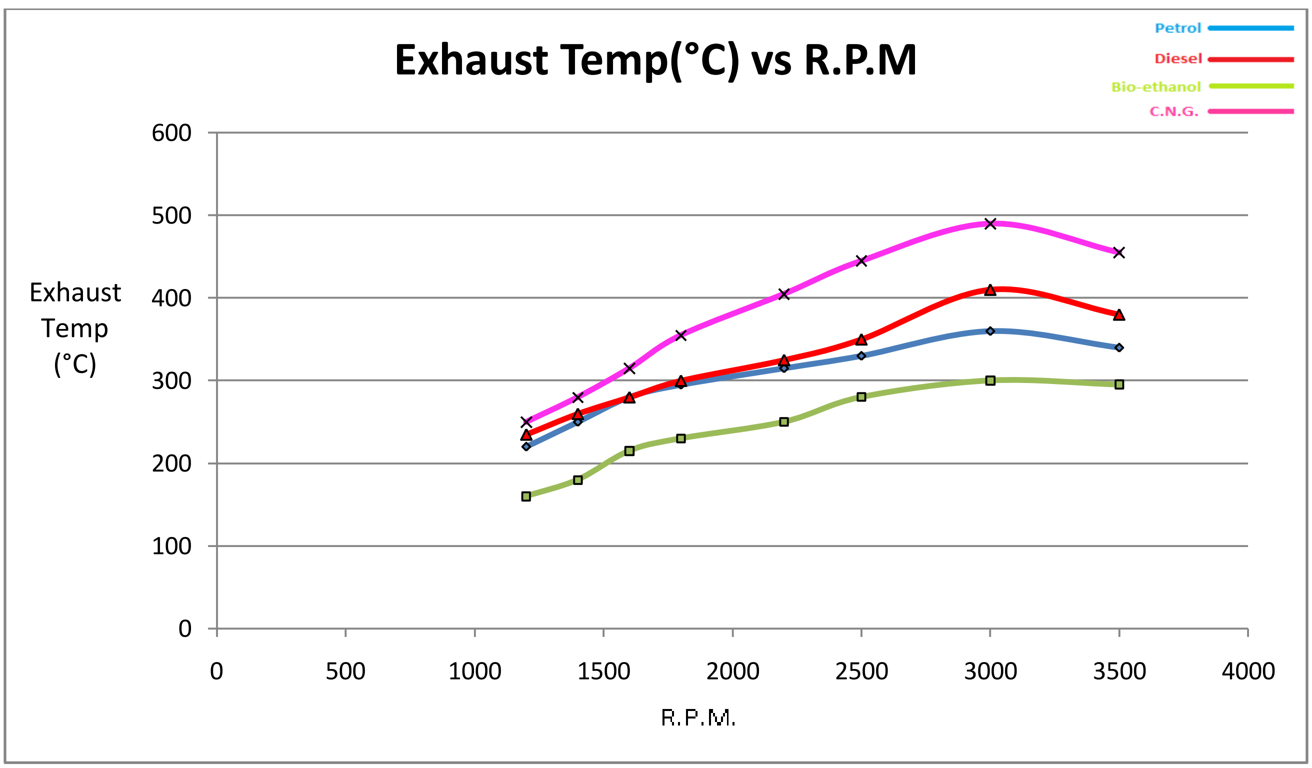
R.P.M. (Rev/min)	Torque (Nm)	Temperature °C	Brake Power (kW)	Time for 8ml (s)	Fuel Mass Flow Rate (kg/hr)	Specific Fuel Consumption (g/kWh)	Brake Thermal Efficiency %
1200	3.15	235	0.4	58.45	0.41	1025	9
1400	3.4	260	0.5	51.12	0.47	940	10
1600	3.9	280	0.65	46.45	0.52	800	11
1800	4.5	300	0.84	37.22	0.65	773.8	12
2200	5.1	325	1.17	34.15	0.71	606.84	15
2500	5.7	350	1.49	30.18	0.8	536.91	17
3000	7	410	2.2	26.11	0.92	418.18	22
3500	6.3	380	2.31	22.45	1.07	463.2	20

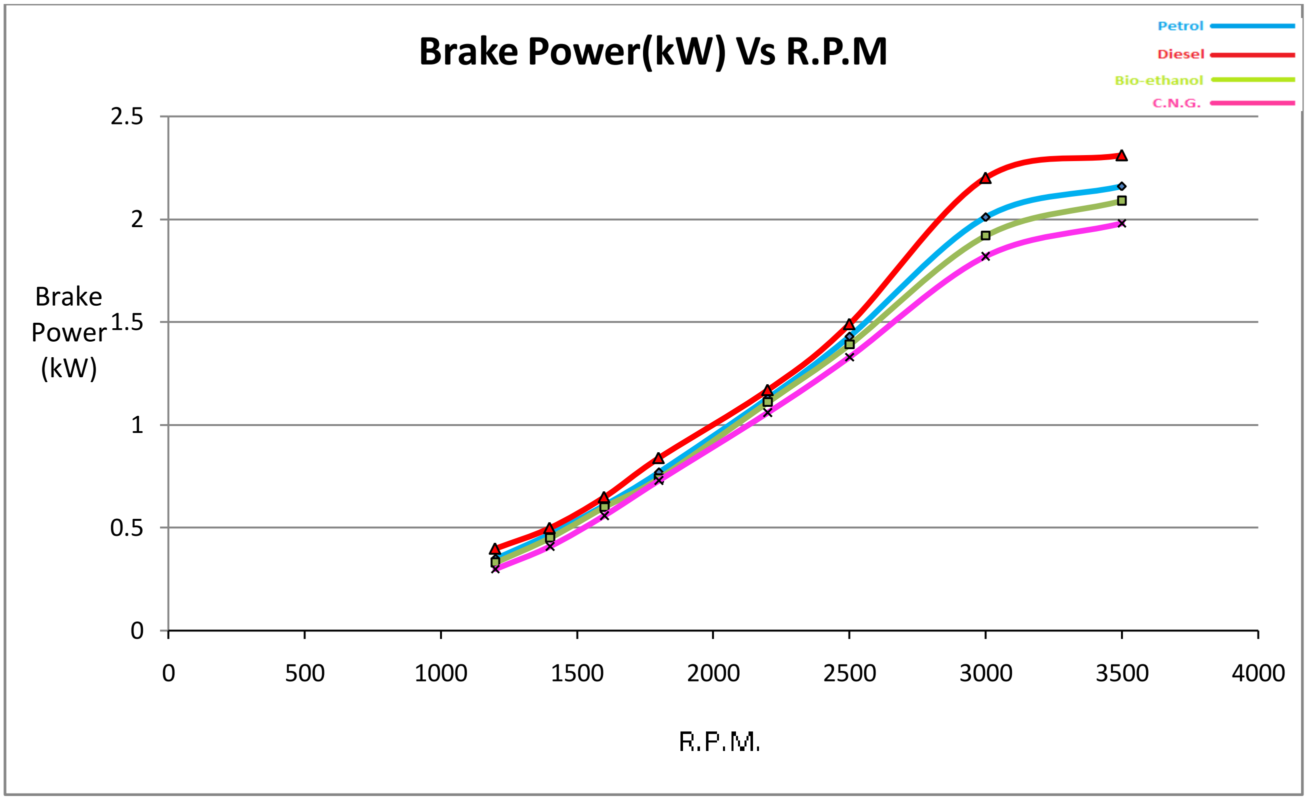
Data Table for CNG

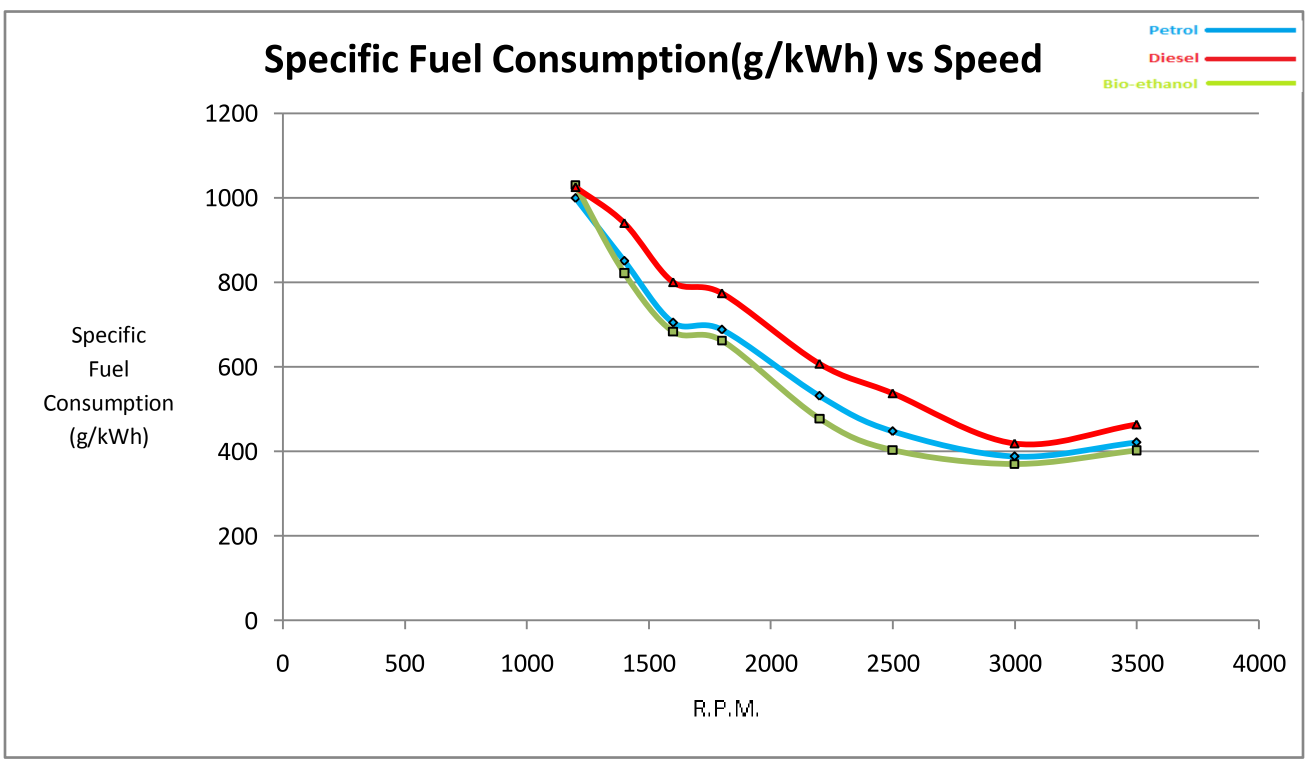
R.P.M. (Rev/min)	Torque (Nm)	Temperature °C	Brake Power (kW)
1200	2.4	250	0.3
1400	2.85	280	0.41
1600	3.35	315	0.56
1800	3.9	355	0.73
2200	4.6	405	1.06
2500	5.1	445	1.33
3000	5.8	490	1.82
3500	5.4	455	1.98

5.3 Curves from the Data of Different Fuels:






Brake Power(kW) Vs R.P.M
Petrol
Diesel
Bio-ethanol
C.N.G.
Brake Power (kW)
2.5
2
1.5
1
0.5
0
0
500
1000
1500
2000
2500
3000
3500
4000
R.P.M.


Specific Fuel Consumption(g/kWh) vs Speed
Petrol
Diesel
Bio-ethanol
Specific Fuel Consumption (g/kWh)
1200
1000
800
600
400
200
0
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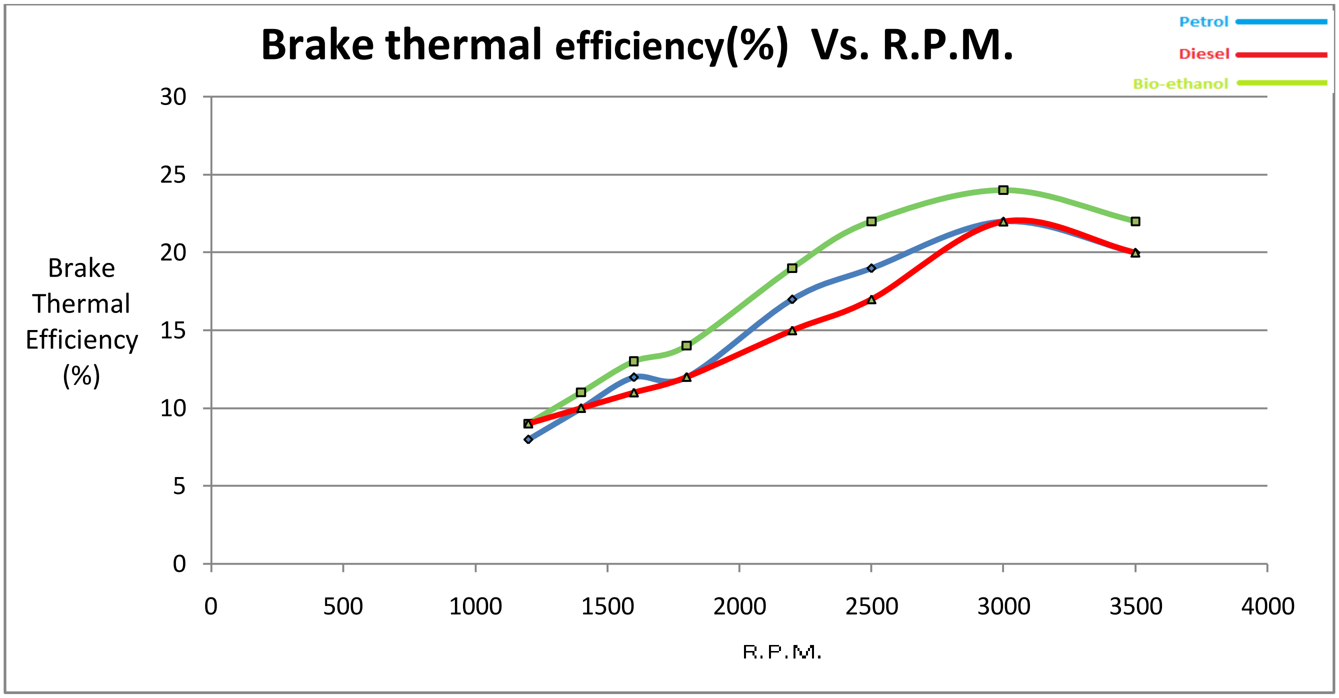
500
1000
1500
2000
2500
3000
3500
4000
R.P.M.



5.4 Comparative Analysis of Experimental Result for all the Fuels:

Fuels		Maximum Value for different parameters				Minimum value for different parameters	
		Torque (Nm)	Brake Power (kW)	Fuel Mass Flow Rate (kg/hr)	Brake Thermal Efficiency %	Exhaust Temperature (Max)	Specific Fuel Consumption (g/kWh)
Petrol	Experimental value	6.4	2.16	0.91	22	360	388.06
	Manufacturer's given value	10.3	3.73	_	_	_	300
Bio-ethanol		6.1	2.09	0.84	24	300	369.79
Diesel		7.0	2.31	1.07	22	410	418.18
C.N.G		5.8	1.98	_	_	490	_

5.5.1 Experimental Result Analysis for Engine

- All the experimental result was close to the manufacture's given specifications. For petrol, experimental value of the maximum torque is 6.4Nm whereas manufacturer's specified value 10.3 Nm. For maximum brake power our experimental value was 2.16 kW whereas the manufacturer's given value was 3.73kW.Specific fuel consumption at maximum torque speed in our experiment was 388.06 g/kWh but in manufacturer's specifications it was 300g/kWh.
- So, we can say the engine is alright and functional. Though, there might be experimental errors and other factors we have to consider here.
- One of the main reasons why engine performance decreased because of its being used for more than 5-6years without overhauling or servicing.
- We have to keep in mind that the atmospheric condition such as temperature and pressure or specific humidity will also affect the results because all the result obtained from engines tested in United Kingdom.

5.5.2 Experimental Result Analysis for Fuels:

- From the comparative analysis it is clear that diesel engine can produce higher torque (7Nm) and break power (2.31 kW) that is why it is used on high load.
- For small capacity engine like automobile vehicle bio-ethanol is much efficient than petrol though it has lower torque (6.1 Nm max) but has much better brake thermal efficiency (24% max) and lower exhaust temperature (300°C max).
- C.N.G. is cost effective and good for environment but has a high exhaust temperature (max 490°C). So, it cannot be used where we have to keep lower temp.

Chapter 6: Conclusion and References

6.1 Conclusion

Our experimental results were close to the manufacturer's given value though there are some deviations as it is an old machine. We kept our analysis within the brake power, specific fuel consumption, fuel mass flow rate, brake thermal efficiency, measurement. Engine test bed is usually used to measure the engine performance for different parameters. But our attempt to find out best possible fuel gave the whole experiment to comprehensiveness. We got excellent results for different parameters using different fuels. It was the first project using this particular machine in IUT. So for our time shortage we have to eliminate manometer reading to measure air pressure by which we can also find out the air-fuel ratio, mechanical efficiency, volumetric efficiency, heat loss exhaust. But apart from this we were able to find out all the parameters successfully to construct a complete analysis method using four different fuels. Using alternative fuels for a small engine was a very innovative approach that gave a tremendous result to our comparative study. We hope our head of the department will continue this project in the future with more innovative ideas to enhance our comparative study to an extensive level.

6.2 Recommendations:

- This engine can be converted into flexible fuel vehicle (FFV) to use bio-ethanol E85 or E90 and we can get comparative data analysis of experimental results with other fuels.
- We can analyze the exhaust gas and for different fuels and comparing with each other to find out the best suitable fuel for environment.

6.3 References

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