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Full Length Research Paper

Study of I.C. engine performance using different fuels

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Comparative study of I.C. engine performance using different fuels ‘refers to the engine performance test, which was successfully carried out by measuring its different properties to construct a relative data analysis using different fuels. Our experiments 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 experiments and with the help of mathematical formulas brake power, specific fuel consumption, fuel mass flow rate, and brake thermal efficiency were measured. Petrol and diesel were the conventional fuels, where as CNG and Bio-ethanol (E15 or Gasohol) were the alternative fuels. In our experiment, we got the maximum torque (7N-m), brake power (2.31kW) and specific fuel consumption (418.18 g/kWh) at maximum torque speed for diesel and that’s why it is used for high load. The relative analysis with alternate fuels like bio-ethanol came out as a tremendous significance to our whole endeavor as it has lower exhaust temperature (300°C) and higher brake thermal efficiency (24%) compared to petrol, which has exhaust temperature (360°C) and brake thermal efficiency (22%) at maximum torque.CNG is cost-effective and good for environment, but it gave the exhaust temperature (490°C) and brake power (1.98 kW),when the CNG system reaches an R.P.M. value at max torque of 5.8 N-m. Thus, our comparative study for output torque, efficiency and temperature was an indisputable approach for our targeted data analysis and fuel solution.

Keywords: Exhaust temperature, Torque, R.P.M., Brake power, Specific fuel consumption, Fuel mass flow rate, Brake thermal efficiency, CNG (Compressed Natural Gas).

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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 (Equipment) 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. Our aim was to measure engine performance by using engine test bed and instrumentation unit. It was done successfully with the measurement Exhaust temperature, R.P.M and Torque and using these values to find out Brake power, Specific fuel consumption, Fuel mass flow rate and Brake thermal efficiency. Thus we were able to find out the

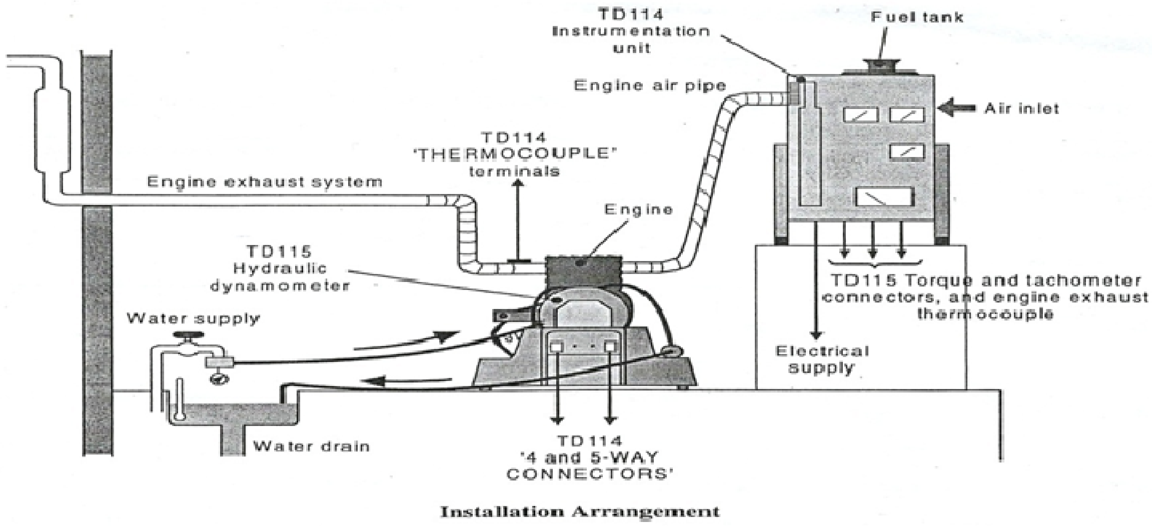


Figure 3.1.1 Engine test bed installation arrangement

Engine's application for particular sector as well as its functionality. But our further analysis was to find out best possible fuel for this very engine considering the global petroleum or natural resources crisis. We used the alternative fuel Bio-ethanol (E15) as a solution for the countries, which are not enriched with petroleum resources. Besides, we also looked into the performance of the diesel engine to test its efficiency on small engines. Petrol and CNG are the most common fuels for small engine all round the world, but yet we measured engine performance using them to compare the results with Bio-ethanol and Diesel. Thus, it was a comprehensive and comparative data analysis, which could provide not only engine performance but also a solution for best possible fuel.

Related Works

Engine test bed is a very common instrument at present time for measuring engine performance. It became very familiar in different industries as well as project purposes after it came on market in 2000. There had been several projects attempted so far using engine test bed. To the best of our knowledge, the first attempt regarding this engine test bed was held in 2006 by the Department of Mechanical Engineering, Faculty of Engineering, and University of North Sumatra, Indonesia. The project was titled as 'Experimental Analysis of Supercharger and the Catalytic Converter to Improve Diesel Engine Performance'. The second project was entitled as '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 in a laboratory with single cylinder, four-stroke variable compression ratio and 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 third research was done in Nigeria in 2012 and it was entitled as '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, where an engine test bed was used for the exercise. Though some ideas of the previous projects were similar to us but our project is totally unique as it has been used to find out engine performance for four different fuels including Bio-ethanol, which has never been tested before. So, we can claim that the planning and execution of our project can be referred as something innovative and creative. We have the opportunity to take some useful ideas from the similar type projects or research to fulfill our target to do something new that will be useful for future research regarding this very instrument.

METHODOLOGY

Experimental Set-up

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

3.1.2 TD114 Instrumentation Unit

Name of characteristics	**Specifications**
Number of strokes	4 strokes
Fuel type	Petrol , Octane, Diesel(for same specifications diesel engine)
Fuel injection system	Carburetor
Number of Cylinder	1cylinder
Engine power range	2.5-7.5 kW
Maximum Torque	15 N-m
Maximum Speed	6000 rev/min
Swept volume	195cc
Cooling system	Air cooling

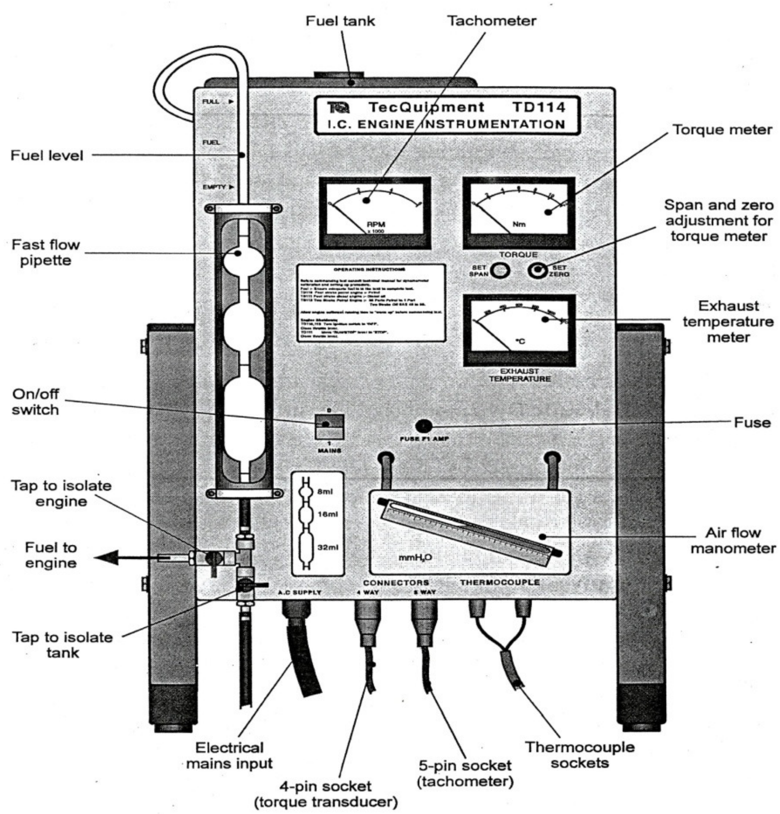


Figure 2.1 TD114 Instrumentation Unit

Figure 3.1.2 TD114 Instrumentation Unit

watch, thermometer and barometer were also used for the experiment. The Instrumentation Unit is designed to stand beside the engine test bed. 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 3.1.2.

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	12V DC
Coil power capacity	20W

Alternative Fuels We Have Used

Compressed Natural Gas (CNG)

We used 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 and it is sold in many parts of the world. All auto manufacturers approve the blending of 15% ethanol or less in their gasoline vehicles.

CNG Conversion of Engine

For CNG conversion we needed a cylinder (60L, maximum pressure 400 bar),a pressure gauge (Gives the reading of cylinder pressure),a 3-Stage pressure regulator (Converts the high pressure of about 300bar to pressure of 1.5 bar at the 2nd stage and an adjustable pressure at stage 3) and an 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).

Preparation of Bio-ethanol (E15)

We used 15% of the 99.96% pure ethanol (manufactured by Merck Company, Germany),85% of petrol and combined them to make our bio-ethanol or gasohol (E15).Ethanol is highly corrosive. But change in engine set up was not required because manufacturers allow using small amount of ethanol with petrol directly.

Experimental Procedure

Engine after that. We kept the throttle or rack open and slowly adjusted the needle valve to increase the flow of water through the dynamometer until the needle valve was fully open. Then we noted the engine speed keeping in mind that the engine would be tested over the established speed range. We chose 8 speeds from two extremes, at which, we took the readings of engine performance. We kept the throttle open and reduced the water flow to a tickle, so that the engine returned to its maximum speed. When the engine was settled down to a steady output, we recorded the speed, torque and exhaust temperature. Then we opened the fuel tap beneath the pipette, so that engine took fuel from the pipette to measure the time of 8ml fuel consumption. We had to check the temperature of water flowing out of the dynamometer whether it was less than 80°C or not. If the temperature was higher than this, we had to increase the water flow to cool the dynamometer bearing seals. Then, we increased the flow of water into the dynamometer until the engine speed dropped to the next highest selected value. Because the time response of the dynamometer was fairly slow, the needle valve had to be operated slowly. We allowed the engine to stabilize before taking another set of results. If the dynamometer was too sensitive to obtain the desired speed, the drain tap had to be partially closed. We repeated the process after changing the fuel, and for taking the result of diesel engine, we had to replace the engine with diesel engine. We collected all the data and made a table for calculating different parameters like brake power, specific fuel consumption and brake thermal efficiency.

Experimental Data Tabulation and Curve Plotting

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 N-m and from Exhaust temperature meter we got the Exhaust gas temperature. By using these values and mathematical formulas, we calculate different properties as below: Barometric pressure = 100 kPa.

Table for Different Fuels

R.P.M. (Rev/min)	Fuels	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	**Petrol**	2.80	220	0.35	61.45	0.35	1000	8
	Bio-ethanol	2.60	160	0.33	63.3	0.34	1030.3	9
	Diesel	3.15	235	0.40	58.45	0.41	1025	9
	CNG	2.40	250	0.30	-	-	-	-
1400	**Petrol**	3.20	250	0.47	53.76	0.4	851.06	10
	Bio-ethanol	3.10	180	0.45	57.87	0.37	822.22	11
	Diesel	3.40	260	0.50	51.12	0.47	940	10
	CNG	2.85	280	0.41	-	-	-	-
1600	**Petrol**	3.70	280	0.61	49.5	0.43	704.91	12
	Bio-ethanol	3.55	215	0.60	52.44	0.41	683.33	13
	Diesel	3.90	280	0.65	46.45	0.52	800	11
	CNG	3.35	315	0.56	-	-	-	-
1800	**Petrol**	4.10	295	0.77	39.87	0.53	688.31	12
	Bio-ethanol	3.95	230	0.74	44.12	0.49	662.16	14
	Diesel	4.50	300	0.84	37.22	0.65	773.8	12
	CNG	3.90	355	0.73	-	-	-	-
2200	**Petrol**	4.90	315	1.13	36.9	0.58	531.27	17
	Bio-ethanol	4.80	250	1.11	40.18	0.53	477.48	19
	Diesel	5.10	325	1.17	34.15	0.71	606.84	15
	CNG	4.60	405	1.06	-	-	-	-
2500	**Petrol**	5.50	330	1.43	33.25	0.64	447.53	19
	Bio-ethanol	5.30	280	1.39	38.21	0.56	402.88	22
	Diesel	5.70	350	1.49	30.18	0.8	536.91	17
	CNG	5.10	445	1.33	-	-	-	-
3000	**Petrol**	6.40	360	2.01	27.45	0.78	388.06	22
	Bio-ethanol	6.10	300	1.92	30.14	0.71	369.79	24
	Diesel	7.00	410	2.20	26.11	0.92	418.18	22
	CNG	5.80	490	1.82	-	-	-	-
3500	**Petrol**	5.90	340	2.16	23.3	0.91	421.3	20
	Bio-ethanol	5.70	295	2.09	25.66	0.84	401.91	22
	Diesel	6.30	380	2.31	22.45	1.07	463.2	20
	CNG	5.40	455	1.98	-	-	-	-

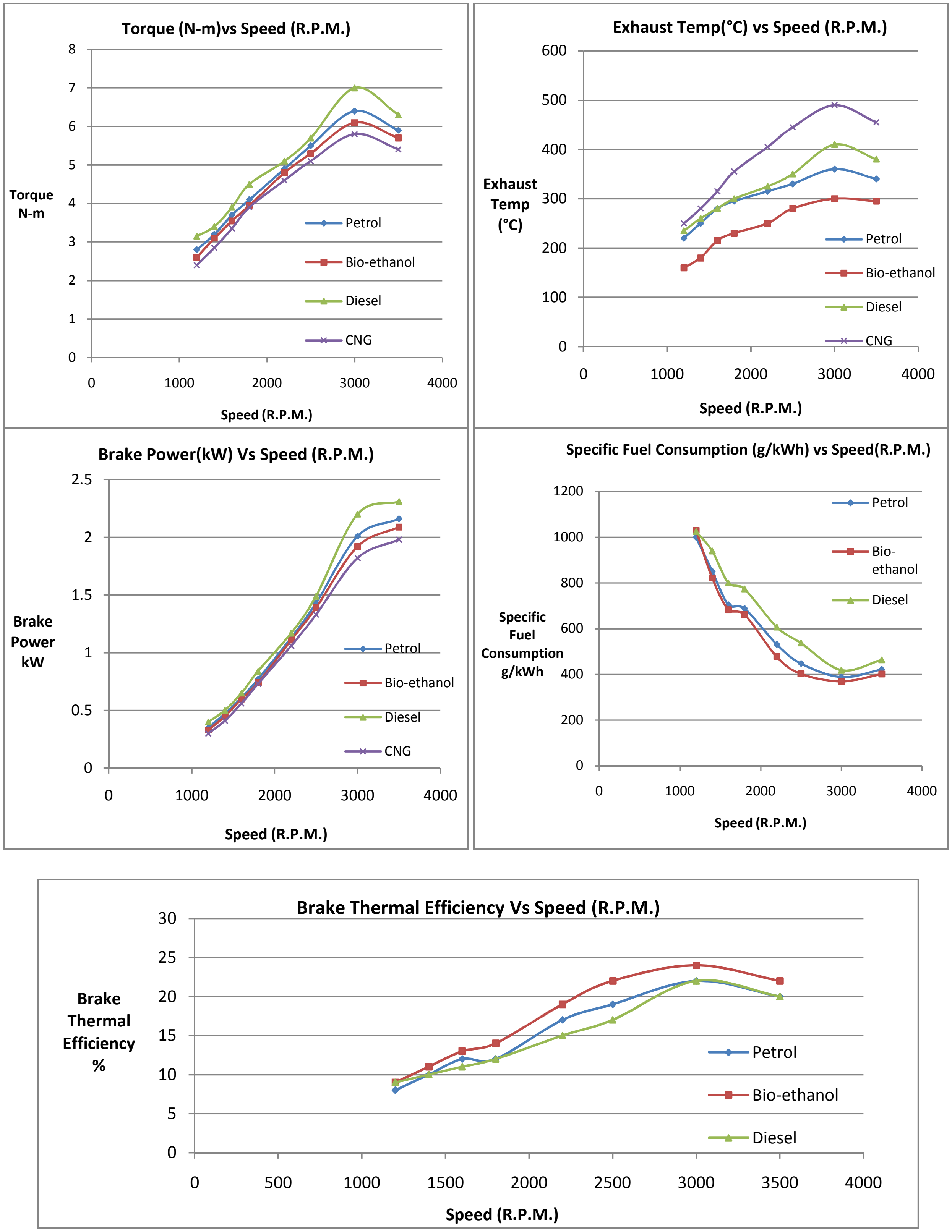
Ambient temperature = 25°C
Specific gravity of Petrol = 0.740
Specific gravity of Bio-ethanol = 0.787
Specific gravity of Diesel = 0.840
Calorific value (C.V.) for Petrol = 42000 kJ/ kg
Calorific value (C.V.) for Diesel = 39400 kJ/kg
Calorific value (C.V.) for Bio-ethanol= 40200 kJ/kg.

Mathematical Formulas

Brake power = ((2 ×π× R.P.M.× Torque))/(60000) kW

Fuel mass flow rate = (Specific Gravity × 8 × 3.6)/ (Time for 8ml fuel consumption)kg/hr

Specific fuel consumption= (Fuel mass flow rate × 1000)/ (Brake Power) g/kWh Brake thermal



Curves from the Data of Different Fuels

Comparative Analysis of Experimental Result for all the Fuels

Experimental and manufacturer's given values for different fuels	Maximum Values for different parameters				Minimum values 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)
Experimental value for Petrol	6.4	2.16	0.91	22	360	388.06
Manufacturer's given value Petrol	10.3	3.73	Not Specified	Not Specified	Not Specified	300
Experimental Values for Bio-ethanol	6.1	2.09	0.84	24	300	369.79
Experimental Values for Diesel	7.0	2.31	1.07	22	410	418.18
Experimental Values for CNG	5.8	1.98	_	_	490	_

efficiency = (Brake power × 3600)/(Fuel mass flow × C.V.) X 100 %

RESULT ANALYSIS

Experimental Result Analysis for Engine

All the experimental results were similar to the manufacture's given specifications. For petrol, experimental value of the maximum torque was 6.4N-m, whereas manufacturer's specified value was 10.3 N-m. For petrol, maximum brake power in 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 that the engine is alright and functional. Though, there might be experimental errors and other factors we have to consider here. Besides, in practical case, constant water flow is difficult to maintain because there are bubbles in tap water and that's why our maximum torque value deviated from the manufacturer's given torque. Another reason for engine performance decrease is because of 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 results obtained from manufacturer's value was in the atmospheric condition of United Kingdom.

Experimental Result Analysis for Fuels

From the comparative analysis it is clear that diesel engine can produce much higher torque (7N-m) and brake power (2.31 kW) and 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 N-m max), but has much better brake thermal efficiency (24% max) and lower exhaust temperature (300°C max).CNG 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 temperature.

CONCLUSION

Engine test bed is usually used to measure the engine performance for different parameters to find out engine performance, which we performed successfully. Our experimental results were similar to the manufacturer's given value though there are some deviations as it is an old machine and constant water flow was interrupted due to the presence of bubbles in tap water, which influenced our torque value. We kept our analysis within the brake power, specific fuel consumption, fuel mass flow rate and brake thermal efficiency measurement. It was the first project using this particular machine in IUT. So, for our time shortage we had to eliminate manometer reading to measure air pressure, by which we could also find out the air-fuel ratio, mechanical efficiency, volumetric efficiency and 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 comprehensiveness to our comparative study. We got excellent results for different parameters using different fuels; specially bio-ethanol which has very low exhaust temperature and higher brake thermal efficiency comparing to petrol. We recommend this engine to be converted into flexible fuel vehicle (FFV) to use bio-ethanol E85 or E90 and to obtain comparative data analysis of experimental results with other fuels. There is also scope for analyzing exhaust gas and for different fuels and comparing with each other to and for different fuels and comparing with each other to find out the best suitable fuel for the environment.

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