World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:3, No:3, 2009

Comparative Emission Analysis of Gasoline/LPG Automotive Bifuel Engine

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Open Science Index, Mechanical and Mechatronics Engineering Vol:3, No:3, 2009 publications.waset.org/4297.pdf

***Abstract*—**This paper presents comparative emission study of newly introduced gasoline/LPG bifuel automotive engine in Indian market. Emissions were tested as per LPG-Bharat stage III driving cycle. Emission tests were carried out for urban cycle and extra urban cycle. Total time for urban and extra urban cycle was 1180 sec. Engine was run in LPG mode by using conversion system. Emissions were tested as per standard procedure and were compared. Corrected emissions were computed by deducting ambient reading from sample reading. Paper describes detail emission test procedure and results obtained. CO emissions were in the range of38.9 to 111.3 ppm. HC emissions were in the range of 18.2 to 62.6 ppm. Nox emissions were 08 to 3.9 ppm and CO_2 emissions were from 6719.2 to 8051 ppm. Paper throws light on emission results of LPG vehicles recently introduced in Indian automobile market. Objectives of this experimental study were to measure emissions of engines in gasoline & LPG mode and compare them.

***Keywords*—**Gasoline, LPG, Emission, Bifuel, Engine.

I. INTRODUCTION

LPG is obtained from hydrocarbons produced during refining of crude oil and from heavier components of natural gas. It is petroleum derived colorless gas LPG consists of propane or butane or mixtures of both. Small quantities of ethane or pentane may also be present. LPG has high octane rating of 112 RON which enables higher compression ratio to be employed & hence gives higher thermal efficiency. Due to low maintenance cost, economic market price and environment friendly characteristics LPG is becoming popular alternative for gasoline.

A. *Characteristics of LPG*

- Relative fuel consumption of LPG is about ninety percent of that of gasoline by volume.
- LPG has higher octane number of about 112, which enables higher compression ratio to be employed and gives more thermal efficiency.
- Due to gaseous nature of LPG fuel distribution between cylinders is improved and smoother acceleration and idling performance is achieved. Fuel consumption is also better.
- Engine life is increased for LPG engine as cylinder bore wear is reduced & combustion chamber and spark plug deposits are reduced.
- As LPG is stored under pressure, LPG tank is heavier and requires more space than gasoline tank.
- There is reduction in power output for LPG operation than gasoline operation.
- Starting load on the battery for an LPG engine is higher than gasoline engine due to higher ignition system energy required.
- LPG system requires more safety. In case of leakage LPG has tendency to accumulate near ground as it is heavier than air. This is hazardous as it may catch fire.
- Volume of LPG required is more by 15 to 20% as compared to gasoline.
- LPG operation increases durability of engine and life of exhaust system is increased.
- LPG has lower carbon content than gasoline or diesel and produces less CO_2 which plays a major role in global warming during combustion.
- LPG powered vehicles have lower ozone forming potential and air toxic concentrations. [1]-[4],[6].

In present study engine of following specifications were tested:

Type: Four stroke, four cylinder, water cooled.
Bore- 85.0mm, Stroke-90.0mm.
Displacement; 1797 cc
Compression ratio: 10.0:1

Emission test was carried out as per BSIII cycle on chassis dynamometer and emissions were recorded. Total cycle time was 1180 seconds with maximum speed 90 km/hr.

II. ENGINE MODIFICATION SYSTEM FOR LPG OPERATION

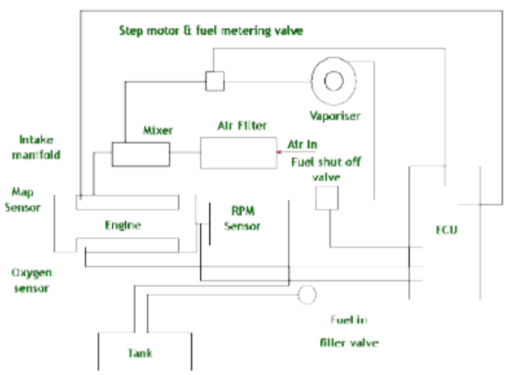

Fig. 1 LPG modification system

Fig. [1] Shows engine modification system for LPG

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operation. This system was used on gasoline engine. Engine can be operated on gasoline mode or LPG mode by using fuel selector switch. If level in tank drops to certain point, gasoline system is automatically switched on. LPG cylinder of capacity 40 to 60 lit supplies liquid LPG to LPG vaporizer which has heating element. Liquid LPG is vaporized and fuel in vapor form is supplied to gas mixer where air is mixed with fuel and supplied to engine manifold. Due to reduction in pressure there may be possibility of freezing within the vaporizer. To overcome this heated coolant is circulated through vaporizer. Fuel metering valve with step motor is used to vary quantity of fuel according to engine speed and load. Fuel shut off valve is used to cutoff fuel supply. Function of step motor and fuel shut off valve are controlled by ECU.

Intake manifold has MAP sensor which measures manifold pressure & sends signal to ECU. Oxygen sensor is located in exhaust which measures oxygen in exhaust and sends signals accordingly to ECU. ECU receives these signals and calculates how much fuel is to be supplied and sends signal to fuel metering valve. RPM sensor measures speed and sends signal to ECU. ECU decides amount of fuel to be supplied depending of engine speed and sends signals to fuel metering valve. [5]

LPG with composition of 60 % propane and 40 % butane was used. Octane no of LPG used was 88.

Following table gives properties of LPG used.

Parameter	LPG
Chemical formula	C_3H_8 – 40% C_4H_{10} -- 60%
LCV in KJ/ kg	46500
Density at 16 C in Kg/m^3	2.26
Stoichiometric air fuel ratio	15.6
Flame speed cm/sec	37
Auto ignition Temp in deg C	410

Lubricating oil used – 20 W 40

III. EMISSION MEASUREMENT

Fig.2 shows equipment layout for emission testing. It has emission equipment room (EER), test cell and control room. Vehicle was mounted on rollers in test room. It has exhaust blower and cooling blower. Driver's aid is provided for driver to operate vehicle. Control room contains data acquisition system, drivers aid and dynamometer controller. These

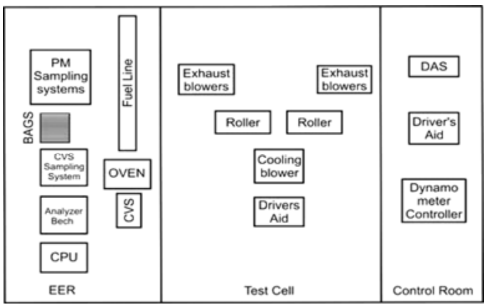

Fig. 2 Equipment layout for Emission testing

equipments perform control functions. Emission equipment room has fuel line, oven and constant volume sampler (CVS).Oven has heating coil which is used to heat gas to about 80^{0}C.Bags are provided for collecting sample exhaust gas.PM sampling system is used to sample and measure particulate matter.Analyser is used to analyze pollutants in exhaust gas.CPU is provided for computer control.

Analyzer measures any three exhaust gas components (CO, CO2, HC or NO) directly and continuously. This system incorporates three specified NDIR analyzers and packaged sample handling system. It measures simultaneously concentrations of three components from exhaust sample from vehicle. These infrared analyzers have micro controlled computer operation and signal processing and quadratic equation/least square method linearization for more precise data. It has solid filter. It has automatic calibration function which avoids complicated calibration process. It has linear output for direct digital readout and large LED display. Dead time is reduced to less than two seconds.

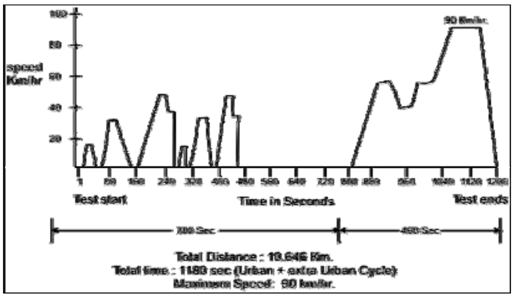

Fig. 3 Driving Cycle for emission measurement

Fig.3 shows driving cycle used for emission measurement. Emissions were measured on chassis dynamometer by using Indian driving cycle. Total cycle time for vehicle was 1180 seconds with total distance covered on dynamometer 10.646 kilometers. Maximum speed of vehicle was 90 km/hr. Driving cycle consists of running vehicle on urban cycle for 780 seconds and running it on extra urban cycle for 400 seconds. Hence total cycle time is 1180 seconds.

Horiba analyzer was used for measuring emissions.

Following test cell conditions were observed.

Test cell temperature-20-30^{0}C.

Absolute humidity- 5.5-12.2 gm of water per kg of dry air.

Emission test procedure followed was as mentioned below:

- Vehicle was received for mass emission test.
- It was ensured that there is no leakage of exhaust gas.
- Necessary connections of fuel, cooling water, and lubricating oil were made.
- Warming up of vehicle and soaking was done. Soaking was done in the range of 6 to thirty six hours between temperatures of 20-30^{0}C.
- Next day vehicle was kept on chassis dynamometer.
- Road load equation was loaded on computer.
- Vehicle was calibrated for bifurcation of losses.
- Dynamometer was put on road load simulation mode.
- Indian driving cycle was started as per BS-III. Cycle duration was 1180 seconds.[7]
- Readings were taken after completion of test from analyzer. Readings were taken in PPM.

Table I shows emission data which was recorded for urban cycle in gasoline & LPG mode. All values are in ppm.

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TABLE I

Pollutant	CO	HC	NOx	CO_2
Gasoline mode	147.89	53.8	5.76	8950.3
LPG mode	103.1	37.7	3.4	8051

Table II shows emission data which was recorded in extra urban cycle in gasoline & LPG mode. All values are in ppm.

TABLE II

Pollutant	CO	HC	NOx	CO_2
Gasoline mode	43.11	11.1	3.043	16509.3 2
LPG mode	38.8	5.5	0.7	14693.3

Following graphs are plotted from above values in urban & extra urban cycles for gasoline & LPG mode.

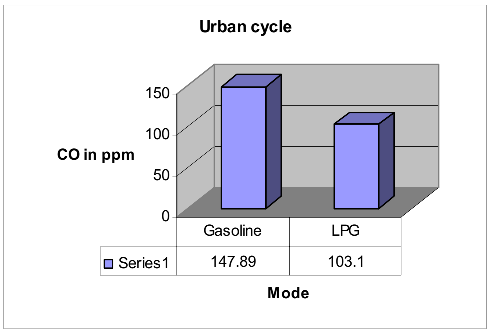

Fig. 4 Graph of CO in urban cycle

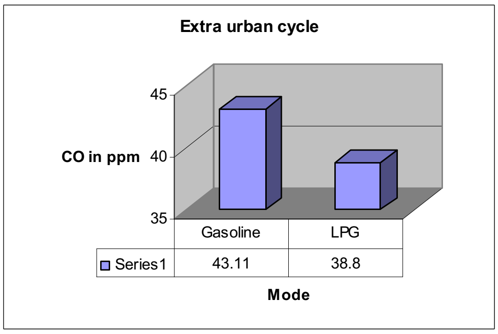

Fig. 5 Graph of CO in extra urban cycle

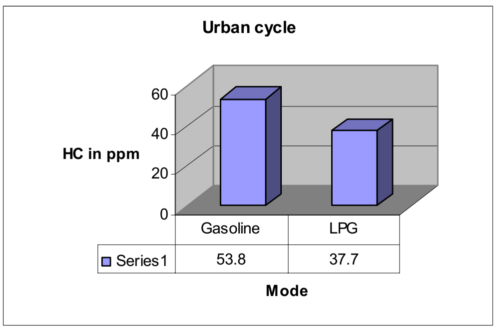

Fig. 6 Graph of HC in urban cycle

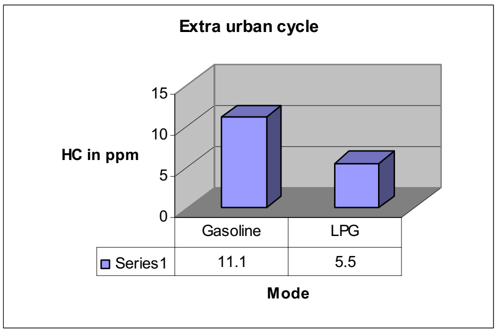

Fig. 7 Graph of HC in extra urban cycle

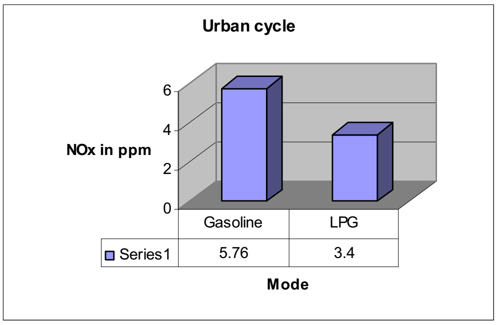

Fig. 8 Graph of NOx in urban cycle

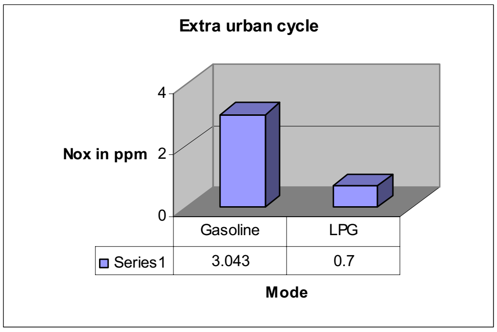

Fig. 9 Graph of NOx in extra urban cycle

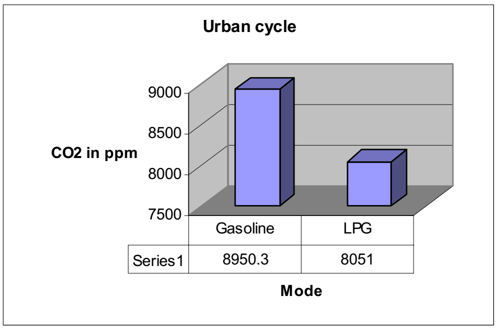

Fig. 10 Graph of CO_2 in urban cycle

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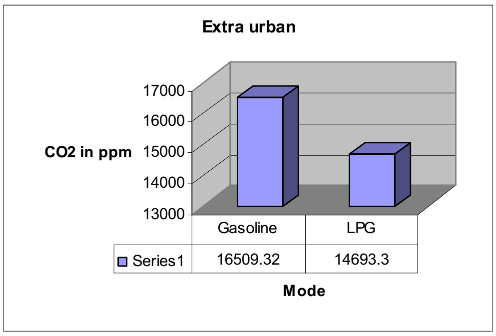

Fig. 11 Graph of CO_2 in extra urban cycle

IV. Conclusion

Emissions in gasoline & LPG mode are shown in graphs. CO emissions in both urban & extra urban cycle are less in LPG mode as compared to gasoline mode. CO emissions were 147.89 ppm in gasoline mode & 103.1 ppm in LPG mode. In extra urban cycle CO emissions were 43.11 in gasoline mode & 38.8 ppm in LPG mode. Hydrocarbon emissions were 53.8 ppm in urban cycle & 11.1 ppm in extra urban cycle in gasoline mode. These values were 37.7 ppm & 5.5 ppm in LPG mode.

NOx emissions were 5.76 ppm in urban cycle & 3.043 ppm in extra urban cycle in gasoline mode. These values were 3.4 & 0.7 in LPG mode.CO_2 emissions were 8950.3 ppm in urban cycle & 16509.32 ppm in extra urban cycle in gasoline mode. These values were 8051 ppm & 14693.3 ppm in LPG mode.

Abbreviations

ECU	Electronic Control Unit
LPG	Liquefied Petroleum Gas
CO	Carbon Monoxide
HC	Hydro Carbon
NOx	Oxides of nitrogen
CO_2	Carbon di oxide
PPM	Parts per million
RON	Research octane number
MAP	Manifold absolute pressure
O_2	Oxygen

Acknowledgment

Authors are sincerely thankful to Mr. Shrikant R. Marathe, Director, ARAI, Pune, India Mr. N.V. Marathe, Deputy Director, ARAI, Pune, India and other staff of EDL department of ARAI, India for their guidance support and help. Authors also acknowledge help and cooperation from library staff of ARAI, Pune, India

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[7] BS III Emission standards for four wheeler vehicle category.