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Research Article

Experimental studies on a SI engine using Plastic Petrol derived from Waste Plastic

Sudhir Kumar.J[a]*, Ravi.K[b], Satyanarayana.D[c], Venkata Subbaiah.K[d], V.V.Prasada Rao.P[e]

[a]Department of Mechanical Engineering, Sir C.R.Reddy College of Engg., Eluru, West Godavari District, Andhra Pradesh, INDIA-534007
[b] Dhanekula Inst.of Technology, Ganguru, Krishna District, Andhra Pradesh, INDIA
[c]Department of Mechanical Engineering,, Sir C.R.Reddy College of Engg., Eluru, West Godavari District, Andhra Pradesh, INDIA
[d] Department of Mechanical Engineering, A.U.College of Engg(A)., Andhra University, Visakhapatnam, Andhra Pradesh, INDIA
[e] Department of Environmental Sciences, Andhra University, Visakhapatnam, Andhra Pradesh, INDIA

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Abstract

Replacement (partial) of fossil fuels with alternate fuels has been set as a target worldwide to reduce greenhouse effect and energy dependence as well as to improve economy. Emissions from transportation engines are considered to greatly contribute to green house gases (carbon dioxide) release. In the present day scenario emissions associated with the exhaust of automobiles resulting in global warming is a major menace to the entire world and also detrimental to health. An experimental investigation is conducted to evaluate the use of Plastic Petrol derived from plastic waste in a Spark Ignition engine. The tests are conducted using each of the Gasoline and Plastic Petrol with the engine working at Constant speed. Fuel consumption, and exhaust regulated gas emissions such as nitrogen oxides, carbon monoxide and total unburned hydrocarbons are measured. The differences in the measured performance, combustion and exhaust emissions from the baseline operation of the engine, i.e., when working with Gasoline fuel and the Plastic Petrol are determined and compared. The experimental results show that plastic petrol under study shall conveniently be used as substitute to gasoline in the existing SI engines without any modifications in the aspect of in-cylinder response. Harmful emissions CO and NO_X were observed to be low that gasoline at almost all working conditions. Unburned HC and CO_2 is observed to be little higher with the use of plastic petrol than the gasoline.

***Keywords**: SI engine, Emissions, Combustion, Plastic Petrol and Gasoline*

1. Introduction

Automobile emissions are increasing day by day and there is catastrophic future in respect of human health degradation. The emission regulatory boards are imposing stringent rules in controlling emissions worldwide. The population of fossil fuel-run vehicles is increasing in multifold every year leading to peak pollution levels. Research round the globe is focused on the ways to reduce regulated and unregulated tail pipe emissions. Regulated emissions like NO_x, HC and CO emissions are important ones to be contained. Therefore, the need for reducing/minimizing emission levels of NO_x, HC, CO etc drawing attention of many a researcher. This can be achieved either by switching over to renewable fuels or by any other method which do not invite major changes in the design aspect of the engine in use which entails additional expenditure.

Rudolph Diesel stipulated as a condition of his rational heat motor that fuel must be introduced gradually so as to maintain an isothermal combustion process (Diesel, 1897). The promise of simultaneously reduced NOx and Particulate Matter (PM) offers attractive incentives, especially considering the associated minor penalties in fuel economy.

The popular press has become excited at the prospects of HCCI-type combustion systems, which are viewed as the internal combustion engine's best response to future competition from fuel cells and hybrids (Shirouzu.N, 2004). All transport vehicles with SI and CI (compression ignition) engines are equally responsible for the emitting different kinds of pollutants (Dhanapal Balaji *et.al* 2010). Some of these are primary kinds having direct hazardous effect such as carbon monoxide, hydrocarbons, and nitrogen oxides while others are secondary pollutants such as ozone, which undergoes a series of reactions in the

* Corresponding author's email: jastisudhir@yahoo.com

atmosphere and become hazardous to health (Goddger, 1978). The emissions exhausted into the surroundings pollute the atmosphere and cause global warming, acid rain, smog, odours and respiratory and other health hazards.

The urgent need for alternative fuel is essential to replace the supplement conventional fuels. The root causes for these emissions are non-stoichiometric combustion, dissociation of nitrogen and impurities in the fuel and air.
The major exhaust emissions HC, CO, NOx, SO_2, solid particles and the performance is increased by adding the suitable additives to the fuel reduced with the present technology. Additives are integral part of today’s fuel. Together with carefully formulated base fuel composition they contribute to efficiency and long life. They are chemicals, which are added in small quantities either to enhance fuel performance, or to correct a deficiency as desired by the current legislation.

Winnington and Siddique (1983), Hamdan and Jurban (1986) and El-Kassaby (1993) have studied the effect of using ethanol-gasoline blends. They used maximum of 15% of ethanol in ATd 34 engine. Palmer (1986) has conducted a test on gasoline engine containing oxygenates. The effect of oxygenate in gasoline on exhaust emission and performance in a single cylinder, four stroke SI engine was studied. Ethanol can be produced form Azeotropic Solution by Pressure Swing Adsorption was studied by Pruksathorn and Vitidsant (2009). The effect of compressed natural Gas on performance and Emission in an Internal Combustion engine was studied by Semin *et al*. (2009a; 2009b) and (Kaleemuddin and Rao, 2009). An experimental study is carried out byShehata.M.S.et.al (2008) to investigate engine performance parameters and methods of reducing emissions from spark ignition engine. The used engine is four stroke four cylinder naturally aspirated spark ignition engine with compression ratio of 9, bore diameter of 80 mm and stroke of 90 mm. The engine performance parameters are presented with and without exhaust gases recirculation (EGR).

Not much research has been done to study the performance, combustion and emission analysis of SI engine with alternate fuels. Hence the objective of this study is to investigate the use of plastic petrol fuel derived from waste plastic as an alternate fuel for the analysis of performance, combustion and emissions without any modifications in the basic SI engine and without adding any additives in comparison with Gasoline fuel.
This work examines the interactions resulting from the application of plastic petrol derived from plastic waste on a practical heavy-duty petrol engine system, with the aim of understanding their impact on emissions and performance. The goal of this experimental study is to assess the new fuel contributions to potential performance and efficiency penalties. Plastic petrol itself is a waste by product known to reduce the serious pollution threat to all most all the nation’s worldwide (Mangalorean on line). An attempt is made to assess the combustion and performance phenomenon of plastic petrol fuel. Some tests were conducted with the neat petrol application to verify the delineation line to fix up the performance of the petrol engine designed for petrol fuel. Marginal changes in the performance in the wise of SFC and BSFC cannot decipher the nature of combustion exactly (J.Sudhir Kumar *et al* 2011, 2012).

Fig.1 Experimental setup of fractional distillation to extract plastic petrol from liquid hydro carbons

That is the reason why an extensive investigation encompassing the performance, emissions is taken up to evaluate the engine under the new conditions of the fuel implementation The merits and the demerits of the plastic petrol fuel implementation with the neat petrol application are discussed. The fuel in the form of liquid hydrocarbons derived from plastic waste constitutes approximately 80% of total post consumer plastic waste in India and includes PET, LDPE, PVC, HDPE, PP, PS etc. into liquid fuel oil (Plastic 2 Petrol on line). The process adopted is based on random de-polymerization of waste plastics in presence of a catalyst into liquid fuel. (Tribute India and Good News India on line). Fractional distillation was carried out by the author at his laboratory to convert the liquid hydro carbons to plastic petrol fuel at a temperature from 60^0 c to 160^0 c as suggested by the inventor and pale color petrol like fuel is derived by distillation with an approximate yielding of 30%. The distillation set up and the derived fuels are shown in the “Figure1”.

2. Methodology

2.1 Experimental set up

Experimentation is carried out at various engine loads (Engine Loading device is eddy current dynamometer) to record the cylinder pressure and finally to compute heat release rates with respect to the crank-angle. Engine performance data is acquired to study the performance and engine pollution parameters. Exhaust gas analysis of different components of exhaust gas are measured and compared and engine performance is analyzed for the parameters mentioned above with the implementation of Gasoline and plastic petrol.

Table 1 Specification of the SI Engine

Make	: Briggs and Stratton
Bore	: 79 mm
Stroke	: 61mm
Capacity: 305 CC	
RPM	: 2500 rpm
BHP	: 10 HP

2.2 QROTECH (Exhaust Gas Analyzer)

The gas analyzer used is a QROTECH make, which is capable of measuring 5 gases i.e. HC, CO, CO_2, O_2, NO_X. It can also be used to find the oil temperature and RPM. A probe is attached to the back panel gas analyzer. The probe is placed in the exhaust pipe of the engine to analyze the emissions while running. The "Figure2"shows the gas analyzer used in the experimentation.

Fig.2 QROTEC H Five Gas Emission Analyzer

Fig. 3 Automotive Research Centre at VIT

The experiment is conducted at VIT University, Vellore, India. The engine used for this experiment is a Single cylinder, 4-stroke, Air cooled engine. The petrol engine is a ***Briggs and Stratton*** make. It is an inclined cylinder engine developing about 10 HP, recoil starter engine (Table 1).

The engine is coupled to an ***Eddy current dynamometer*** to impose load on the engine. The consumption of the fuel is measured by means of ***high sensitive weighing machine and stop watch.*** The consumption of the fuel is measured for every minute. Figure 3 shows the images of the division at which the experimentation is done at VIT, "Figure 4" and "Figure 5" shows mounting the engine to the dynamometer and the "Figure 6 and 6a" shows experimentation and the oscilloscope setup respectively.

Fig. 4 Briggs & Stratton S.I Engine

Fig. 5 Mounting the Engine

Fig. 6 Experimentation

Fig. 6a Oscilloscope and Computer Setup

3. Results and discussions

3.1 Combustion Analysis

Combustion, performance analysis of plastic petrol in comparison with gasoline was done by recording the in-cylinder pressure response as a function of the crank angle while the engine running with both the fuels separately under the same operating conditions.

"Figure 7" shows the comparison of in-cylinder pressure variation with use of 100% plastic petrol and gasoline when the engine runs at zero load. In-cylinder Pressure variation with the use of plastic petrol appears similar to that of the use of gasoline in the first zones (Ignition lag & Propagation of Flame) combustion till it reached the peak value and in the third phase (After Burning) combustion of plastic petrol is slightly different from the gasoline, which might be due to the variation of distillation properties of the fuels. Further the pressure graph reveals no abnormal combustion throughout the combustion zone.

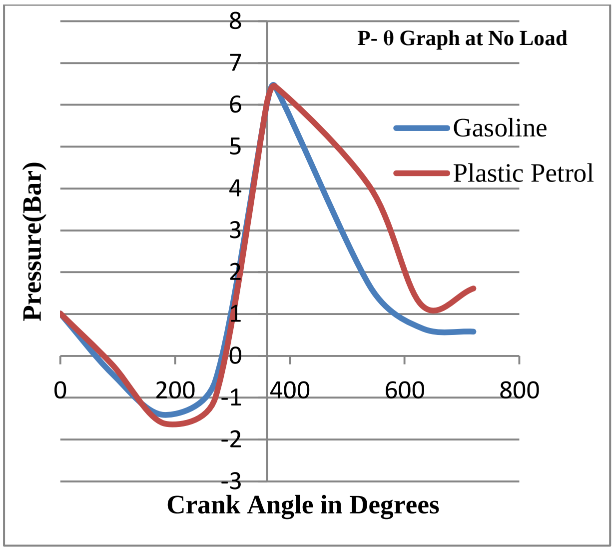

Fig.7 Comparison of Pressure Variation against crank angle with gasoline and 100% Plastic Petrol at Zero Load

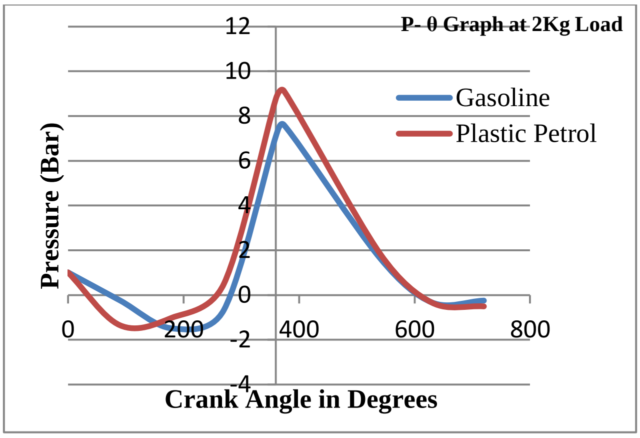

Fig.8 Comparison of Pressure Variation against crank angle with gasoline and 100% Plastic Petrol at 1/4th Load.

"Figure 8" shows the comparison of pressure variation at 1/4th load when the engine run with 100% plastic petrol and gasoline. Under the mentioned operating conditions pressure response appears similar to that of the gasoline with the use of neat plastic petrol. Peak pressure is slightly higher with plastic petrol and in-cylinder pressure recorded throughout the combustion period is slightly higher, but no abnormal combustion is recorded and hence the plastic fuel is safe to run the SI engine less than 1/4th load. "Figure 9" shows the pressure variation at half load with use of both the fuels under test. At higher range of operation part of the pressure curve appears similar to the ideal cycle, which can be observed in the below pressure graphs. Peak pressure was observed to be slightly higher with the use of plastic petrol than the gasoline and knocking was not observed in the total combustion range and hence combustion is smooth with plastic petrol at the mentioned load.

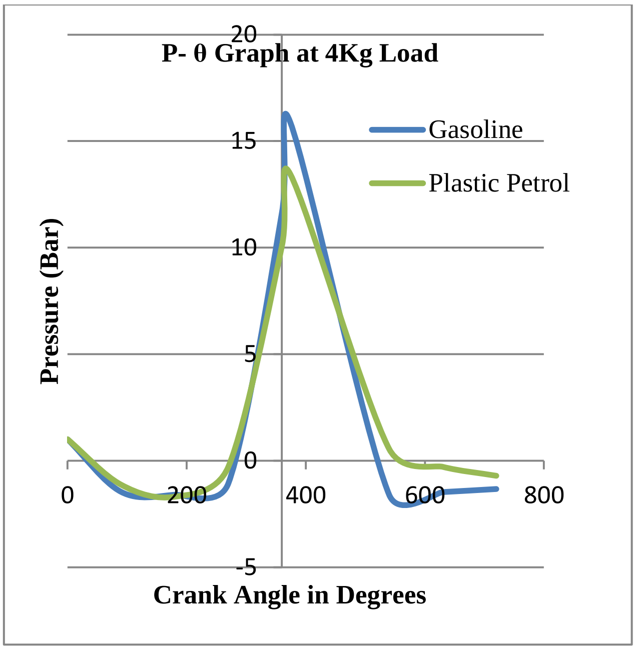

Fig.9 Comparison of Pressure Variation against crank angle with gasoline and 100% Plastic Petrol at half load.

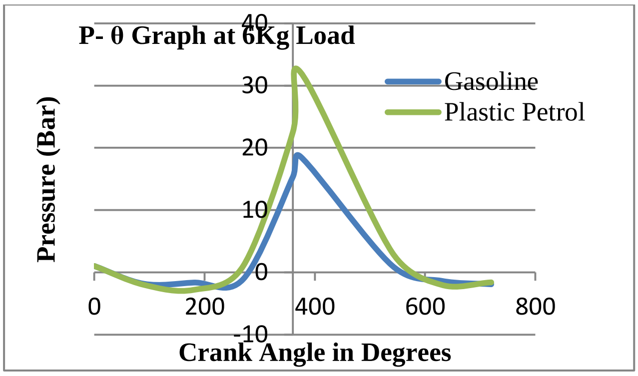

Fig.10 Comparison of Pressure Variation against crank angle with gasoline and 100% Plastic Petrol at $3/4^{th}$ Load.

Above pressure curves ("Figure 10") shows the pressure variation at $3/4^{th}$ load, peak pressure with 100% plastic petrol is observed to be about 30% higher than that of the gasoline. No knocking phenomena is observed in the pressure curve even with high pressure recorded and hence the combustion is said to be smooth and it's safe to run the engine at this operating conditions.

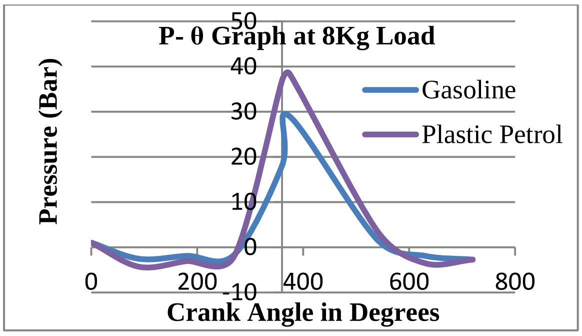

Fig.11 Comparison of Pressure Variation against crank angle with gasoline and 100% Plastic Petrol at Full Load.

Pressure trend at full load ("Figure 11") is slightly different to that of the previous trends and the pressure curve with plastic petrol is above that of the gasoline shows the higher level of in-cylinder pressures with use of plastic petrol, which may deliver more torque under same operating condition. No abnormal combustion was observed and hence it is safe to use plastic petrol even at full load.

Peak pressure and knocking phenomena are the two major issues that damage the engine. Overall combustion response of the plastic fuel is said to be smooth because of absence of knocking phenomena at various operating conditions of the engine and peak pressures observed may be tolerable. More over the second phase of combustion (Propagation of Flame) which is an important phase for proper conversion of heat energy into useful torque is almost similar to that of the gasoline, so there may not be any damage to the engine due to combustion of the plastic petrol. Hence plastic petrol under study now shall conveniently be used as substitute to gasoline in existing SI engines without any modifications in the aspect of in-cylinder response.

3.2 Performance Analysis

Graph ("Figure 12") shows the comparison of break thermal efficiencies of the SI engine run with gasoline and 100% plastic petrol. Break Thermal Efficiency increase with the increase of load. Efficiencies are almost observed to be same except at half load and it is slightly higher than the gasoline. Break Specific Fuel Consumption is same as that of the gasoline as observed in "Figure13".

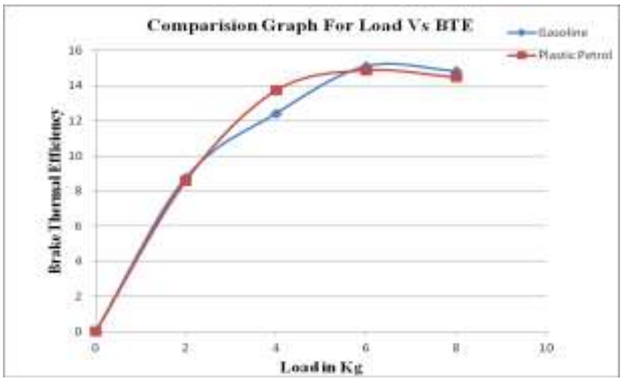

Fig. 12 Comparison of Brake Thermal Efficiencies with 100% Plastic Petrol and Gasoline at various loads.

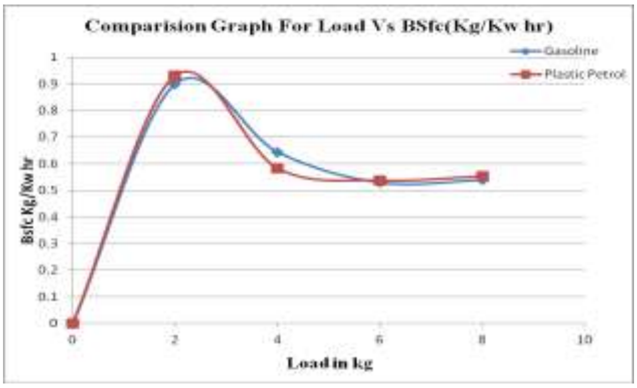

Fig. 13 Comparison of Brake Specific Fuel consumption with 100% Plastic Petrol and Gasoline at various loads.

3.3 Emission Analysis

Emission study was carried out by measuring CO, HC, CO_2, O_2 and NO_X with use of Plastic Fuel and Gasoline and comparison made and represented in the below graphs from "Figure 14 to Figure 18". CO, NO_X and O_2 emission levels were observed to be very low with plastic petrol than that of gasoline at respective operating conditions as shown in "Figure 14 and Figure.17". Unburned hydrocarbons emissions are observed to be higher in case of Plastic Petrol than that of the Gasoline, visible in the graph shown in "Figure 15", might be due to the incomplete combustion of Plastic Petrol because of variation in fuel properties.

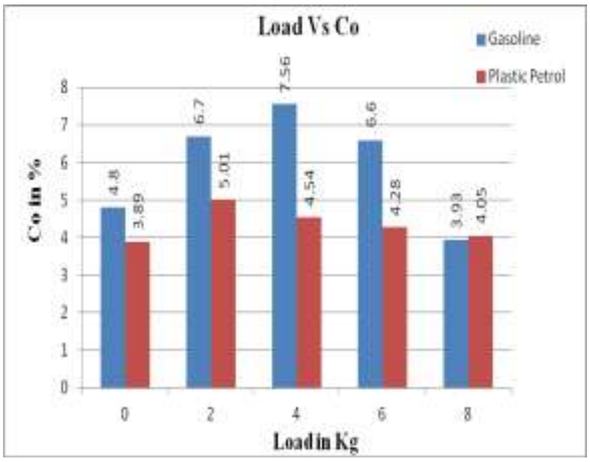

Fig. 14 Comparison of CO emission with use of Gasoline and 100% Plastic Fuel.

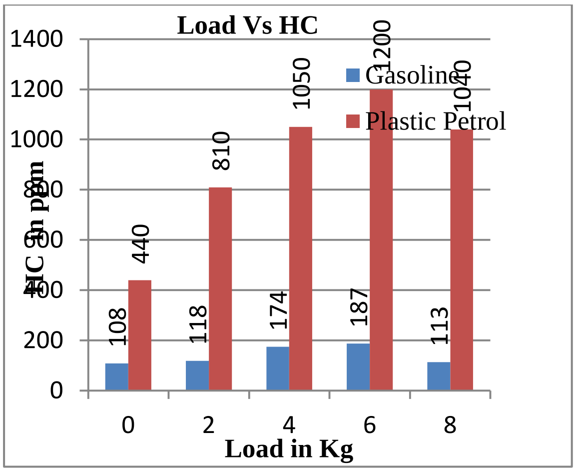

Fig. 15 Comparison of HC emission with use of Gasoline and 100% Plastic Fuel

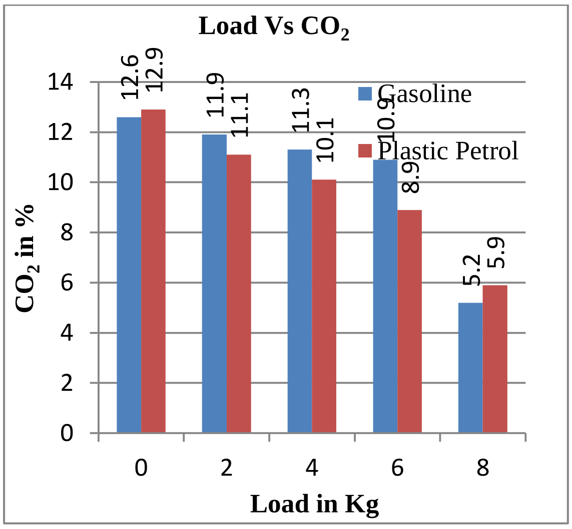

Fig.16 Comparison of CO_2 emissions with the use of gasoline and 100% Plastic Petrol

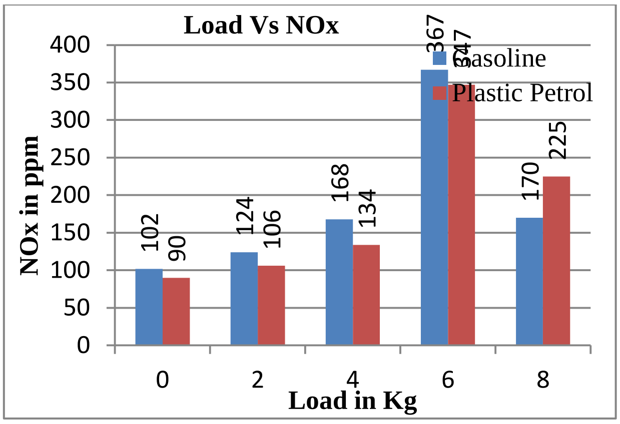

Fig. 17 Comparison of NO_x with use of Gasoline and Plastic Petrol

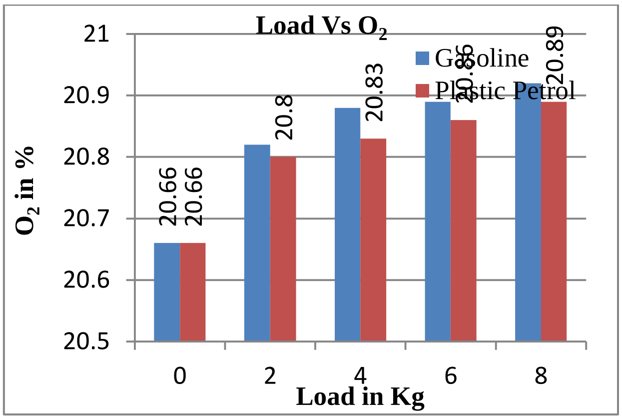

Fig. 18 Comparison of O_2 with use of Gasoline and 100% Plastic Petrol

4. Conclusion

Plastic Petrol as substitute to Gasoline has been effectively used in existing S.I Engine without any modifications. Combustion performance with use of Plastic Petrol was analyzed by capturing the in cylinder pressure against the crank angle and comparison made with that of the gasoline data. No abnormal combustion has been recorded at various operating conditions and even the mean effective pressure is observed to be high with that of the plastic petrol than gasoline at some loads. Performance parameters like Break Thermal Efficiency and Specific Fuel Consumption has been recorded with the use of Plastic Petrol and compared with that of the gasoline and found to be on par with gasoline. Emission study has been carried out by measuring CO, HC, CO_2 and NO_X and compared against the emissions of gasoline at the similar working conditions. Harmful emissions CO and NO_X were observed to be low that gasoline at almost all working conditions. Unburned HC and CO_2 is observed to be little higher with the use of plastic petrol than the gasoline. Total study reveals that the plastic petrol shall be conveniently used as substitute to gasoline without any engine modifications.

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