STUDY OF PERFORMANCE AND EMISSION ANALYSIS OF A 4 STROKE SINGLE CYLINDER SI ENGINE FUELLED BY PETROL MIX WITH PLASTIC OIL

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ABSTRACT:-

Because of the environmental pollution and common use for gasoline fuel in our country Iraq, the wide used for cars in the transport sector and the increasing number of cars day after day, it is important to search for alternative fuel to operation the internal combustion engines. In this work, the practical results have been obtained through the experiments to evaluate the use of Gasoline and plastic oil extracted from waste plastic in spark ignition engine. The research aims to study the effect of using the plastic oil in spark ignition engines without any modification of the engine. In this study, the test was conducted on a single - cylinder, 4-stroke SI engine runs at a constant speed, by using of gasoline and mixed with the plastic oil proportions (10%, 20%, 30%, 40%, and 50%) by volume. The brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and exhaust gas emissions such as: carbon monoxide (CO), carbon dioxide (CO_2), and unburned hydrocarbons (HC) are measured. As well as the differences in the engine performance have been found which works by a gasoline mix with plastic oil, this provides better performance of the engine while that a calorific value for the plastic oil is the highest. Hence the experimental results have shown that a 50% proportion of plastic oil blended with gasoline can be the alternative fuel for the operation of spark ignition engine without any modifications .

KEY WORDS : Performance ،spark ignition engine, Petrol and plastic oil, emission, waste plastic

دراسة اداء وتحليل الانبعاثات لمحرك رباعي الاشواط احادي الاسطوانة يعمل بشرارة الاشتعال يغذى بواسطة البنزين وزيت البلاستك

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الخلاصة:-

نظرا للتلوث البيئي والاستخدام الشائع للوقود البنزين في بلدنا العراق والاستخدام الواسع للسيارات في قطاع النقل, وتزايد اعداد السيارات يوما بعد يوم. فمن المهم البحث عن وقود بديل لتشغيل محركات الاحتراق الداخلي. في هذا العمل تم الحصول على النتائج العملية لتقييم استخدام البنزين وزيت البلاستك المستخلص من النفايات البلاستيكية في المحركات الانفجارية. ويهدف البحث دراسة تأثير استخدام زيت البلاستك في محركات البنزين دون أي تعديل للمحرك. في هذه

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الدراسة تم اجراء الاختبار على اسطوانة واحدة رباعي الاشواط محرك يعمل بسرعة ثابتة عن طريق استخدام البنزين ويمزج مع زيت البلاستيك بنسب (10%،20%،30%،40%،50%). تم قياس كفاءة الحرارية الفرامل، استهلاك الفرامل محددة الوقود وانبعاثات الغاز العادم مثل اوكسيد الكربون وثاني اوكسيد الكربون والهيدروكربونات الغير محترقة. كذلك تم العثور على الاختلافات في أداء المحرك الذي يعمل عن طريق مزيج البنزين مع زيت البلاستيك، وهذا يوفر أداء أفضل للمحرك في حين أن القيمة الحرارية لزيت البلاستيك هي الأعلى. وبالتالي فقد أظهرت النتائج التجريبية أن نسبة 50% من زيت البلاستيك المخلوطة مع البنزين يمكن أن يكون وقود بديل لتشغيل المحرك الانفجارية دون أية تعديلات.

الكلمات الدالة :- الاداء، محرك الاشتعال بالشرارة، البنزين وزيت البلاستك، الانبعاثات، النفايات البلاستيكية

NOMENCLATURE :-

10%PPO	10% Plastic Fuel blended with 90% Petrol.
BP	Brake Power, (KW).
BSFC	Brake Specific Fuel Consumption, (Kg/KW- sec).
CO	Carbon Monoxide, (%Vol).
CO_2	Carbon Dioxide, (%Vol).
EGR	Exhaust Gas Recirculation.
EGT	Exhaust Gas Temperature.
HC	Unburnt Hydrocarbons, (PPM).
NO_x	Nitrogen Oxides, (PPM).
O_2	Oxygen.
PE	Poly Ethylene.
PO	Plastic oil.
PP	Poly Propylene.
PPM	Parts Per Million.
PS	Poly Styrene.
TFC	Total Fuel Consumption, (Kg/sec.).
WPO	Waste Plastic Oil.
η_{bth}	Brake Thermal Efficiency, (%).
λ	Air Fuel Ratio.

1. INTRODUCTION :-

The use of internal combustion engines is considered of the most important reasons which leads to environmental pollution due to the emission of harmful exhaust gases. So, there should be an alternative fuel of low-cost and environment friendly that meets the local needs. The use of SI engine is widely, for example: transport modes, small power generators, as well as the engines of construction machines and other uses. Regulated emissions like NO_x, HC and CO emissions are important ones to be contained. So, it is necessary to lowering/minimizing levels of these emissions NO_x, HC, CO etc this is drew the attention of many a researcher.

(Rudolph Diesel, 1879) stipulated as a condition of his rational heat motor that fuel should be introduced gradually in order to maintain an isothermal combustion process. The promise at the same time to reduce each of the nitrogen oxides (NO_x) and particulate matter (PM) offers attractive incentives, especially considering the associated minor penalties in fuel economy. (Anup, 2014) prepared a review of research papers on various operating parameters for better understanding of operating conditions and constrains for waste plastic pyrolysis oil of both grade fuel and its blends fuelled in compression and spark ignition engine. (Sudhir Kumar J, 2013) The tests have been carried out by using gasoline and mixed with proportions from plastic oil in the engine runs at constant speed. The differences in the measured performance of the engine which works by petrol and mixed with proportion from plastic oil are determined and compared. The experimental results showed that the plastic oil under study and it can be used as an alternative fuel to gasoline for the operation of spark ignition engines without any modifications. (Palmer F.H, 1986) The experiments were carried out on SI engine which contains on the oxygen. The effect of oxygenate in gasoline on the performance and exhaust emissions 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 and Kaleemuddin and Rao, 2009). An experimental study was carried out by (Shehata.M.S and Abdel Razek S.M, 2008) to investigate engine performance parameters and methods of reducing emissions from SI engine. (Sudhir Kumar J. and Ravi K, 2012) experimental results showed 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. CO and NO_x emissions have been observed to be lower when using the gasoline as a fuel, but the unburned HC and CO_2 are little higher with the use of plastic petrol compared with the gasoline. 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).

The review of previous literatures clearly shows that any one of the researchers had not improved the performance of SI engine for the above fuel blend (thermal efficiency and brake specific fuel consumption) by the engine test specification and additive proportions from the plastic oil to gasoline as well as the reduction of exhaust emissions (carbon monoxide, carbon dioxide, nitrogen oxides, and the unburned hydrocarbons). The objective of this current research is to study the performance and analysis of emissions from SI engine single cylinder, 4-stroke fueled by gasoline and blends with plastic oil.

1. PERFORMANCE AND EMISSION ANALYSIS

The engine performance parameters such as brake power, total Fuel Flow Consumption**,** Brake Specific Fuel Consumption, and Brake Thermal Efficiency were evaluated using the following equations:

To calculate the Brake Power (BP) from Eq 1.

$$\mathbf{BP} = \frac{\text{Voltmeter reading X Ammeter reading X 0.8}}{1000} \quad \text{(kw)} \qquad (1)$$

Power factor = 0.8

To calculate the Fuel Flow (Consumption) ($\dot{m}_f$) from Eq 2.

$$\dot{\mathbf{m}}_{\mathbf{f}} = \frac{V \times \rho \times 10^{-6}}{t} \quad \text{(kg/sec.)} \tag{2}$$

V = Amount of fuel consumption = 10 cm^3.
ρ = Fuel Density (kg/m^3).
t = Time taken for 10 cm^3 of fuel consumption (sec.).

To calculate the Total Fuel Consumption (TFC) from Eq 3.

$$\mathbf{TFC} = \dot{m}_f \times 3600 \quad \text{(kg/hr)} \tag{3}$$

To calculate the Brake Specific Fuel Consumption (BSFC) from Eq 4.

$$\mathbf{BSFC} = \frac{TFC}{BP} \quad \text{(kg/kw.hr)} \tag{4}$$

To calculate the Brake Thermal Efficiency ($\eta_{bth.}$) from Eq 5.

$$\eta_{\mathbf{bth.}} = \frac{BP}{\dot{m}_f \times LCV} X\, 100 \quad (\%) \tag{5}$$

2. EXPERIMENTAL SETUP :-

Practical test was conducted on a single-cylinder, 4-stroke petrol engine, to evaluate the performance and emissions. Figure 1. Shows a schematic diagram of the engine test which consists of the petrol engine, electrical dynamometer, burette setting with fuel consumption pipe and fuel tank, air and fuel supplied to engine, and gas analyzer.

Figure 2. shows a photographic image for the engine used in this research, which consists of: single-cylinder, 4-stroke, cooling system for the engine by the air, electrical dynamometer that works in turn as a loading device, indicator for measuring the temperature of the engine parts and voltmeter, ammeter to measure the power output.

Engine Specifications:-

The table 1 shows the engine specifications of a 4 stroke single cylinder SI engine fuelled by petrol mix with plastic oil.

Physical properties of petrol and plastic oil:-

In this research, the petrol and mixed with proportion of plastic oil has been used in spark ignition engine. Plastic oil was obtained through the pyrolysis method; pyrolysis refers to the thermos - chemical process for conversion of waste plastic by heating waste plastic inside the cylindrical reactor at high temperatures of 350°C – 450°C and low pressure in the absence of oxygen, where producing vapor gasses which condense to get on the liquid fuel. The table 2. shows the physical properties of petrol and plastic oil (Viswanath K. Kaimal , P. Vijayabalan, 2015).

Experimental Procedure:-

A series of experiments have been conducted on the SI engine using a fuel blend (gasoline and plastic oil), that have been prepared in the test before the experiment starts to make sure the homogeneity of fuel blend as well as the engine warm-up for 15-20 minutes. All types of fuel blend at different mixing proportions have been tested (10%, 20%, 30%, 40% and 50%) from plastic oil with gasoline as well as the engine operation at different loads (0, 16.66%, 33.33%, 50%, 66.66%, 83.33%, 100% load) by electrical dynamometer and respective readings that taken for 10 ml of fuel consumption for every test. The tests were conducted to the engine performance with utmost rotation speed for the engine. It was obtained the optimum load for the engine through the dynamometer control (engine speed, fuel consumption, engine load, brake power, torque and brake specific fuel consumption). The emissions (CO, CO_2, UHC, and NO_x) have been measured by gas analyzer device (AVL DIGAS 444) as shown in figure 3, and the engine tests were conducted for three times run to get on the average ideal values for adoption in the operation data. After the engine reaches to the steady state the required parameters have been recorded from the engine during operation for all the generated gas emissions for the engine. The exhaust gas temperature during the tests period has been observed in order to ensure the operation of the engine at steady stat.

4. RESULTS AND DISCUSSION

4.1 Engine Performance Characteristics

4.1.1. Brake Power

Figure 4. shows the variation of brake power with the load for all blends. At the load increase the brake power increases, as well as at the increased of plastic oil proportion in the blend the brake power increases and be higher compared with petrol. It has been observed that the higher value of brake power at 50% PO in the full load conditions and increased by (19.31 %) compared with petrol fuel. This is because of that plastic oil has a higher calorific value than petrol.

4.1.2 Brake Specific Fuel Consumption

Figure 5. shows the variation of BSFC with the load for various blends. The BSFC for the engine decreased with the load increase because of less fuel required producing the same power by the fuel. As well as the BSFC be lower with increasing plastic oil blend in the fuel. Plastic oil has calorific value and density higher than those it petrol. At the full load conditions it have been observed that the BSFC at 50% plastic oil blended with petrol (PO) is less compared with the 100% petrol.

4.1.3 Brake Thermal Efficiency

Figure 6. shows the variation of brake thermal efficiency with the load. When the load increase the brake thermal efficiency increases, and also at increased in proportion of plastic oil in blend the brake thermal efficiency is the higher compared with petrol. So the brake thermal efficiency for 50% PO in the full load conditions increased by (29.2 %) compared with 100% petrol fuel. This is due to of lesser fuel consumption in case of blended fuel (plastic oil with petrol), Similarly, with the increase of plastic oil proportion in blends, the fuel consumption is consistently decreasing.

4.2 Emission Characteristics

4.2.1. Oxides of Nitrogen (NO_x)

NOx emissions increase with the peak cylinder temperature increase. Peak cylinder temperature increased with the load increase. SI engines operated at a slightingly richer equivalence ratio. At this state the flame temperature is the highest, the high temperature triggers the NO_x formation. When the load increases the NO_x emissions increase as shown Figure. 7. as predicted. It has been observed that the NO_x emissions for 50% PO to be higher by 1.6 times compared with 100% petrol as a fuel. The reason behind increased in NO_x emissions with the increase of plastic oil proportion in blends are the higher heat release rate. The higher heat release rate causing the increase in the in-cylinder temperature, and hence increase in NO_x emissions.

4.2.2 Carbon Monoxide (CO)

Carbon monoxide (CO) emissions increased with the load increase as shown in figure 8, because of incomplete combustion of fuel inside engine cylinder, this is due to either inadequate oxygen or flame quenching or air-fuel mixture may not be a homogeneous throughout the cylinder. But at high loads (fourth and fifth loads) the CO emission reached to the maximum and there after slightly decreased, because of the availability of oxygen in sufficient quantity. In this research as the engine is equipped with a carburetor to supply fuel to the engine cylinder. Therefore, there is slightly increase in the carbon monoxide emissions with the increased of plastic oil proportion in blend. It has been observed that the CO emissions in 50% PO are 1.7 times more than that of the engine fuelled with the 100% Petrol. The reason behind increased CO emission is incomplete combustion due to absence of oxygenated compounds in plastic oil.

4.2.3 Carbon Dioxide (CO_2)

Figure 9. shows the variation of CO_2 emissions with load for various blends. Carbon dioxide emissions represent how well the air/fuel mixture is burned in the engine. This gas gives a direct indication of combustion efficiency. It can be observed that CO_2 emissions decreased with increase in load for all blends. As the CO goes up and O_2 goes down, this an indicator on the engine is operating in a rich mixture. Because of an air/fuel imbalance and hence CO_2 decrease. The CO_2 emissions are higher in the engine with 50% PO compared to the 100% petrol by 40.7%. This may be due to advance burning of fuel leading to complete oxidation of CO.

4.2.4 Unburnt Hydro Carbons (UHC)

Figure 10. shows the variation of unburnt hydrocarbon emissions with load for all blends. Unburnt hydrocarbon emissions increase with the load increase. In-cylinder temperature is a key factor in determining unburned HC and CO emissions characteristics. The reason for increase HC and CO emissions at the same time indicates a misfire due to excessively rich mixture. But at third load (50%) and fourth load (66.66%) the HC emission reached to the maximum and there after decreased, Because of the availability of oxygen in sufficient quantity. Also it has been observed that the HC emissions with the increase in proportion of plastic oil are lesser than those it petrol. Because of higher viscosity for the plastic oil, this leads to non-participation the amount from fuel in the combustion process .

5. CONCLUSIONS :-

Plastic oil extracted from waste plastic is tested in test engine, single cylinder, 4- stroke spark ignition engine, the performance and emissions were measured on the fuel blend in various additive proportions from plastic oil, as explained in the following conclusions:

1. Plastic oil is obtained from conversion process the waste plastic into industrial fuel used in internal combustion engines by certain proportions with gasoline.
2. It was observed that the proportion of 50% from the plastic oil blend with gasoline has reduced the brake specific fuel consumption (BSFC) by approximately 26% for the full load of the engine compared with the use of 100% gasoline.
3. An increase in brake power by 19.31% for fuel blend at 50% PO for the full load of the engine compared with the gasoline.
4. Brake thermal efficiency increased by 29.2% for 50% PO blends at full load conditions compared with 100% gasoline.
5. NO_x emissions are higher by 1.6 times in 50% PO compared to that from the engine with a 100% gasoline as fuel.
6. CO emissions in 50% PO also are more by 1.7 times compared with the engine which operates at 100% gasoline as fuel.
7. CO_2 emissions in the 50% PO are lesser by 40.7 % compared to the engine which works at sole gasoline.
8. UHC emissions are lesser by 43.58% in case 50% PO compared with the engine fuelled with the 100% Petrol.

Therefore, using of plastic oil proportion with gasoline helps in improved the engine performance and reduced the emissions.

Table 1 Engine Specifications

Make	Greaves (Enfield)
Bore	70 mm
Stroke	66.7mm
B.H.P	3 HP at 3000rpm
Compression ratio	4.67:1
Fuel	Petrol

Table 2 Physical properties of petrol and plastic oil

SI no.	Characteristics	Petrol	Plastic oil
1	Flash point ℃	-	40
2	Fire point ℃	-	44
3	Kinematic Viscosity m^2/sec. @ 40 ℃	0.6 x 10^{-6}	2.64 x 10^{-6}
4	Density kg/m^3	736.8	830
5	Calorific Value kJ/kg	43919	44200

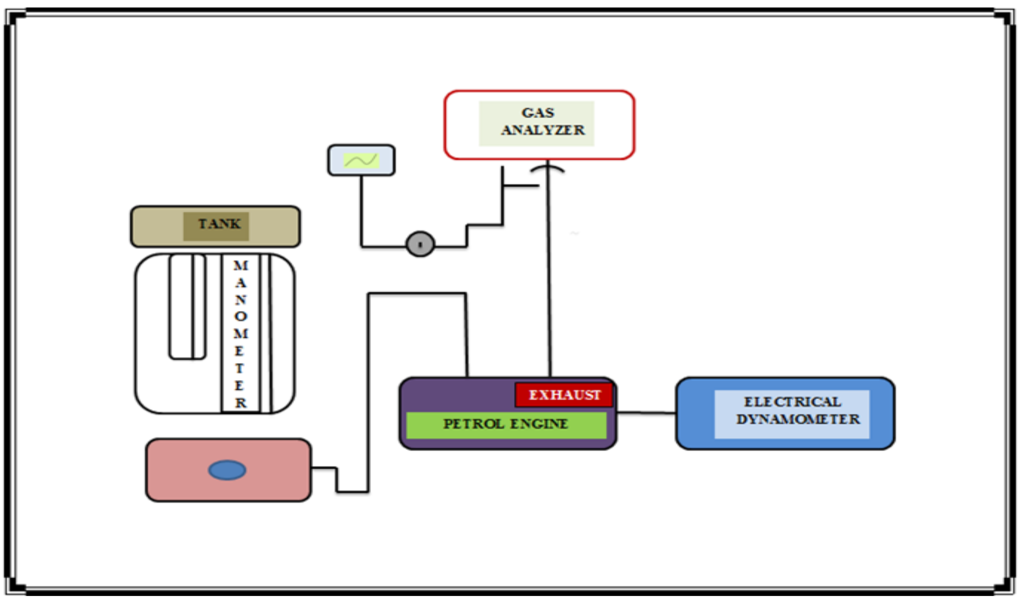

Fig.1 . Schematic Diagram of Experimental Test Rig

Fig.2 . Photographic image of the engine

Fig. 3 . AVL Gas Analyzer

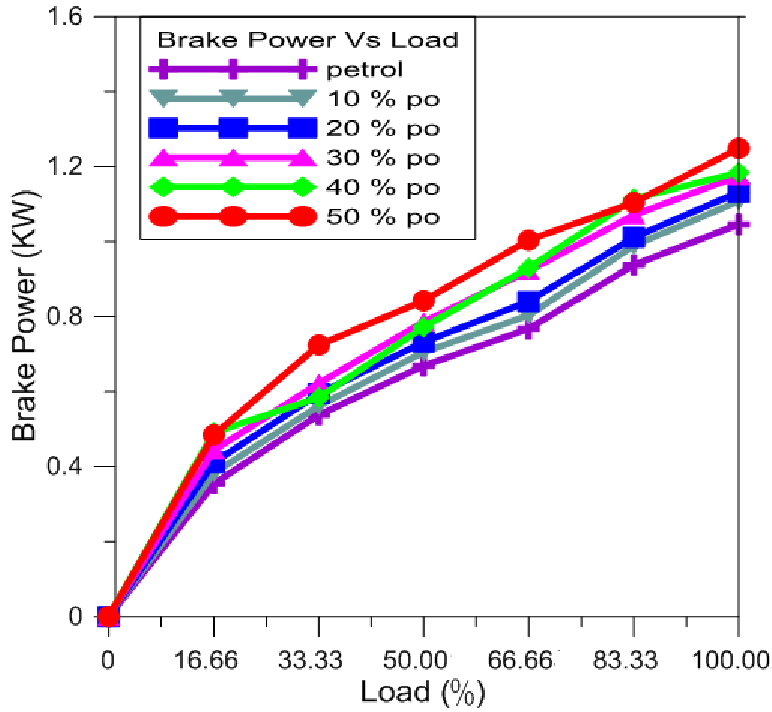

Fig. 4 . Brake Power versus Load

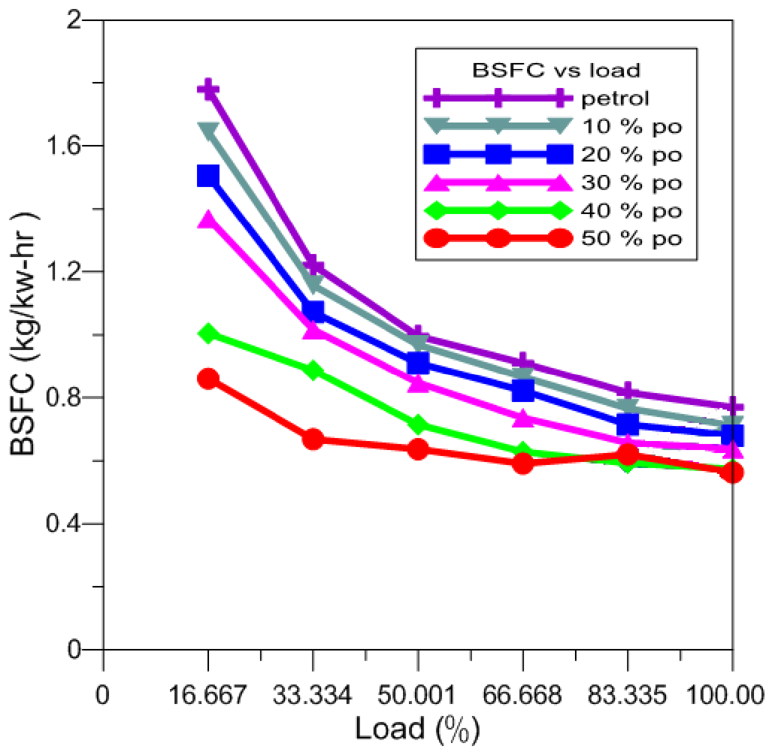

Fig. 5 . BSFC versus load

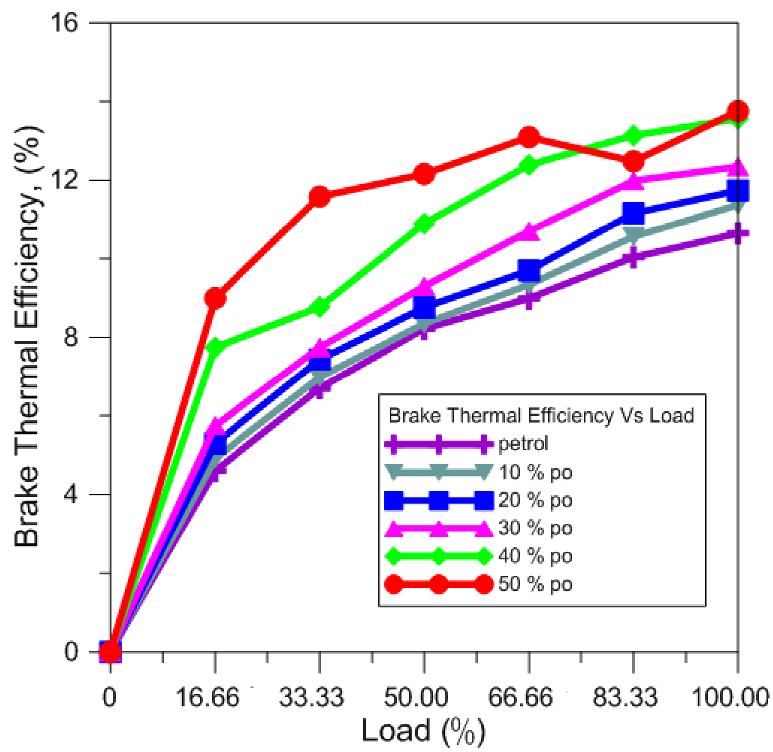

Fig. 6 . Brake Thermal Efficiency versus Load

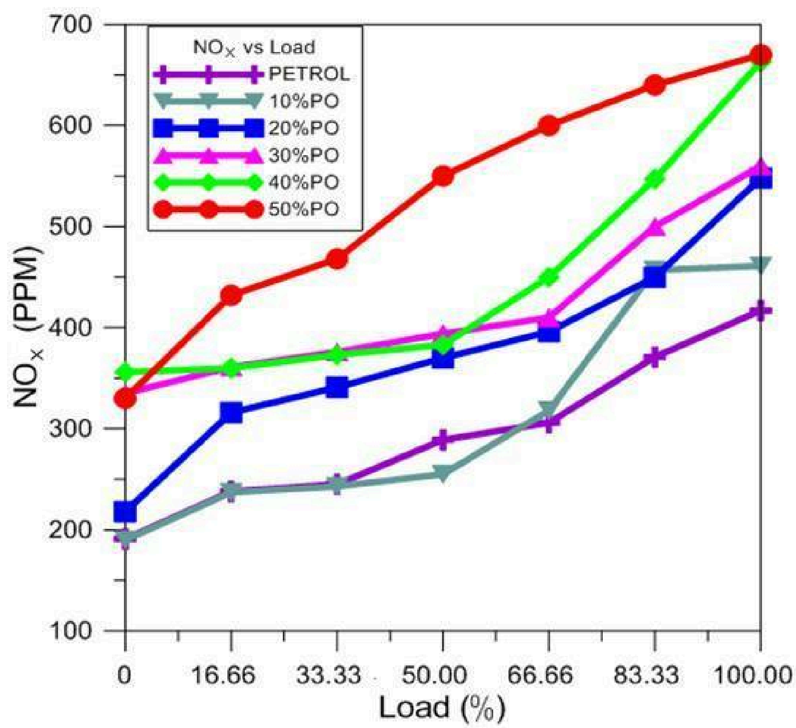

Fig. 7 . NOx (PPM) versus load

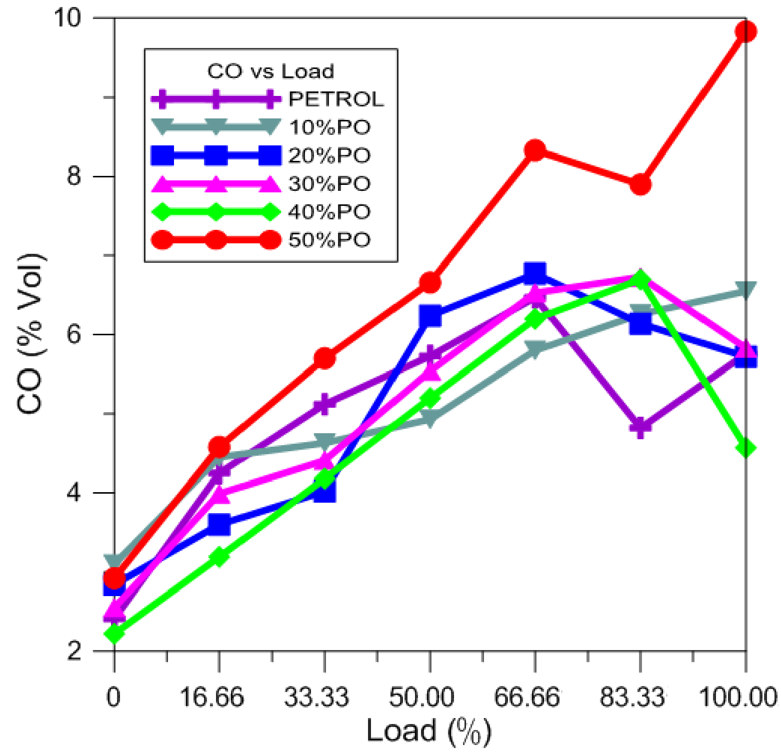

Fig. 8 . CO emissions versus load

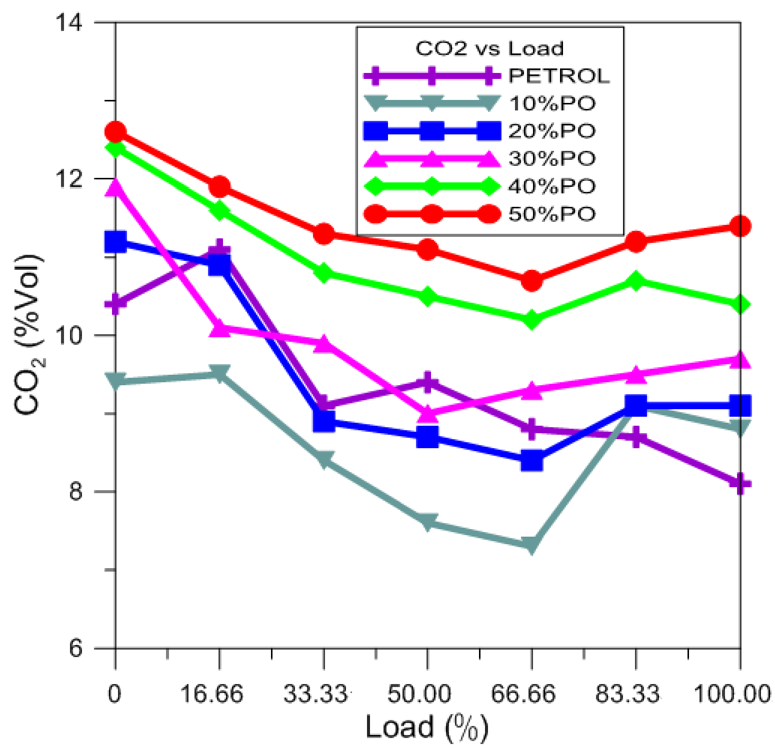

Fig. 9 . CO_2 emissions (% vol) versus load

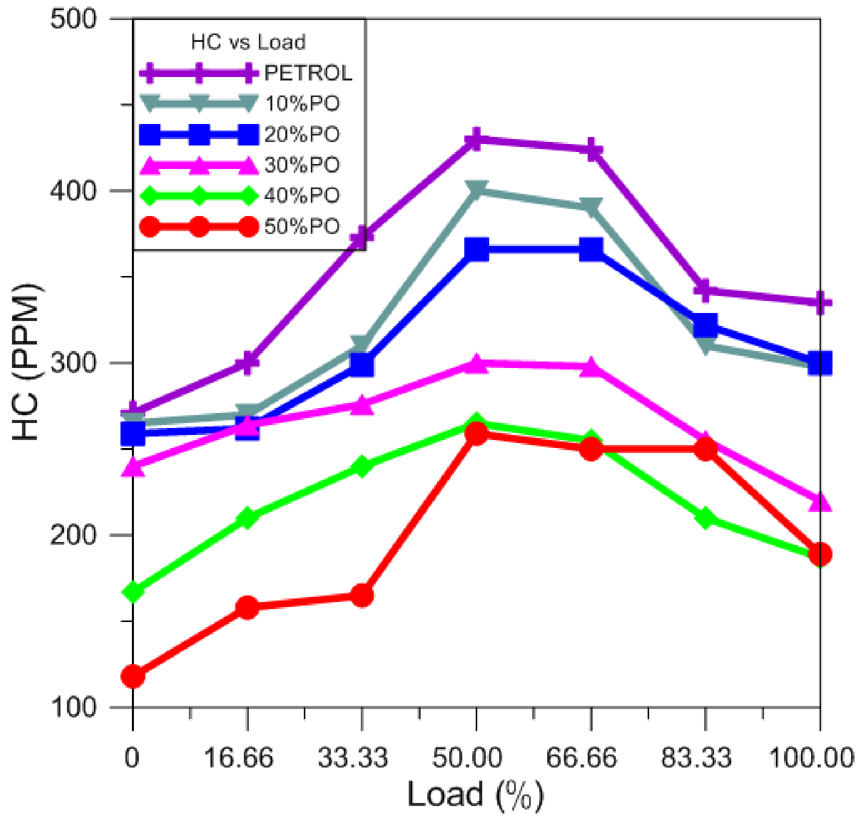

Fig. 10 . HC emissions (PPM) versus load

REFERENCES :-

Anup T J, Vilas Watwe "Waste Plastic Pyrolysis Oil as Alternative For SI and CI Engines" Vol. 3, Issue 7, July 2014.

B.M. Masum , H.H. Masjuki, M.A. Kalam , S.M. Palash, M.A. Wakil, S. Imtenan (2014) "Tailoring the key fuel properties using different alcohols (C2–C6) and their evaluation in gasoline engine" Energy Conversion and Management, vol. 88, pp 382–390.

Dhanapal Balaji, Periyasamy Govindarajan, Jayaraj Venkatesan,(2010) "Emission and combustion Characteristics of SI Engine Working Under Gasoline Blended with Ethanol Oxygenated Organic Compounds" American Journal of Environmental Sciences 6 (6), pp. 495 - 499 .

Diesel, R (1897), Diesel's Rational Heat Motor, Progressive Age Publishing Company.

Kaleemuddin, S. and G.A.P. Rao (2009) "Development of dual fuel single cylinder natural gas engine an analysis and experimental investigation for performance and emission" Am. J. Applied Sci.,vol. 6,pp 929-936.

Palmer, F.H (1986) "Vehicle performance of gasoline containing oxygenates" Proceeding of the paper C319/86, International Conference on Petroleum Based Fuels and Automotive Applications, ICPBFA'86, I. Mech. E. Conference, London, pp36-46.

Pruksathorn, P and T. Vitidsant (2009) "Production of pure ethanol from azeotropic solution by pressure swing adsorption" Am. J. Eng. Applied Sci., vol.2, pp 1-7.

Semin, A.R. Ismail and R.A. Baskar, (2009) "Combustion temperature effect of diesel engine convert to compressed natural gas engine" Am. J.Eng. Applied Sci.,vol.2, pp 212-216.

Shehata, M. S, Abdel Razek, S. M. (2008) "Engine Performance Parameters and Emissions Reduction Methods for Spark Ignition Engine" Engineering Research Journal, 120, M32 – M57.

Sudhir Kumar.J (2013) "Performance and Emission Characteristics of Spark Ignition Engine Fuelled With Plastic Petrol Derived From Waste Plastic".

Sudhir Kumar.J*., Ravi.K, Satyanarayana.D, Venkata Subbaiah.K , V.V.Prasada Rao.P (2012) "Experimental studies on a SI engine using Plastic Petrol derived from Waste Plastic" Vol.2, No.2.

Viswanath K. Kaimal*, P. Vijayabalan (2015) "A detailed study of combustion characteristics of a DI diesel engine using waste plastic oil and its blends" Energy Conversion and Management Vol. 105, pp. 951–956.