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Performance and Emission Analysis of Plastic Synthetic Oil

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Abstract:- The discovery of plastic has revolutionized our society by introducing an enormous and expanding range of products. We use plastic in numerous ways, but plastic has its disadvantages. Plastic is one of the biggest litter issues not only in India but also in the world. As far as Plastic waste management in India (1960-2015) is concerned, there are nearly about 2,50,00,000 Tons of plastic which is not been recycled and is thrown in the landfills. Hence there is a tremendous need to convert plastic into biodegradable products or in any form of energy. The price of biodegradable plastic products is higher than their synthetic plastic counterparts. Hence, the efficient way to handle plastic category of waste is to convert it into any form of energy.

Both plastics and petroleum are derived fuels of hydrocarbons that contain the element chain of carbon and hydrogen .The difference between them is the plastic molecule have longer carbon chains than those in LPG, petrol and diesel fuels. Therefore it is possible to convert waste plastic into fuel.

Currently there are two existing methods: Catalytic degradation and Pyrolysis process. This processes are economical, and do not emit any hazardous gases as well as the conversion rate (efficiency) is on higher side whereas its byproducts can be used in our day today life. The plastic synthetic oil obtained after this experimentation is thoroughly tested and analyzed for concluding the performance and emission characteristics of the oil.

Keywords:- *Plastic Waste Management, Biodegradable Plastic, Catalytic Degradation, Pyrolysis, Performance And Emission Characteristics.*

I. INTRODUCTION

The present rate of economic growth is unsustainable without saving of fossil energy like crude oil, natural gas or coal. International Energy Outlook 2010 reports that the world consumption of liquid and petroleum products grows from 186.1 million barrels per day in 2007 to 92.1 million barrels per day in 2020 and 110.6 million barrels per day in 2035 and natural gas consumption increases from 108 trillion cubic feet in 2007 to 156 trillion cubic feet in 2035. This way, the oil and gas reserve available can meet only 167 years further. Thus mankind has to rely on the alternate/renewable energy sources like biomass, hydropower, geothermal energy, wind energy, solar energy, nuclear energy, etc. Waste plastic to liquid fuel is also an alternate energy source path, which can contribute to depletion of fossil fuel as in this process liquid. Various technologies have been developed in order to extract fuel with similar properties as that of existing fuels. Before looking at the process options for the conversion of plastic into oil products, it is worth considering the characteristics of these two materials, to identify where similarities exist, and the basic methods of conversion. The principal similarities are that they are made mostly of carbon and hydrogen, and that they are made of molecules that are formed in chains of carbon atoms. Crude oil is a complex mixture of hydrocarbons, which are separated and purified by distillation and other processes at an oil refinery. The majority of the crude oil is used for the production of fuels for transportation, heating and power generation. These oil products are not single components, but are a blend of components used to meet the relevant fuel specifications in the most economic manner, given the composition of the crude oil and the configuration of the oil refinery. These components have a wide range of chain lengths: gasoline has compounds with a chain length of between three and 10 carbon atoms, and diesel has compounds with a chain length of between five and 18 carbon atoms, but both contain only hydrogen and carbon. So here the best alternative for efficient plastic waste management is considered and pyrolysis process is selected for experimentation.

II. OBJECTIVES

The objectives of this project is to encourage plastic waste management by converting waste dead plastic into useful form of energy. To create an efficient, cheaper and eco-friendly alternative fuel for existing fuels like petrol and diesel. To design a system or a special purpose machine for converting the waste dead plastic into fuel. To protect the health and wellbeing of people by providing an affordable waste conversion service and to reduce the dependency on gulf countries for fossil fuels, thereby contributing to the Economic growth of the country. At last the objective is to check and analyze whether the extracted plastic synthetic oil meets up the performance and emissions requirements.

III. METHOD & PROCEDURE

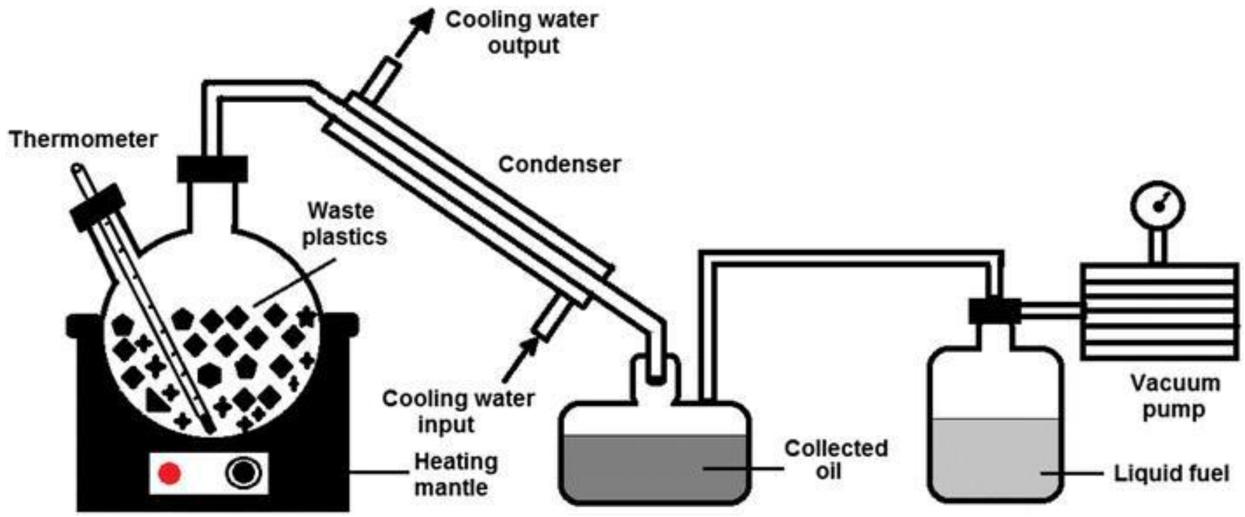

Fig. 1:- Pyrolysis Process.

Pyrolysis is generally defined as the controlled heating of a material in the absence of oxygen. In plastics Pyrolysis, the macromolecular structures of polymers are broken down into smaller molecules and sometimes monomer units. Further degradation of these subsequent molecules depends on a number of different1conditions including (and not limited to) temperature, residence time, presence of1catalysts and other process conditions. The Pyrolysis reaction can be carried out with or without the presence of catalyst. Accordingly, the reaction will be thermal and catalytic pyrolysis. Plastic waste is continuously treated in a cylindrical chamber. The plastic is heated at 300°C to 500°C. The pyrolysis is a simple process in which the organic matter is subjected to higher temperature. About 300°C to 500°C in order to promote thermal cracking of the organic matter so as to obtain. The end products in the form of –liquid, char and gas in absence of oxygen. After heating the waste plastic at a temperature of about 300°C to 500°C in the reactor the gas is allowed to escape through the outlet dipped into the water containing jar so as to condense the fumes to obtain the raw fuel floating over the surface. Once the raw fuel is obtained it is further subjected to distillation process so as to obtain the fuel i.e. diesel in its pure form by removing the impurities present in it which can be then tested into diesel engines for its efficiency.

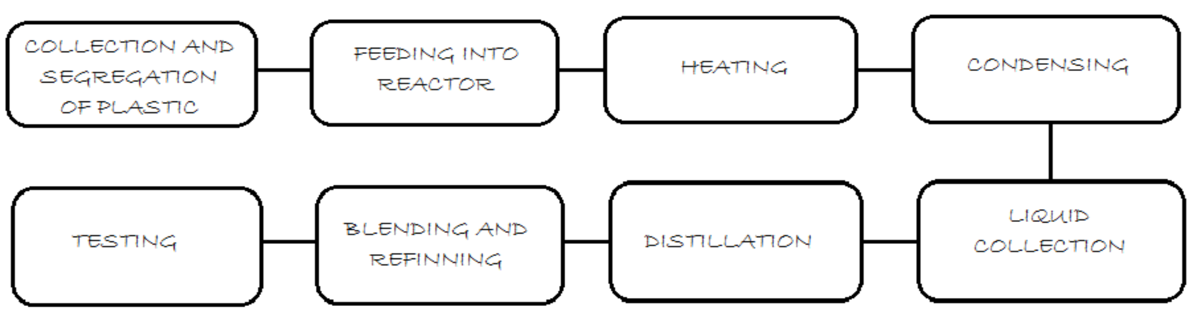

Fig. 2:- Laboratory process.

A. *Collection and Segregation of plastic waste:*

The plastic waste is collected from different sources such as household, hotels, market etc. and separated on the basis of their types. The plastics can be separated as PET, HDPE, LDPE, polypropylene, etc. After the separation, plastic is cleaned to remove any impurities like dust, dirt, with the help of soap water. The plastic is then dried in the sun to remove the moisture present and crushed into small powder.

B. *Feeding into Reactor:*

Once the waste plastic is crushed into small powder, the next step is feeding into the reactor. The reactor is made from Round bottom glass flask. The flange is opened and plastic powder is fed into the reactor and the flange is closed again. It is necessary to prevent any leakage in the reactor. Hence, rubber cork is provided for that. However, rubber cork should be able to sustain high temperature else it will burn out.

C. Heating:

An electric heating mantle, which has capacity of 300 W is used to heat the reactor. An induction coil is used as heating element and power supply is 230V, 50Hz AC. A thermometer and controller are used to record and maintain the required temperature. The heater can reach the temperature up to 300°C within 15 minutes and the thermometer and controller can record temperature up to maximum of 450°C.

D. Condensing:

The plastic waste gets evaporated at temperature 300-350°C. This vapor is condensed to atmospheric temperature by using tube condenser.

E. Liquid Collection:

The vapor coming out of condenser is condensed and passed through vacuum bend, wherein gases present and the liquid oil are separated. Once the oil stops coming from the condenser, the oil is collected in the flat bottom flask and the gas is collected in gas container.

F. Distillation:

Once the fuel is collected, the oil is distilled to increase purity. For this, a sample of oil is taken in a round bottom flask and heated to about 70°C, according to its density variation the oil is categorized as petrol and diesel. Thus the fuel with better properties is achieved.

G. Blending and Refining:

Once the distilled fuel is obtained. The distilled fuel is refined to increase the purity and remove the impurities present in the oil. It is further blended with the existing fuel i.e. petrol or diesel in proportion of 50:50.

H. Testing:

The oil sample is finally taken to laboratories for testing its properties like density, calorific value, flash point, fire point, viscosity, etc. The test is carried out for different samples before coming to final result.

IV. PLASTIC OIL TEST RESULTS

Sr. No.	Test Parameters	Unit	Plastic Oil
1	Gross Calorific Value	K.Cal/Kg	10800
2	Moisture	% by mass	0.21
3	Sulphur	% by mass	0.12
4	Flash Point	ºC	28
5	Pour Points	ºC	24
6	Total Sediments	% by mass	0.087
7	Specific gravity at 15ºC	-	0.8047
8	Viscosity at 50ºC	cSt	2.56
9	Density at 15ºC	g/c.c	0.8013
10	Ash content	% by mass	Nil

Table 1:- Plastic oil test results.

V. RESULTS AND DISCUSSIONS

After extracting the oil from the dead plastic waste. The limitations in fuel resulted in blending of the plastic diesel and plastic fuel with the standard in the amount of 50:50. These blended fuel where tested at Apex Innovations Pvt. Ltd. Sangli. These tests were taken on Petrol and Diesel engines for various compression ratios and also on the smoke and exhaust analyzer. Following are the engine specifications on which the tests were conducted:

- IC Engine set up under test is Research Diesel having power 3.50 kW @ 1500 rpm which is 1 Cylinder, Four stroke, Constant Speed, Water Cooled, Diesel Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm), Connecting Rod length 234.00(mm), Swept volume 661.45 (cc).

- *Combustion Parameters:*

Specific Gas Const (kJ/kgK): 1.00, Air Density (kg/m^3): 1.17, Adiabatic Index: 1.41, Polytrophic Index: 1.09, Number of Cycles: 10, Cylinder Pressure Reference: 4, Smoothing 2, TDC Reference: 0

- *Performance Parameters:*

Orifice Diameter (mm): 20.00, Orifice Coeff. Of Discharge: 0.60, Dynamometer Arm Length (mm): 185, Fuel Pipe dia (mm): 12.40, Ambient Temp. (Deg C): 27, Pulses Per revolution: 360, Fuel Type: Diesel, Fuel Density (Kg/m^3): 830, Calorific Value of Fuel (kj/kg): 42000

- IC Engine set up under test is Research Petrol having power 4.50 kW @ 1800 rpm which is 1 Cylinder, Four stroke , Variable Speed, Water Cooled, Petrol Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm), Connecting Rod length 234.00(mm), Swept volume 661.45 (cc).

➢ *Combustion Parameters:*

Specific Gas Const (kJ/kgK): 1.00, Air Density (kg/m^3): 1.17, Adiabatic Index: 1.41, Polytrophic Index: 1.05, Number of Cycles: 10, Cylinder Pressure Reference: 4, Smoothing 2, TDC Reference: 0

➢ *Performance Parameters:*

Orifice Diameter (mm): 20.00, Orifice Coeff. Of Discharge: 0.60, Dynamometer Arm Length (mm): 185, Fuel Pipe dia (mm): 14.50, Ambient Temp. (Deg C): 27, Pulses Per revolution: 360, Fuel Type: Petrol, Fuel Density (Kg/m^3): 720, Calorific Value of Fuel (kj/kg): 35000.

The results obtained from this engines are depicted in the graphs below:

❖ *Compression Ratio: 16*

➢ *Comparison of diesel emissions:*

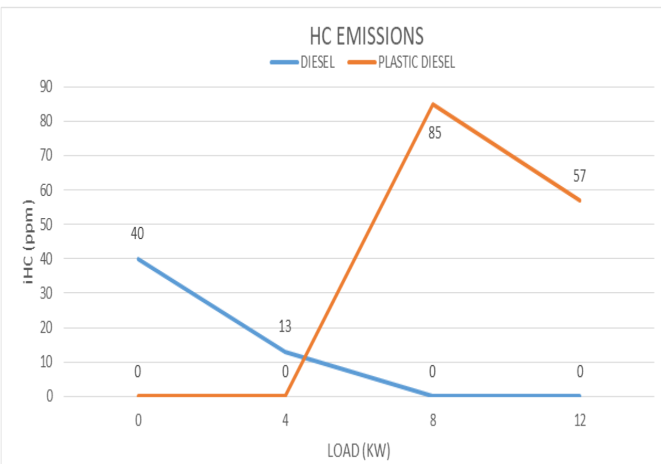

Fig. 3:- Diesel HC emissions.

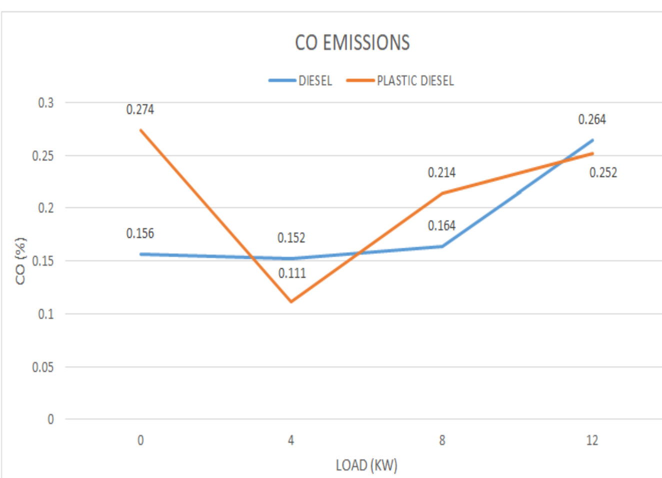

Fig. 4:- Diesel CO emissions.

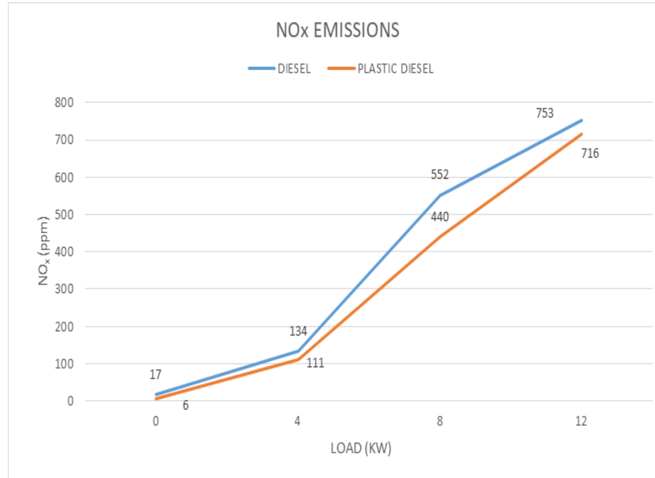

Fig. 5:- Diesel NO_x emissions.

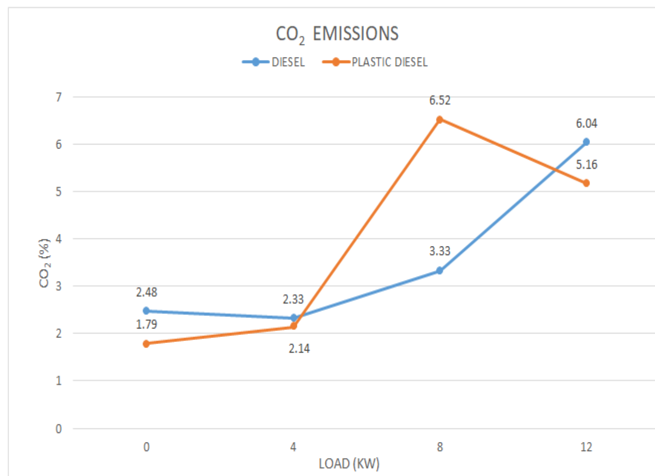

Fig. 6:- Diesel CO_2 emissions.

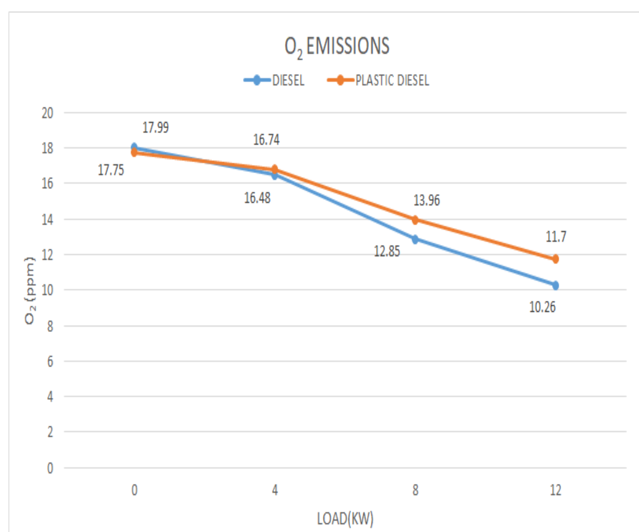

Fig. 7:- Diesel O_2 emissions.

➢ *Comparison of Performance on Diesel Engine: (CR16)*

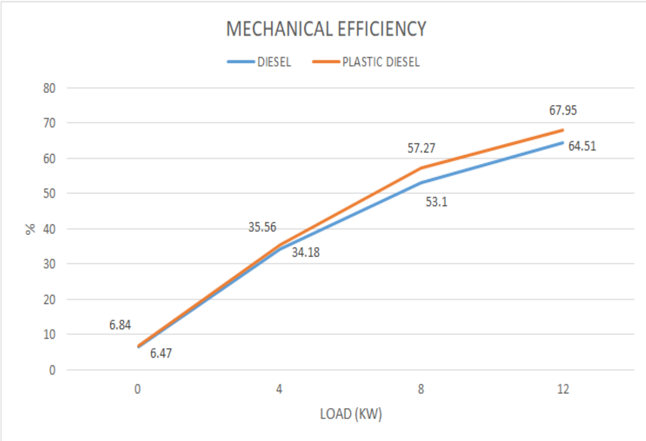

Fig. 8:- Diesel mechanical efficiency.

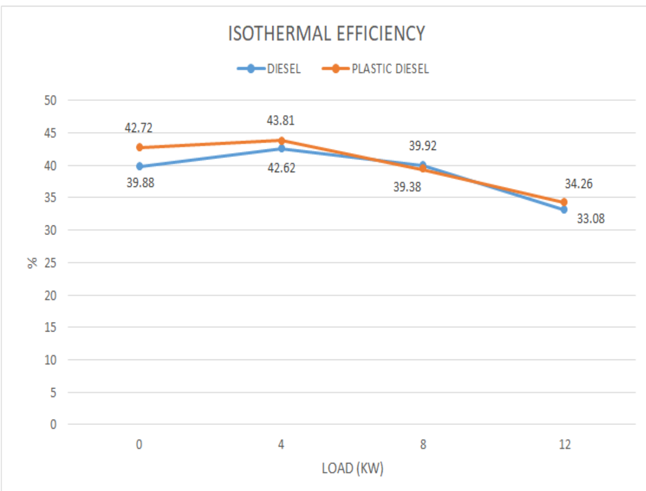

Fig. 9:- Diesel isothermal efficiency.

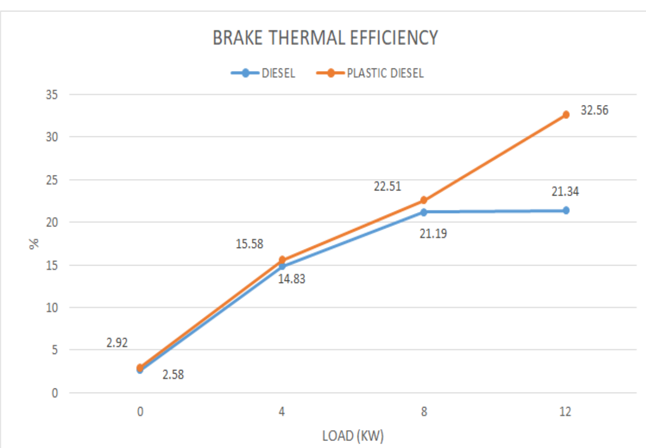

Fig. 10:- Diesel brake thermal efficiency.

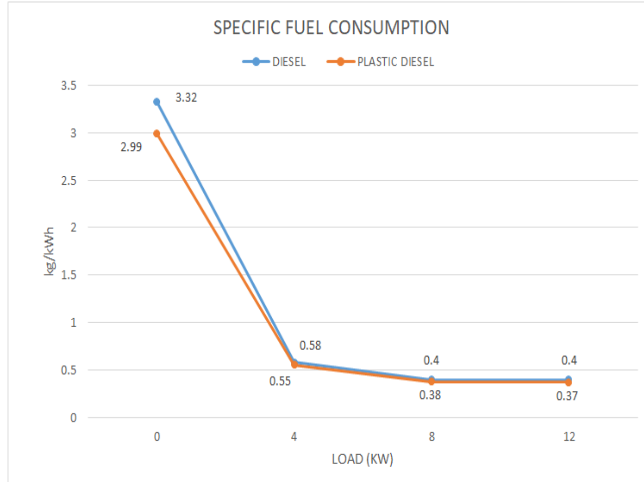

Fig. 11:- Diesel specific fuel consumption.

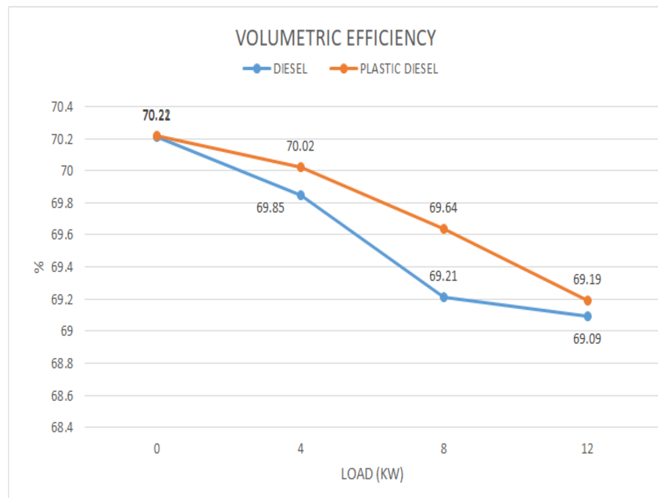

Fig. 12:- Diesel volumetric efficiency.

➢ *Compression Ratio: 18*

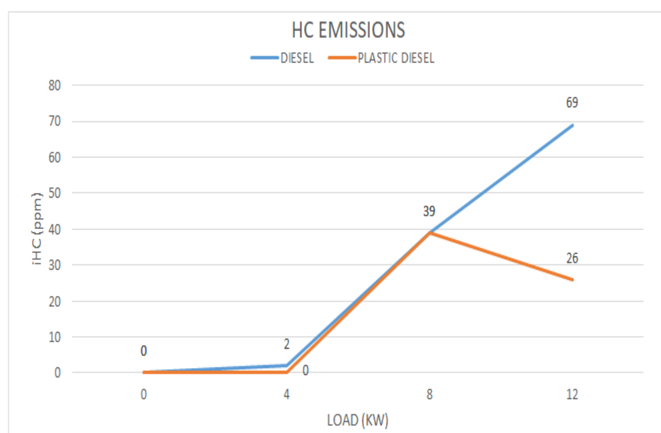

Fig. 13:- Diesel HC emissions.

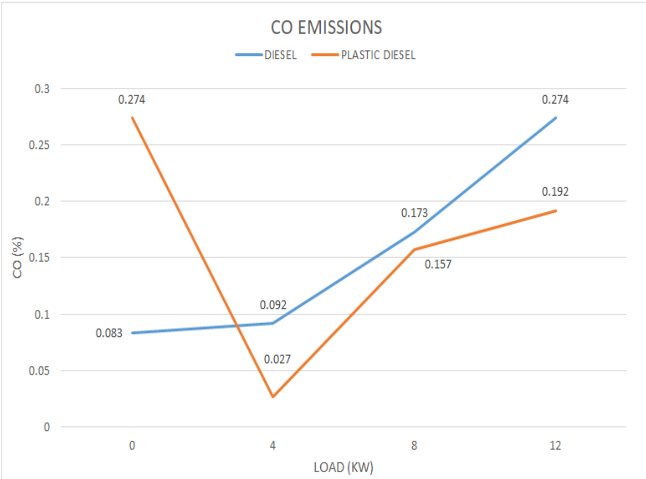

Fig. 14:- Diesel CO emissions.

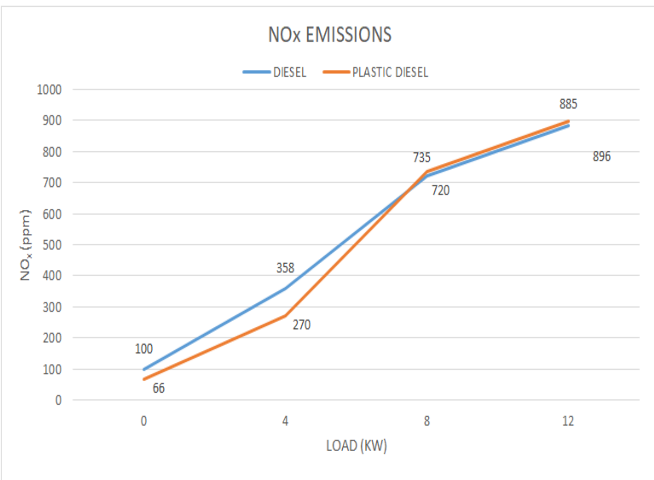

Fig. 15:- Diesel NO_x emissions.

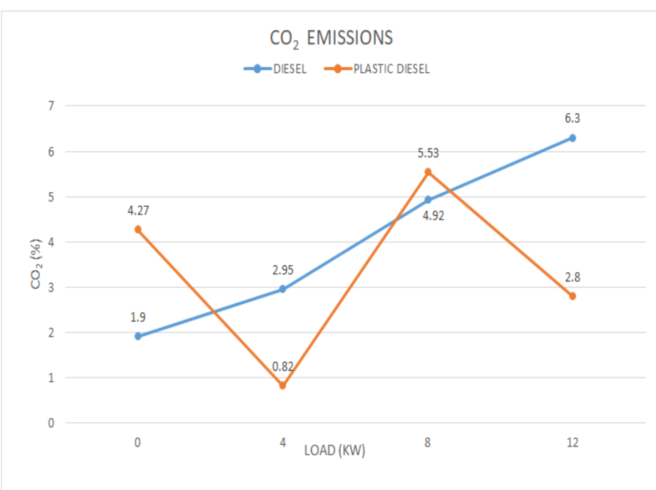

Fig. 16:- Diesel CO_2 emissions.

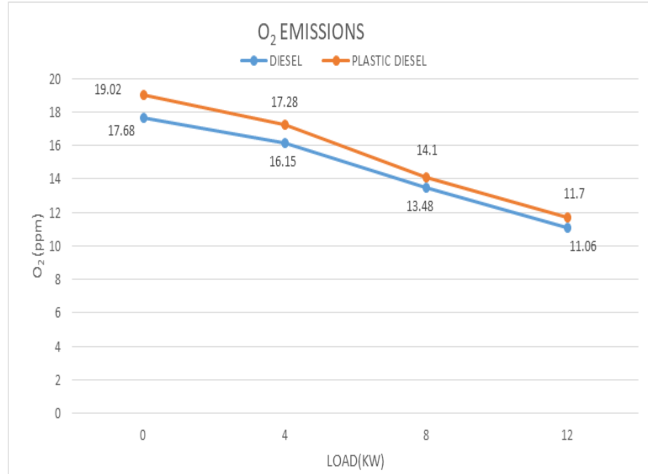

Fig. 17:- Diesel O_2 emissions.

➢ *Comparison of performance on Diesel Engine: (CR18)*

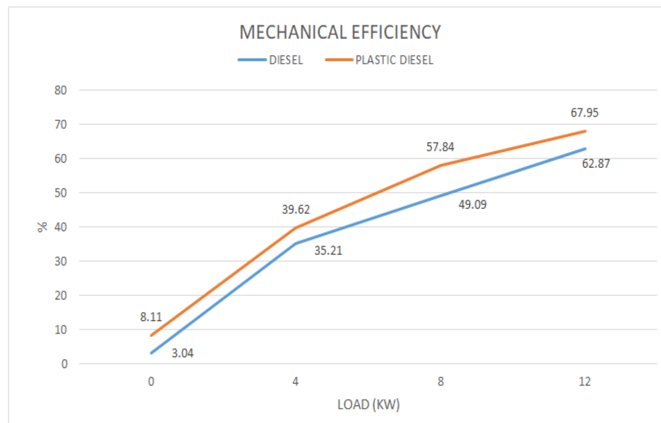

Fig. 18:- Diesel mechanical efficiency.

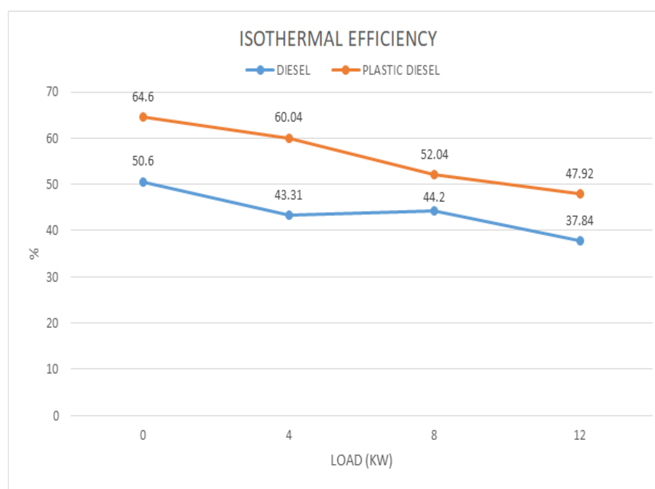

Fig. 19:- Diesel isothermal efficiency.

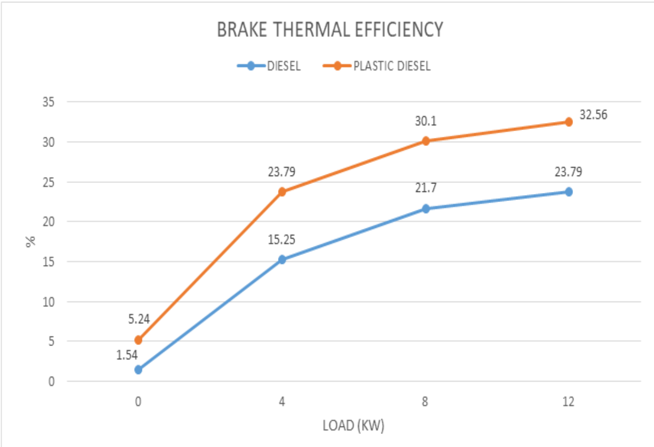

Fig. 20:- Diesel brake thermal efficiency.

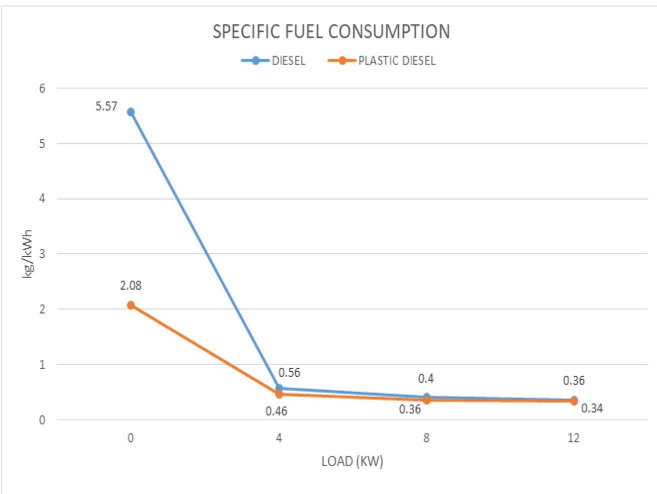

Fig. 21:- Diesel specific fuel consumption.

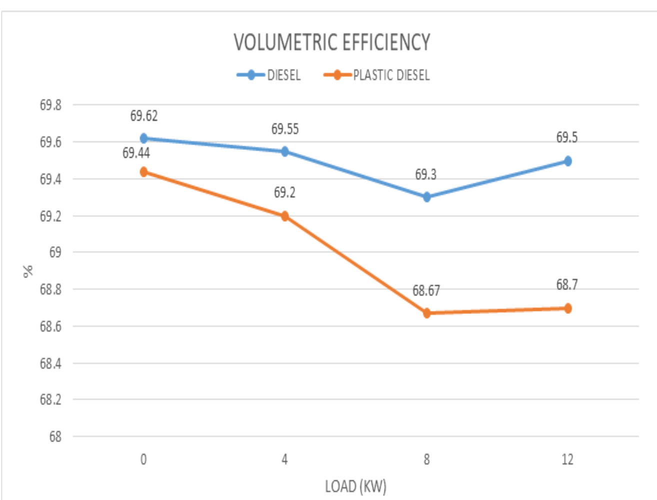

Fig. 22:- Diesel volumetric efficiency.

➢ *Compression Ratio: 9*

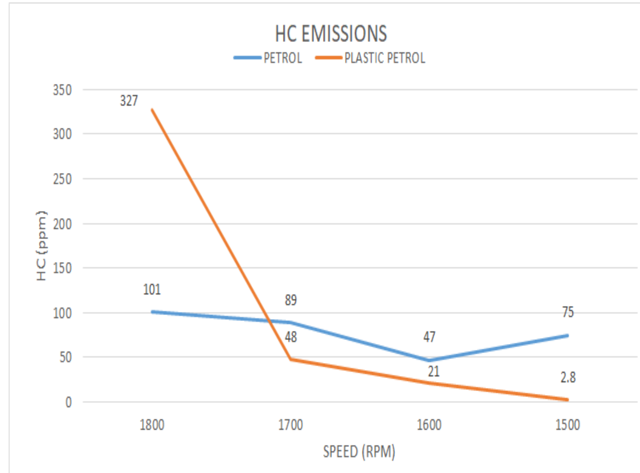

Fig. 23:- Petrol HC emissions.

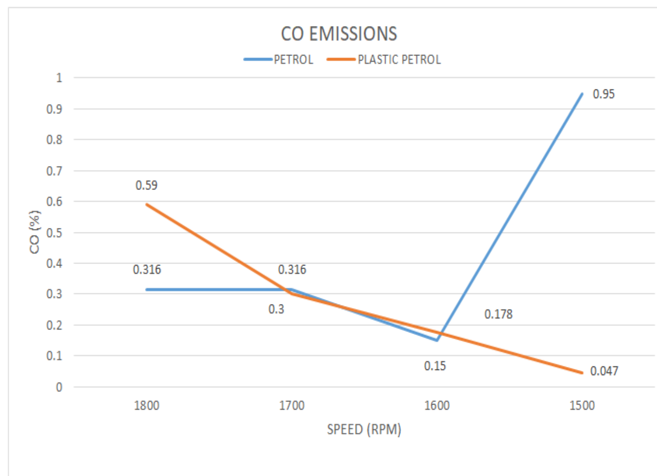

Fig. 24:- Petrol CO emissions.

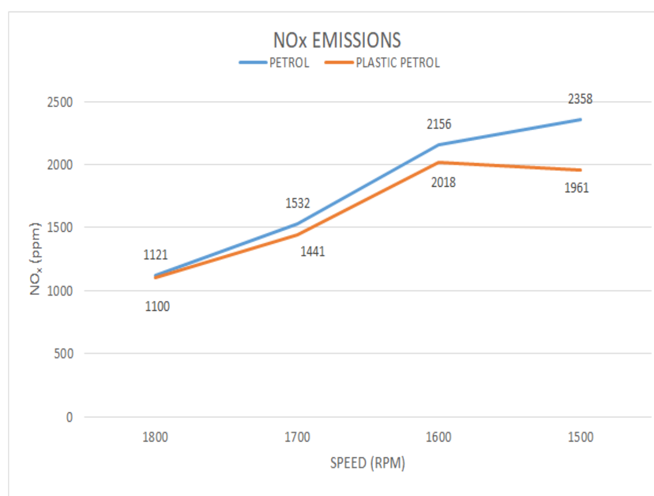

Fig. 25:- Petrol NO_x emissions.

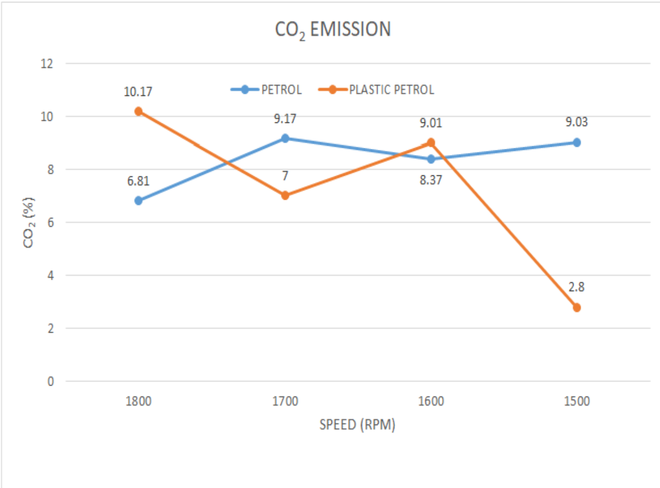

Fig. 26:- Petrol CO_2 emissions.

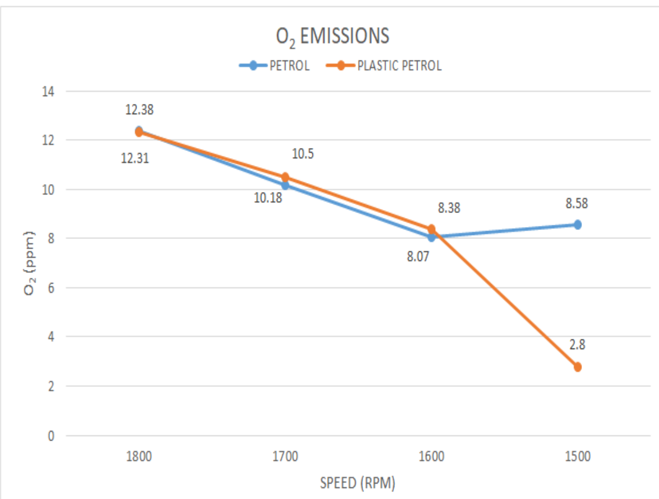

Fig. 27:- Petrol O_2 emissions.

➢ *Comparison of Performance on Petrol Engine: (CR9)*

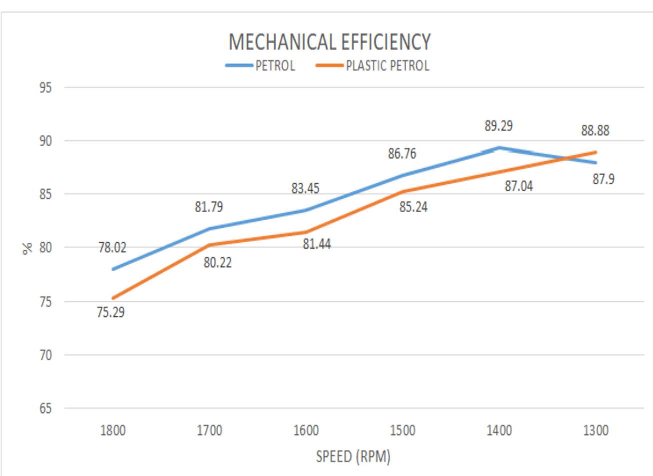

Fig. 28:- Petrol mechanical efficiency.

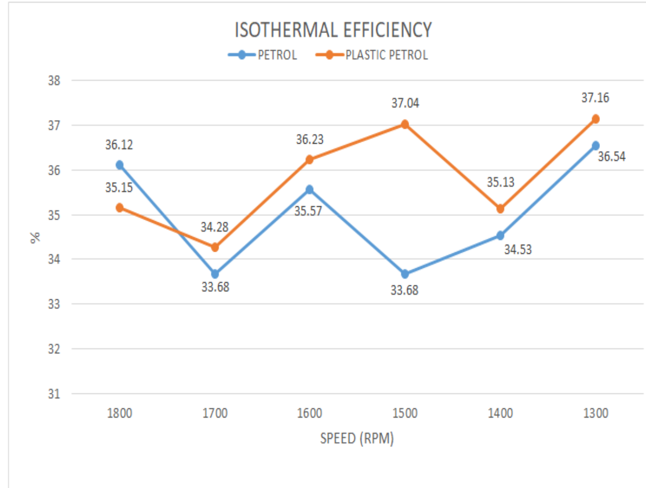

Fig. 29:- Petrol isothermal efficiency.

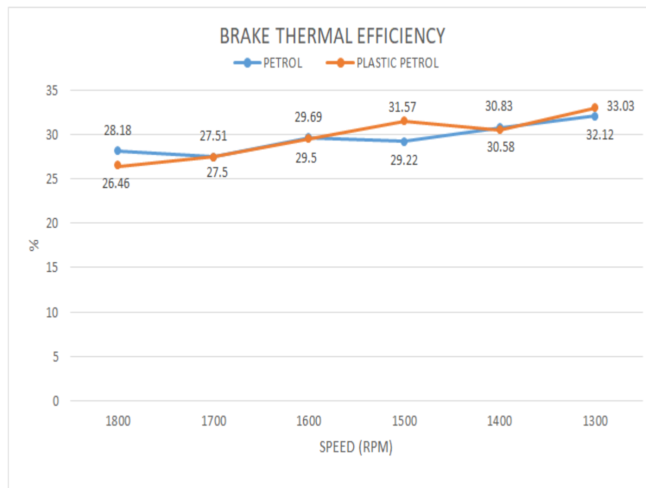

Fig. 30:- Petrol brake thermal efficiency.

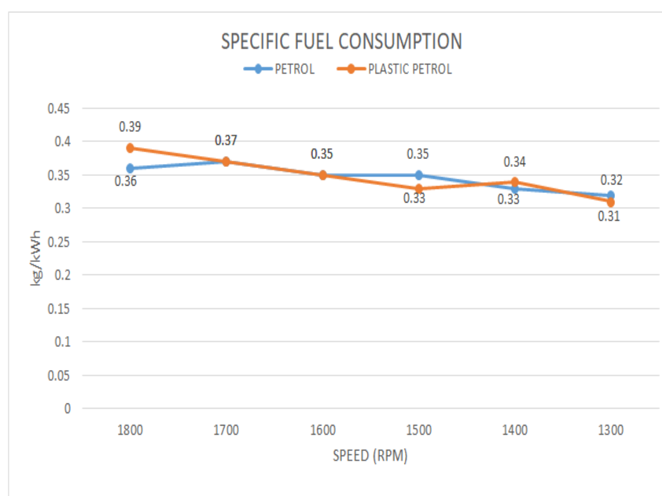

Fig. 31:- Petrol specific fuel consumption.

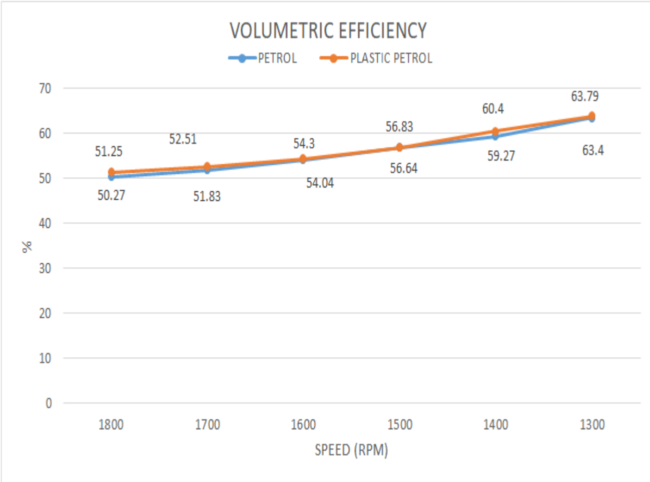

Fig. 32:- Petrol volumetric efficiency.

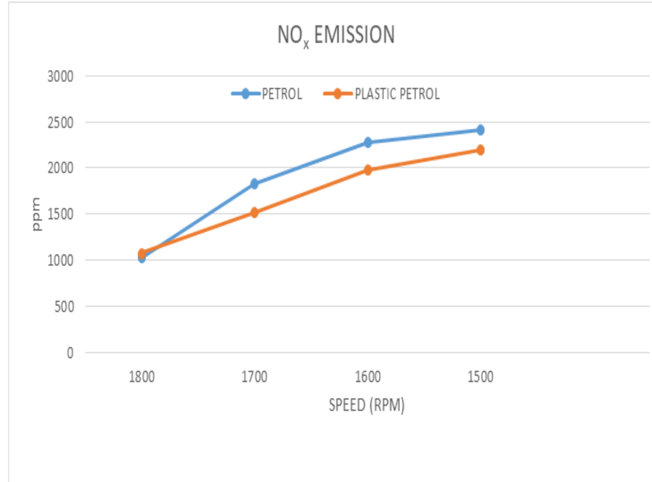

Fig. 35:- Petrol NO_x emissions.

➢ *Compression Ratio: 10*

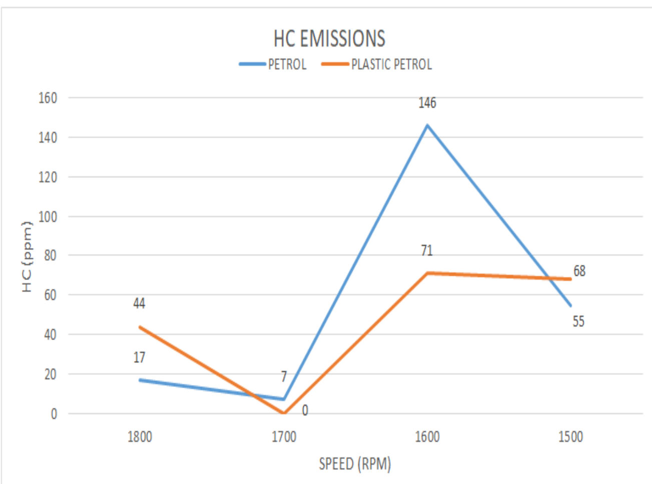

Fig. 33:- Petrol HC emissions.

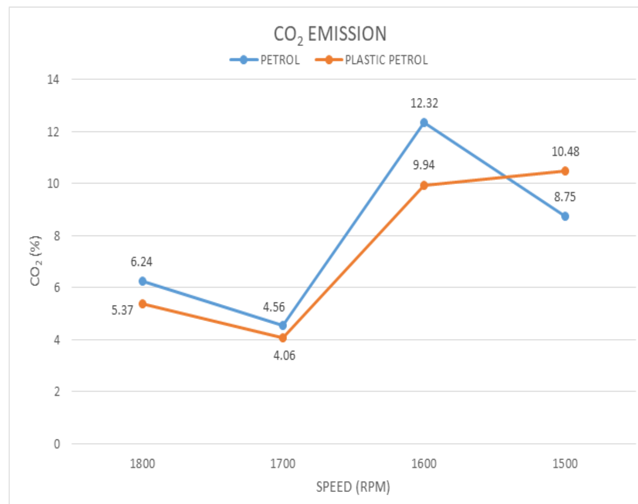

Fig. 36:- Petrol CO_2 emissions.

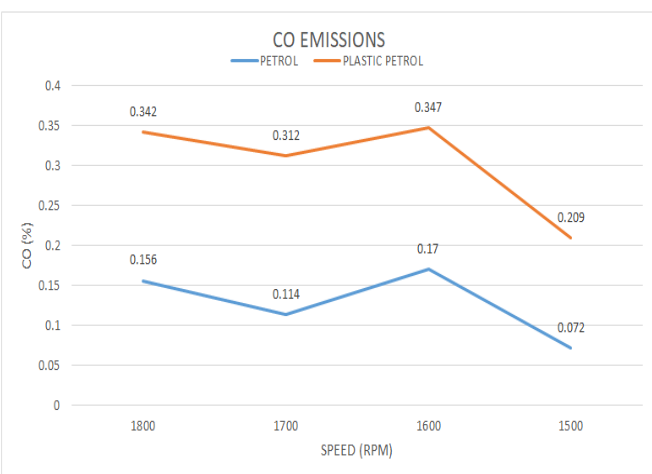

Fig. 34:- Petrol CO emissions.

Fig. 37:- Petrol O_2 emissions.

➢ *Comparison of Performance on Petrol Engine: (CR10)*

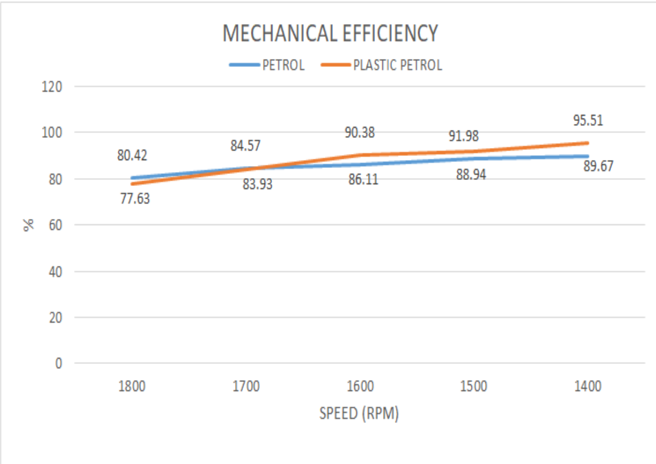

Fig. 38:- Petrol mechanical efficiency.

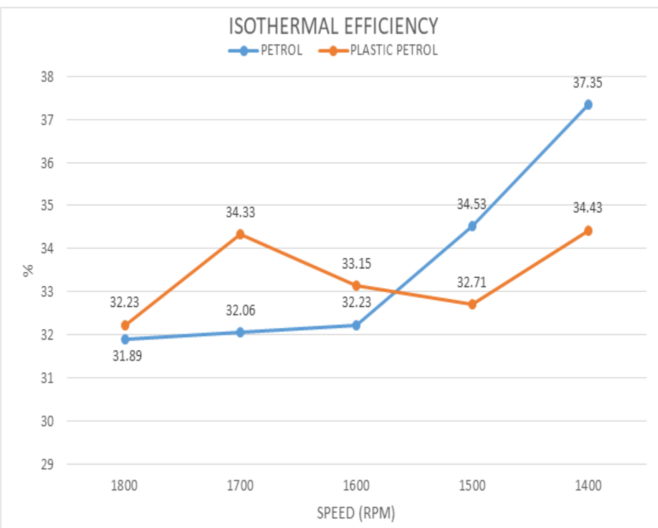

Fig. 39:- Petrol isothermal efficiency.

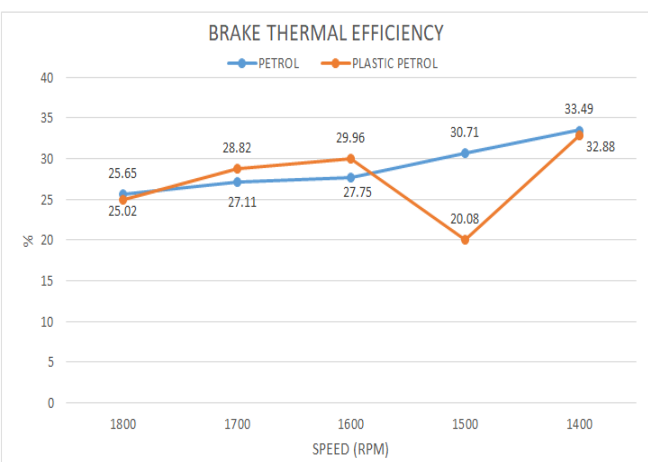

Fig. 40:- Petrol brake thermal efficiency.

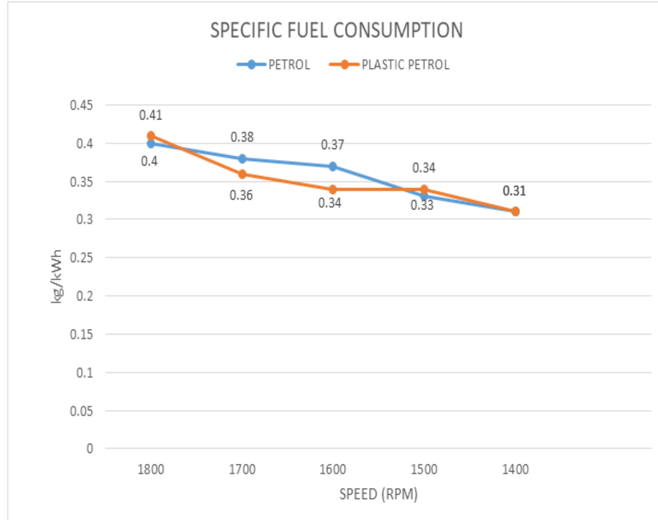

Fig. 41:- Petrol specific fuel consumption.

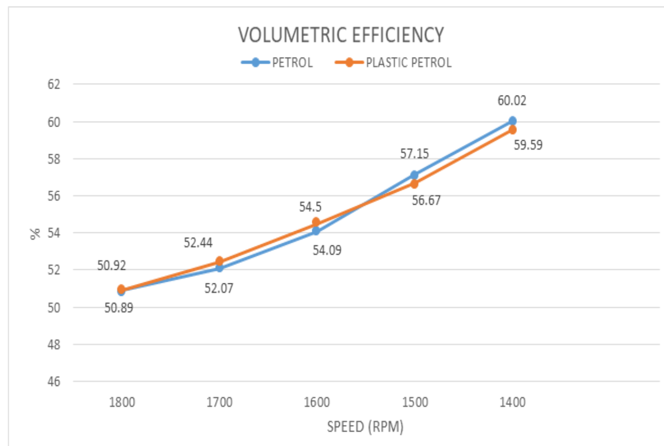

Fig. 42:- Petrol volumetric efficiency.

CONCLUSION

Plastic bears a major threat to the current scenario and the environment. Millions of tons of plastics are produced on the daily basis and only few percentage of the waste plastic are being successfully recycled. Since, plastic takes long years to decompose, some alternative to plastic should be developed. Also, the world is facing the problem of shortage of petroleum. Therefore, conversion of waste plastic into fuel can provide a better solution to the disposal problem of waste plastic as well as act as an alternative to fossil fuel. However, the output varies depending on the type of plastic used. Also, the plastic fuel showed properties similar to that of diesel fuel. Hence, we can conclude that pyrolysis of plastic into fuel can solve both the problem of plastic waste management as well as shortage of fossil fuel if plant is set up at the commercial level. This project has lot many future applications and scope, which are listed below:

1. Oil extracted from the system can be used as alternative fuel for the engines, generators etc. Harmful effect due to plastic deposition on environment can be reduced.
2. The obtained fuel could be utilized in diesel generators, vehicles such as tractors and also passenger vehicles such as cars.
3. The application of this project could help in reducing the dependency on the gulf countries and promote a step towards innovation.
4. The fuel has to be refined at the industrial establishments, based on the results of which small scale industry can be established.
5. As there is a high demand of crude oil and due to its sky reaching prices, we could take up this project to setup large or small scale industries and produce the fuel locally at much cheaper rates directly benefiting the National economy and also a step towards SWAACH BHARAT by recycling the waste plastic.

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