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A Review of Plastic Oil in IC Engine

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ABSTRACT: Over 1.3 billion metric ton of plastic is being manufactured every year to meet the demands of modern world. Plastic is made by polymerization of hydrocarbons. These hydrocarbons are of typically high molecular mass and may contain some other additives to enhance the capabilities of the final product. Plastic is an important material which is strong, durable, and cheap and has numerous other properties. Disposal of waste plastic is of great concern for everybody as it takes decades to decompose if left as its own. On the other hand, continuous increase in industrialization and urbanization has created measurable rise in demand of fuels. Nowadays it has become the need to seek the alternate energy source on the place of conventional fuels. In this scenario, conversion of plastic to fuel is a hope to solve both the problems. Pyrolysis is a process which involves thermochemical decomposition of organic matter at high temperature (>370C) in the absence of oxygen. Products of this process are pyrolysis oil, carbon black, and hydrocarbons. This review paper is focusing the most efficient and widely used method of converting plastics to fuels: 'pyrolysis' and its effectiveness on resolving the both issues of waste plastic management and the requirement and the requirement of a good alternative fuel for use.

I. INTRODUCTION

The Diesel engine (also known as a compression-ignition or CI engine), named after Rudolf Diesel, is an internal combustion engine in which ignition of the fuel, which is injected into the combustion chamber, is caused by the elevated temperature of the air in the cylinder due to the mechanical compression (adiabatic compression). Diesel engines work by compressing only the air. This increases the air temperature inside the cylinder to such a high degree that atomized Diesel fuel injected into the combustion chamber ignites spontaneously. With the fuel being injected into the air just before combustion, the dispersion of the fuel is uneven; this is called a heterogeneous air-fuel mixture. The process of mixing air and fuel happens almost entirely during combustion, the oxygen diffuses into the flame, which means that the Diesel engine operates with a diffusion flame. The torque a Diesel engine produces is controlled by manipulating the air ratio; this means, that instead of throttling the intake air, the Diesel engine relies on altering the amount of fuel that is injected, and the air ratio is usually high.

The Diesel engine has the highest thermal efficiency (engine efficiency) of any practical internal or external combustion engine due to its very high expansion ratio and inherent lean burn which enables heat dissipation by the excess air. A small efficiency loss is also avoided compared to two-stroke non-direct-injection gasoline engines since unburned fuel is not present at valve overlap and therefore no fuel goes directly from the intake/injection to the exhaust. Low-speed Diesel engines (as used in ships and other applications where overall engine weight is relatively unimportant) can reach effective efficiencies of up to 55%.

Diesel engines may be designed as either two-stroke or four-stroke cycles. They were originally used as a more efficient replacement for stationary steam engines. Since the 1910s they have been used in submarines and ships. Use in locomotives, trucks, heavy equipment and electricity generation plants followed later. In the 1930s, they slowly began to be used in a few automobiles. Since the 1970s, the use of Diesel engines in larger on-road and off-road vehicles in the US has increased.

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Energy is a basic requirement for economic development. Growing energy consumption has resulted in world becoming increasingly dependent on fossil fuels such as coal, oil and gas; therefore, it becomes necessary to develop a sustainable path of energy. Gaseous fuels and bio-fuel seems to have the potential to contribute significantly to India's energy security. Alternate fuels are derived from sources other than petroleum. Most are produced domestically, reducing our dependence on imported oil, and some are derived from renewable sources. Often, they produce less pollution than gasoline or diesel.

Fuel for transport makes up almost a third of the current world energy consumption. Biofuel – renewable liquid or gaseous transport fuels derived from plant or animal material have emerged as one of a number of possible alternatives to fossil fuels that might help meet our energy needs in an environmentally sustainable way. However, biofuel production which mainly uses food crops, has been controversial because in some cases it has led to deforestation and to dispute over rising food prices and land use. New types of biofuels, such as those using non-food crops and algae, are being developed with the aim of meeting our energy demands whilst avoiding the problems of the past.

Diesel engines are the most preferred power plants due to their excellent drive ability and higher thermal efficiency. From the last few decades strict emission norms are followed to cut back the environmental pollutions. The major pollutant of diesel engine is NO_x which affect human health and environment adversely? Investigation on alternate fuel is enhanced in recent years because of the depletion of available fuel resources and increase in production of automotive vehicles. Recent works have been conducted in diesel engine with use of WPO and the result shows that NO_x emission is found to be increased; with reduction in brake thermal efficiency when compared to diesel.

II. EXPERIMENTAL INVESTIGATION

Dr. I. Nageshwara Rao and team has performed an experiment for detecting the properties of the pyrolysis oil. A mixture of 1 ton of plastic waste is subjected to produce oil. The process involves washing of waste is dried up to room temperature to remove moisture content. The reaction is carried out in presence of catalyst 'Aluminium silicate'. The volume of catalyst is kept to 2.5% of the mass of waste. The mixture is heated at 603k-723k. As a result of this pyrolysis, three products are obtained pyrolysis oil (60-70%), gas (15-20%) and carbon black (20-30). Further various mixture containing 40% oil +60% diesel, 30% oil+70% diesel, are subjected to various characteristic tests and are found similar to that of pure fuel oils

Aishwarya and sidhu studied the process of pyrolysis by using microwave oven. This system generates microwaves in continuous cycles. The setup is gravity feed and nitrogen is used to prevent oxygen to enter in the process. The plastics is heated by microwaves at a specified temperature. The product of the heating is then transferred to condenser where vapour are converted into liquid oil. Pyrolysis oil was obtained as product.

Mohammed et al. studied the process of pyrolysis in preparing fuel from the plastics waste generated from electric and electronics equipment. This type of waste consist of acrylonitrile butadiene styrene, polypropylene, polystyrene, polyethylene, polycarbonate, etc. two type of pyrolysis catalyst reaction system was used to convert low density polyethylene into fuel. In the first stage of the process the sample was heated the sample of plastic waste to a temperature of 500C is maintained and it is held for 30minutes. Pyrolysis oil obtained was further tested for its properties.

Soe et al. studied catalytic degeneration of HSPE using a batch reactor at a temperature of 450C. The pyrolysis formed with the catalyst zeolite ZSM-5 had higher yield of the gaseous fraction and smaller yield of liquid fraction when compared with thermal cracking explained by the properties of the catalyst. Most zeolite including ZSM-5, showed excellent catalytic efficiency in cracking, isomerization and aromatization due to its strong acidic property and its micro porous crystalline structure. The ZSM-5 zeolite has a three- dimensional pore channel structure with pore size of 5.4x5.6Å which allows an increased cracking of larger molecules, beyond the high Si/Al ratio which leads to an

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increase in thermal stability and acidity.

Product yield (%wt.)		Thermal pyrolysis	Catalytic pyrolysis
Gas fraction		13	63.5
Liquid fraction	Total	13	35
	C6-c12	84	99.92
	C13-c23	37.79	0.08
	>c23	5.66	0
Solid fraction		3	1.5

Zhang et al. The catalytic microwave degradation was carried out at 375C with catalyst to feed mass ratio of 0.1 or 0.2 to produce different proportions of aliphatic and cyclic hydrocarbons. It is found that in catalytic microwave degradation of LDPE carbon yields were found 66.18% and 56.32% respectively. For obtaining optimal conditions for the production of fuels different parameters were changed in hydrogenation process. More catalyst loading could facilitate rate of catalytic cracking to form gaseous compounds. The gas was primarily composed of ethylene, ethane, hydrogen, and methane because of the large extent of catalytic cracking and oligomerization reactions.

III. COVERSION PROCESS AND FUEL PROPERTIES

LDPE (low density polyethylene) and EVA (ethylene-vinyl acetate) were used as feed stocks and converted into high quality oils via the fast pyrolysis process. The schematic layout of the pyrolysis plant that was used is shown.

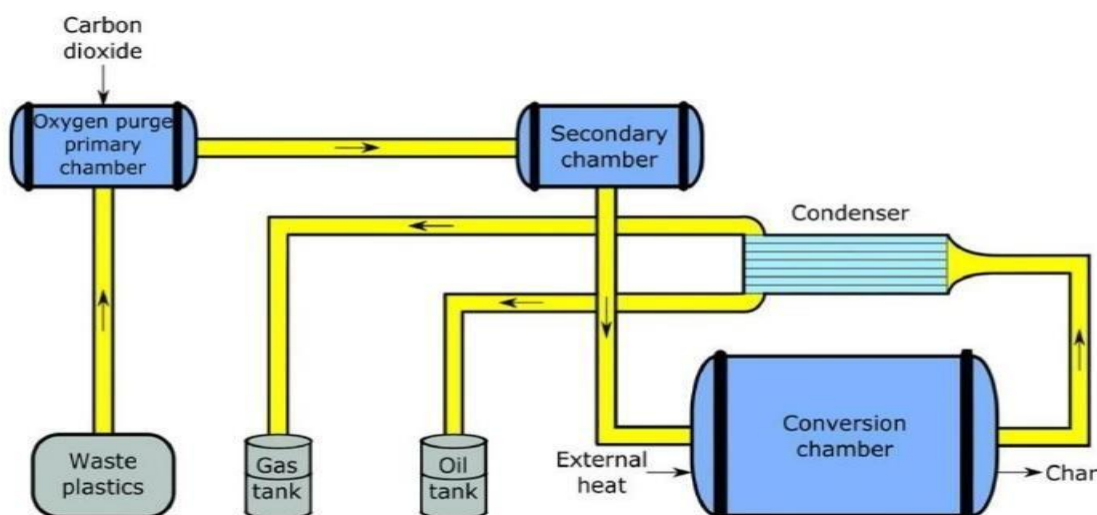


Fig. 1 schematic layout of the pyrolysis process

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Pyrolysis technology is thermal degradation process in the absence of oxygen. Plastic waste is treated in a cylindrical reactor at temperature of 300-350 C. The plastic waste is gently cracked by adding catalyst and the gases are condensed in a series of condensers to give a low sulphur content distillate. All this happens continuously to convert the waste plastics into fuel that can be used for generators. The catalyst used in this system will prevent formation of all the dioxins and furans. All the gases from this process are treated before it is let out in atmosphere. The flue gas is treated through scrubbers and water/ chemical treatment for neutralization. The non-condensable gas goes through water before it is used for burning. Since the plastics waste is processed about 300-350 C and there is no oxygen in the processing reactor, most of the toxics are burnt. However, the gas can be used in dual fuel diesel-generator set for generation of electricity.

IV. PERFORMANCE CHARACTERISTICS

The various performance parameters such as brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature under study is summarized as follows

Brake specific fuel consumption

An experimental study on diesel engine with blends of diesel-plastic pyrolysis oil indicates that BSFC was found to increase with load for WPPO 50, WPPO 70 and diesel fuel. As the load increases, BSFC decreases for all fuel blends. At full load, WPPO blends show the specific fuel consumption is higher than diesel. The main reason for this could be that percent increase in brake power due to relatively less portion of the heat losses at higher loads [21]. The brake specific fuel consumption for the waste plastic oil varies from 0.574 g/kWh at no load to 10.297 g/kWh at full load for standard injection timing, and it varies from .514 g/kWh at no load to .235 g/kWh at full load for retarded injection timing.

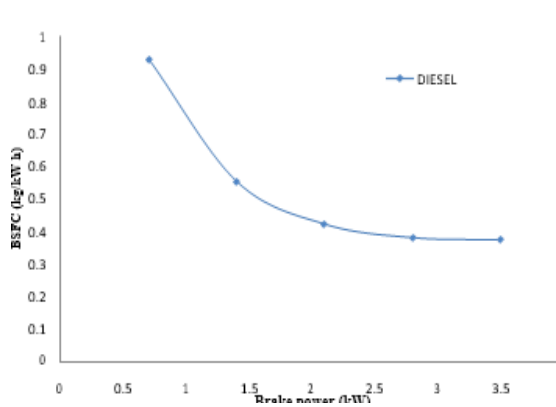


Fig 2

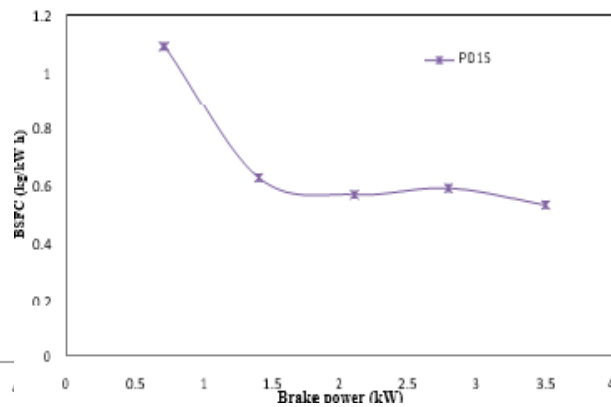


Fig 3

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Exhaust gas temperature

An experimental study on diesel and waste plastic blend in CI engine proved that with increasing load more fuel is burnt to meet power requirement that's why exhaust gas temperature increases with load. From the experimental study it observed that in the case of pure plastic oil the exhaust gas temperature varies from 240 C at low load to 450 C at full load. In CI engine while increasing the amount of plastic oil in the blend the exhaust gas temperature continuously goes on increasing[20].

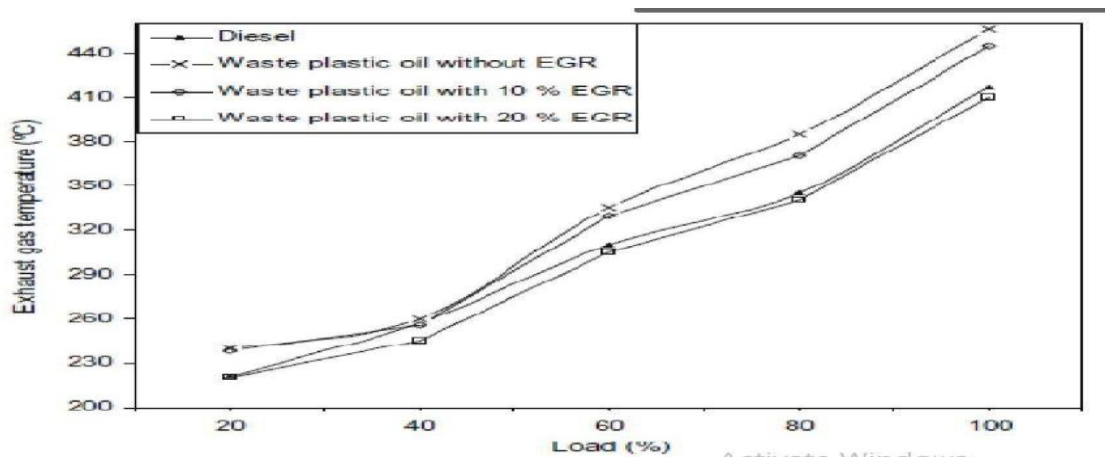
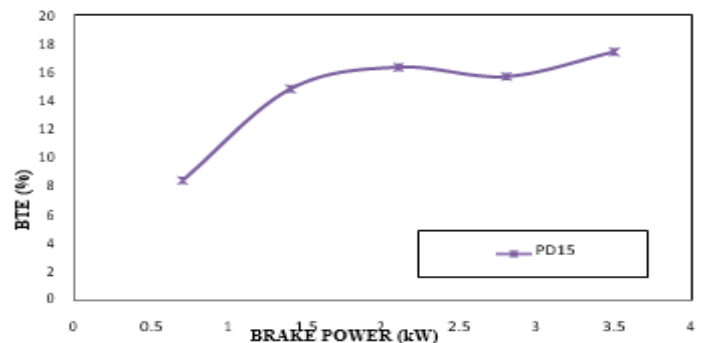
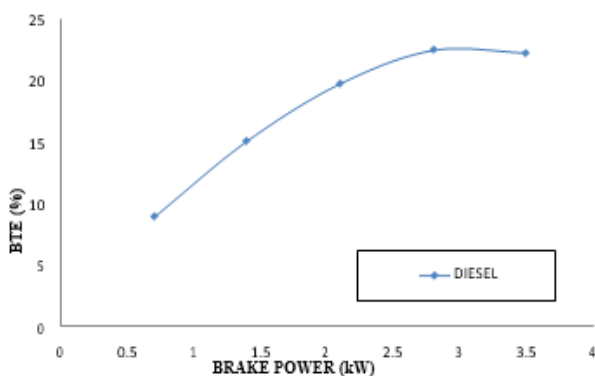


Fig. 4 variation of exhaust gas temperature with load for various EGR [24]

Brake thermal efficiency

The experimental study on a single cylinder, four-stroke, air cooled DI diesel engine with waste plastic oil [20], results the thermal efficiency is 28.2% at rated power for diesel and for the waste plastic oil it is 27.4%. Further the brake thermal efficiency of the waste plastic oil is closer to diesel up to 75% of rated power, beyond which it starts decreasing. At full load, the efficiency is higher for diesel fuel. This is due to the fact that at full load, the exhaust gas temperature and the heat release rate are marginally higher for waste plastic oil compared to diesel. An experimental study on waste plastic oil with varying injection timing results the thermal efficiency is 28.2% at full load for standard injection timing and 32.25% for the retarded injection timing of the waste plastic oil. Retardation of injection timing leads to fast start of combustion and combustion continues in the power stroke. This results in smaller peak heat release rate and increases effective pressure to do work. Consequently, the work output is high for retarded injection timing and therefore the brake thermal efficiency increases as the injection timing retarded.



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V. EMISSION CHARACTERSTICS

Internal combustion engine emission have been major contributor to air pollution regulated pollutants are carbon monoxide, Knox and unburnt fuel or partly oxidized HC. Which are summarized as follows

Carbon mono-oxide (CO) and carbon dioxide emission

Generally, CI engine lean mixture is used, and hence the CO emission would be low. CO emission is harmful for human being so it must be controlled. Reason of CO emission is incomplete combustion of hydrocarbon fuel. The experiment performed on a single cylinder, four stroke, air cooled diesel engine with waste plastic oil. For the diesel engine CO concentration varies from 14.14g/kWh to 5.75g/kWh at 25% of rated power and for waste plastic oil it varies from 18.51g/kWh to 6.19g/kWh. Hence it concluded that the CO emission is higher for waste plastic oil. The reduced cylinder temperature is the cause of incomplete combustion [20]. Waste plastic oil with exhaust gas recirculation in direct injection diesel engine indicate that the concentration of CO₂ in the the exhaust is continuously decreasing with increasing amount of EGR [24].

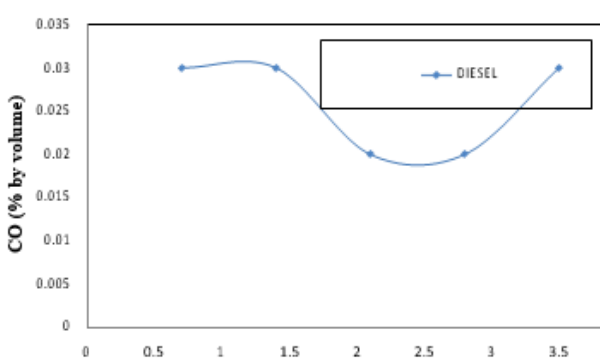


Fig 5

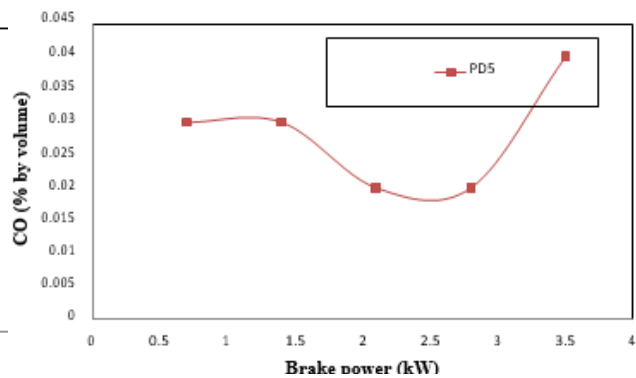


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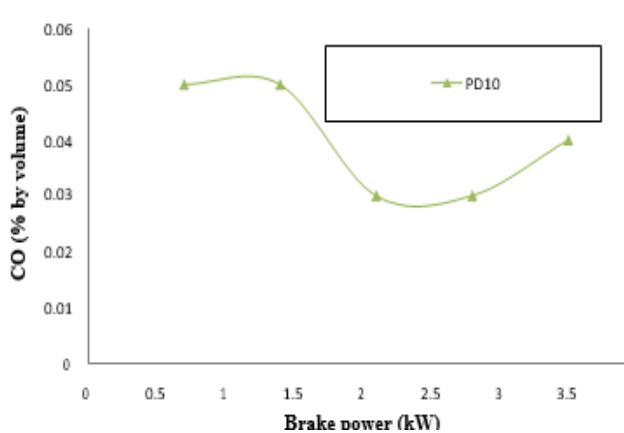


Fig 7

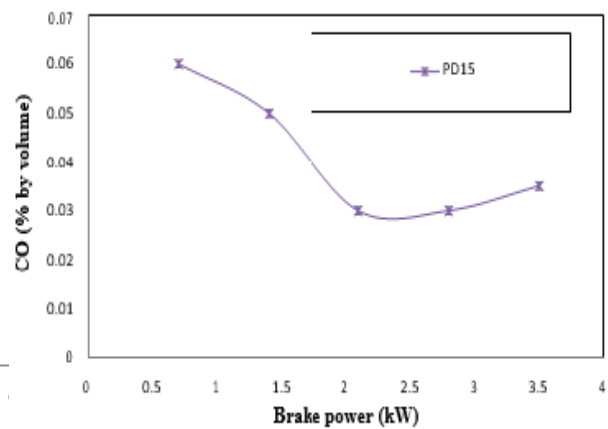


Fig 8

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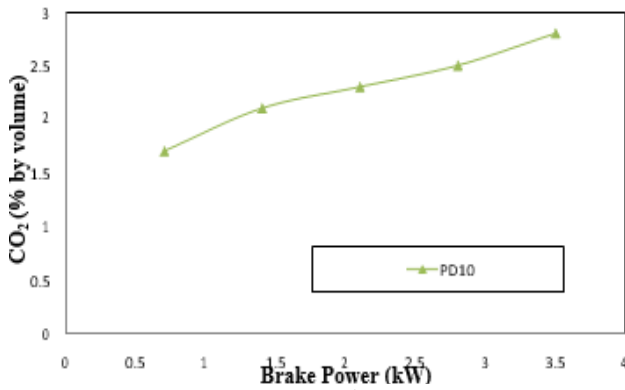


Fig 9

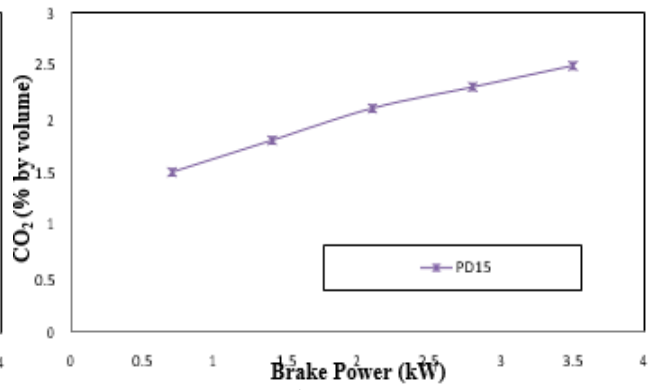


Fig 10

Nitrogen oxide emission

An experimental study on waste plastic oil and diesel fuel blends in compression ignition engine indicate that, the concentration of NO_x varies from 12.15 g/kWh to 7.61 g/kWh for diesel fuel with increasing load and from 14.68 g/kWh to 8.23 g/kWh for WPO with increasing load. For WPO10, it varies from 12.16 g/kWh to 7.75 g/kWh with load. It was also observed that with increasing amount of waste plastic oil in blend the amount of NO_x emission goes The experimental work on waste plastic oil with exhaust gas recirculation in direct injection diesel engine indicate that NO_x emission continuously decreasing with increasing load and the NO_x emission continuously decreasing with increasing amount of EGR. The reason of decrement in NO_x concentration is presence of inert gas in EGR. These gases absorb heat release by combustion due to which in cylinder temperature reduces and also it replaces the oxygen in the chamber.

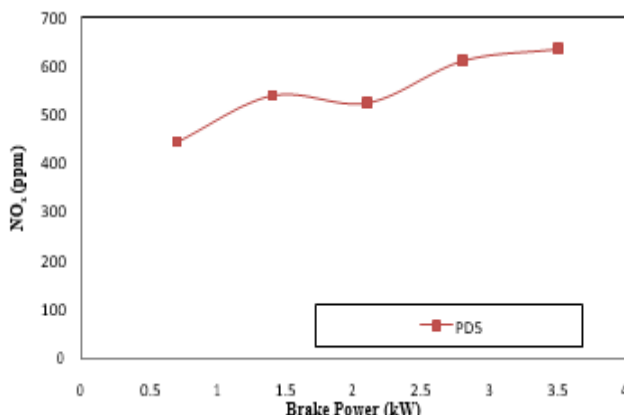


Fig 11

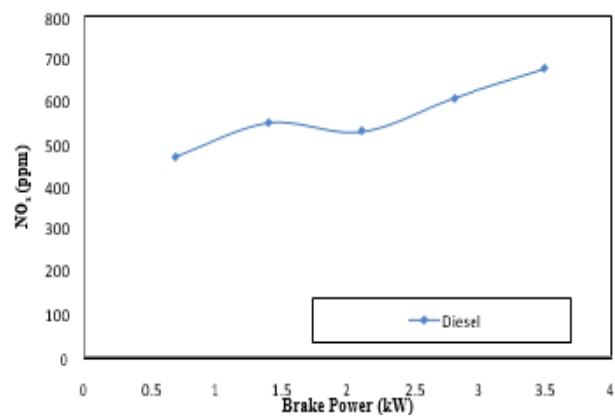


Fig 12

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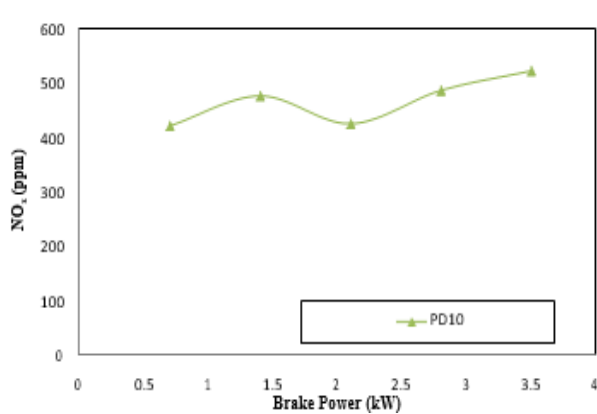


Fig 13

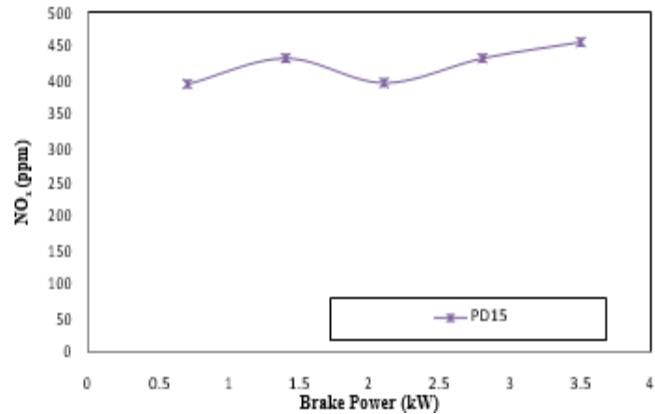


Fig 14

Unburned hydrocarbon

Hydrocarbon means organic compounds in the gaseous state and solid hydrocarbon are part of the particulate matter. Unburned hydrocarbon produced due to incomplete combustion. At higher load in CI engine UHC become a serious issue. At light load fuel quantity is less so less fuel impinges on surface, but because of poor fuel distribution, low

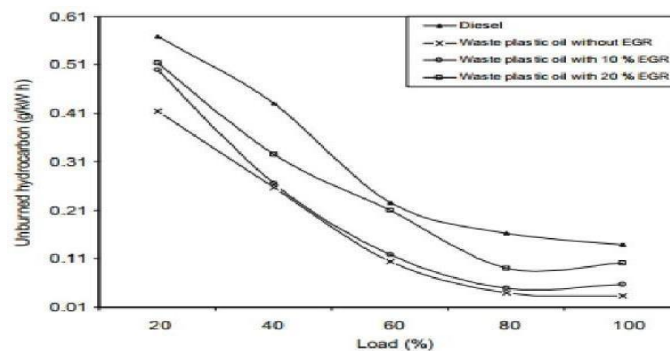


Fig. 15 Variation of UHC with load for various % of EGR

Exhaust temperature and lean air fuel an experimental study on waste plastic shows that concentration of UHC of waste plastic is higher than diesel. Due to fumigation rate and non-availability of oxygen the concentration of unburned hydrocarbon is higher in waste plastic oil [20]. An experiment shows that with increasing amount of EGR concentration of unburned hydrocarbon goes on increasing. The formation of NO_x is highly dependent on in cylinder temperature, the oxygen concentration and

VI. RESULT AND DISCUSSION

By the process of pyrolysis, plastics can be converted into fuel and in most scenarios three major products are obtained at the end of process. These products are namely pyrolysis oil, carbon black and a gaseous mixture. All these three are arranged in order of their composition in the product. The properties of pyrolysis oil can be improved by hydrogenation. The pyrolysis oil is a good substitute of conventional fuel and in various test run by Dr.Rao and team [8] it is found that the oil when blended with conventional fuel like petrol and diesel, shows same characteristics as pure dose. It is worth mention to notify that not only pure plastics but also plastics in which additives were used to be treated to form equally good oil. Thermal and catalytic pyrolysis has their own yield aspects for different products. It has been

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found that can be opted thermal pyrolysis for liquid product and to catalytic pyrolysis can be preferred for gaseous products.

VII. CONCLUSION

In the light of addressing solution for energy and environmental issues. Pyrolysis has been found the most effective technique of conversion of waste plastic to fuels. It is noticeable that the fuel obtained by pyrolysis is cleaner than conventional fuels

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