STUDY ON THE USE OF OIL DERIVED FROM MEDICAL WASTE PLASTIC AS A SUITABLE FUEL IN KIRLOSKAR TV-I ENGINE

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Abstract
Oil has been obtained by the pyrolysis of medical waste plastic such as masks, saline bottles, syringes and covers used to store them. This oil has been separated into two fractions, one boiling below and above 150 °C all the oil fraction boiling above 150 °C has been characterized using elemental analysis. The oil from masks, saline bottles and syringes is found to contain largely alkenes. However, the oil from plastic covers contains significant amounts of alkenes with ester group. The physical properties of the fraction boiling above 150 °C have been determined and comparable with diesel. These fractionated fuels are tested on a Kirloskar TV 1 engine. From the results it is seen that the mask oil produces higher brake thermal efficiency of 33%. Also, it produced high pressure inside the cylinder to release heat. However, the production of smoke and hydrocarbon is less for cover oil.

Keywords: *Medical Waste Plastic Oil, Frictional Distillation, Elemental Analysis, Diesel Engine, Emission.*

1. INTRODUCTION

Transport is an essential need of life. Fuels are important for transport. Diesel is an important fuel. Diesel is a fossil fuel. We have a limited stock of fossil fuels. Research is being done to find the suitable of sources like bio diesel, algae oil, animal fat oil as transport fuel.

In modern days the utilization of plastic has increased due to its higher advantage than other materials. Due to high in use post plastic waste is produced in huge amount. This waste plastic causes environmental pollution. So, plastic can be converted into liquid fuel.

Shashank pal et al [1] have converted municipal plastic waste into liquid fuel by pyrolysis at 550 °C. They have obtained 69.8 wt % of oil. From the obtained oil they made blends by mixing it with diesel. They mixed oil and diesel in three different ratios and used these blends to run diesel engine. The non-blended plastic oil produces less brake thermal efficiency. Increase in diesel proportion increases the cylinder pressure which in turn produces high heat release rate.

Viswanath et al., [2] utilized the oil produced from municipal waste plastic and blend it with diesel at different ratios. They found that blends and neat plastic oil produced less brake thermal efficiency than diesel. They reported that the cylinder pressure, heat release rate, combustion duration and injection delay for the plastic oil and its blend are higher when compared to diesel.

Loannis et al., [3] converted waste plastic into oil by utilizing fast pyrolysis process. They infer that the waste plastic oil and diesel properties are near to each other. They tested it in a four-cylinder CI engine. It was found that the oil derived from waste plastic can be utilized to run the CI engine at higher loads. The performance of the engine is good. But in low load due to longer injection delay period the performance went down. Plastic oil produces less brake thermal efficiency than diesel and NOx emission is higher.

Mani et al., [4] utilized the oil derived from trash plastic in a single cylinder CI engine by changing the injection timing. They found that reduction in NOx, CO and HC when the injection timing was 14° bTDC. During the test there is an increase in smoke and CO emission. Injection timing of 14° bTDC produce higher brake thermal efficiency.

Devaraj et al., [5] mixed 5 & 10% of diethyl ether with waste plastic oil and tested in a six-cylinder DI engine. It was found that the di ethyl ether blended fuel produced great brake thermal efficiency. The waste plastic oil without mix and diesel fuel produce less brake thermal efficiency. The CO and NOx emission were minimized for the mixed fuel.

Rinaldini et al., [6] they used engine run on diesel for testing the oil obtained by pyrolysis of waste plastic oil. The performance of the engine is low when it runs on waste plastic oil. It produces smooth heat release rate and less soot.

Nishanth et al., [7] have converted the used plastic cover into liquid hydrocarbon. During the pyrolysis process biogas is used as a heating source. They utilize the blended oil in a diesel engine. They found that the performance was good with it run on WPO25 mix oil.

Prem et al., [8] investigated the combustion, brake thermal efficiency and emission formation in VCR diesel engine run on diesel and waste plastic oil blends. The oil is derived by pyrolysis of used polythene covers using catalyst as red mud. Experiments were conducted and the results indicated that brake power, brake thermal efficiency and brake specific fuel consumption improved slightly for 20% blend. As the blend ratio increases the NOx and HC emission increases. The study concluded that the best blend is D80PO20.

Gungor et al [9] convert the waste polyethylene into waste plastic oil and blend it using diesel. They tested the waste plastic oil physical properties are found that all properties are near to diesel. They run the mistsubishi engine in waste plastic oil and the performance combustion & emission with diesel. They reported that the power produced by mistubishi engine is higher when it runs on waste plastic oil and its blends.

Premkumar et al., [10] have utilized the waste plastic in a Kirloskar TV 1 engine by blending it with diesel at three different ratios and non-blended waste plastic oil. They vary the injection pressure from standard pressure 220 bar to a lower pressure of 210, and higher pressure of 230 and 240 bar. They found that the blend B25 with high injection pressure of 240 bar produces better brake thermal efficiency. The emission CO, HC & smoke amount reduced. The NOx emission has increased.

Abdul munaf et al., [11] have obtained the plastic pyrolysis oil (PPO) from waste plastic made up of HDPE by catalytic degradation. The obtained oil was blended with diesel to run the diesel engine. After the run they found that B75 plays a good role in performance and emission at higher load condition.

Reuv et al., [12] they run the CI engine using waste plastic oil in a diesel engine by advancing the timing of injection. Advancing the injection timing gives better engine performance and produces more energy. They reported that the blend with lower concentration produces improvement in combustion & performance and produce less emission. As the concentration gets increased in the blend revers impact occurs in the combustion, performance and emission.

From the previous study implies that most of the researchers used waste plastic oil blended with diesel to run the diesel engine. The study on combustion, performance and emission was done with diesel blend with waste plastic oil only. There is no work published by utilizing the neat waste plastic oil in a diesel engine.

In the study the obtained oil is fractionated and the fraction above 150°C is directly used as a fuel in Kirloskar TV 1 Engine

2. EXPERIMENTAL SETUP

2.1 Test Engine

The figure 1 shows with the essential instrumentation to find the performance, combustion and emission parameters of the fuel at various operating conditions.

Naturally aspirated (NA) engine is most commonly used engine in agricultural field till now. The Kirloskar TV 1 engine is commonly used to run the pump used for irrigation purpose. These engine is most sensitive because of its longer injection delay and lower injection. which is typical of this engine design.

The construction of the engine is rigged to with stand high peak pressure. Since the cylinder head its heavy in construction so the required alternative can do easily. Hence, Kirloskar TVF engine used for this research work. Due to this advantage this engine is selected for this study. It is a vertical, single cylinder, four stroke, water cooled and direct injection compression ignition engine with a rated power of 5.2 kW at 1500 rpm. The rated injection pressure is 220 bar and the static injection timing is 23° bTDC. The photography of the experimental setup is shown in Figure 1 and the engine specifications are given in Table 1.

Figure 1. Experimental Setup

Table 1 Engine Specification

Make	Kirloskar engine TV1
Engine details	Single cylinder, compression ignition, four stroke, water cooled diesel engine
Compression ratio	17.5:1
Rated power	5.2 kW
Cylinder Bore and Smoke	87.5 mm and 110 mm
Speed	1500 rpm
Dynamometer	Eddy current
Injection timing	23◦ before TDC
Injection pressure	2.20 kg/mm^2

2.2 Elemental Analysis

CHNS analyser were performed on a CHNS, Model vario macro cube, made by Elementar Excellence in Elements at Research Laboratory, Mining Engineering, Annamalai University.

3. RESULT AND DISCUSSIONS

3.1 Properties of Medical Waste Plastics Oils

The Table 2 shows the physical property of the oil obtained from medical waste plastic like plastic covers, mask, saline & syringe.

Table 2 Physical properties obtained oils

Property	Methods	Plastic oil from				Diesel
		Syringe	Saline	Mask	Plastic cover	
Density 15°C kg/m^3	IS-1448-P16	773	771	757	766	820
Kinematic viscosity at 40°C [cst]	IS-1448-P25	2.35	2.35	1.77	1.86	2.5
Flash point °C	IP-36	67	64	57	54	62

Fire point °C	IP-16	54	54	52	53	43
Pour point °C	IP-16	-	-	-	-	-
Gross calorific value MJ/kg	IS-1448	43.2	42.5	43.7	44.3	42.3

From the property Table 2 it is seen that the value of density, kinematic viscosity, flash point and fire point are not equal to the sole fuels. All these property values are lower than that of petrol and diesel. From the property Table 2 it is seen that the obtained oils contain low and high boiling liquid hydrocarbon. So, the obtained and should be fractioned to 150 °C to remove low boiling liquid hydrocarbon. Then these oils can be utilized to run the engine at lower emission.

3.2 Fractional distillation of plastic oil from medical waste plastic

The volumes of two fractions obtained by the fractional distillation of 1000 mL plastic oil derived from medical waste plastic are given in Table 3.

Table 3 Volume of the two fractions

Plastic oil	Volume mL		
	Fraction < 150 °C	Fraction > 150 °C	Losses
Syringe	130	830	40
Saline	230	730	40
Mask	300	650	50
Plastic cover	315	625	60

Low boiling hydrocarbon always contains short chain alkenes. It the rate of degradation gets increased the production of short chain alkene get increased. This is because of the weak and strong chemical chain of the plastic nature. From Table 3 it is seen that the extent of degradation increases in the order syringe < saline < mask < plastic cover.

Table 4 Properties for fractionated oil above 150 °C

Property	Methods	Plastic oil from				Diesel
		Syringe	Saline	Mask	Plastic cover	
Density 15°C kg/m^3	IS-1448-P16	773	771	757	767	820
Kinematic viscosity at 40°C [cst]	IS-1448-P25	2.4	2.3	2.0	2.1	2.5
Flash point °C	IP-36	77	72	67	69	62
Fire point °C	IP-16	87	83	76	80	43
Pour point °C	IP-16	-	-	-	-	-
Gross calorific value MJ/kg	IS-1448	43.2	42.5	43.7	44.3	42.3

3.3 CHNS Analysis

Elemental analysis of the fractionated oil degraded from plastic covers, used mask, saline & syringe.

By elemental analysis the percentage weights of various elements present in an organic compound can be determined. Hydrocarbons contain only carbon and hydrogen. Hence, in any hydrocarbon the total percentage of carbon and hydrogen should be 100.

In any acyclic alkene such as butene, octene, dodecene etc., for every carbon atom there will be two hydrogen atoms. Hence, in acyclic alkenes the ratio of the weight percentage of carbon to that of hydrogen will be 6. In acyclic alkanes this ratio will depend on the alkane. In methane this ratio will be 3 whereas in butane this ratio will be 4.8. This ratio will increase with the increase in the number of carbon atoms. However, this ratio will be less than 6. Hence, if an oil fraction contains significant amounts of acyclic alkanes the ratio of percentage of carbon to that of hydrogen will be less than 6.

In benzene this ratio will be 12. In toluene this ratio will be 10. In ethylbenzene and xylenes this ratio will be 9.6. Hence, in any oil fraction if these aromatic compounds are present to a significant extent the ratio of weight percentage of carbon to that of hydrogen will be greater than 6.

The presence of oxygen in any organic compound will not change the ratio of the weight of carbon to that of hydrogen. However, the total percentage weights of carbon and hydrogen will be less than 100. For example, ethanol has two carbons, six hydrogens and one oxygen. The weight percentages of carbon, hydrogen and oxygen in ethanol are 52.17, 13.04 and 34.78, respectively. The total weight percentage of carbon and hydrogen comes to 65.21. This is much less than 100. However, the ratio of the weight percentage of carbon to that of hydrogen is 4.00 which is the same as that in ethane. In higher alcohols which contain a greater number of carbon atoms the percentage of oxygen will be less. Thus, in 1-decanol which contains ten carbon atoms the weight percentage of oxygen is only 10.13.

For a mixture of hydrocarbons and alcohols the total weight percentage of carbon and hydrogen will be less than 100. The difference will depend on the alcohol present and its amount. If an oil contains 90% hydrocarbons and 10% 1-decanol the total weight percentage of carbon and hydrogen will be 99.

The percentages of carbon and hydrogen were determined for the high boiling oil fractions in all cases and the results are shown in Table 5. For the oil obtained from plastic covers the total weight percentage of carbon and hydrogen comes as 89.05. This suggests that the oil from plastic covers contains significant amount of oxygen. The CHNS analysis of waste plastic covers have shown that the plastic covers used in this study contain significant amount of polymethylmethacrylate [PMMA]. Hence, this oil from the waste plastic covers also may contain some alkenes with ester groups. Since ester group contains oxygen the total percentage of carbon and hydrogen is significantly lower than 100. The ratio of percentage of carbon to that of hydrogen is 6.60. This ratio is higher than 6.00 due to the presence of ester groups.

For the oil obtained from mask the total percentage of carbon and hydrogen comes as 99.00 and the ratio of the percentage of carbon to that of hydrogen is found as 6.00. This suggests that this oil contains largely alkenes. The CHNS analysis of mask used in this study contains some amount of polyether's. Probably these polyether's have given some gaseous products on degradation. Hence, the oil comes from the polyalkene content of the plastic.

The total percentage of carbon and hydrogen for the oil obtained from saline bottles is 99.11 and the ratio of the percentage of carbon to that of hydrogen is 5.97. These observations suggest that the oil from saline bottles contains largely alkenes.

The total percentage of carbon and hydrogen is 99.20 for the oil obtained from syringes. In this case the ratio of percentage of carbon to that of hydrogen comes as 5.97. These observations suggest that this oil contains largely alkenes.

Table 5 Elemental analysis of the fractionated oil derived from medical waste plastics

Sl. No.	Name	C [%]	H [%]	%C+%H	%C/%H
1.	Syringe oil	84.97	14.23	99.20	5.97
2.	Saline oil	84.89	14.22	99.11	5.97
3.	Mask oil	84.85	14.15	99.00	6.00
4.	Plastic cover oil	77.34	11.71	89.05	6.60

3.4 Characteristics of Combustion, Performance & Emission

Combustion Parameters

Cylinder Pressure

Cylinder pressure is the main parameter of the engine. If the combustion is perfect, then the cylinder pressure and heat release rate is high. This produces better break thermal efficiency. The combustion inside the engine depends on the fuel property. The physical and chemical properties of the fuel have impact on the generation of pressure. High calorific value with less viscosity produces better combustion which results in high cylinder pressure.

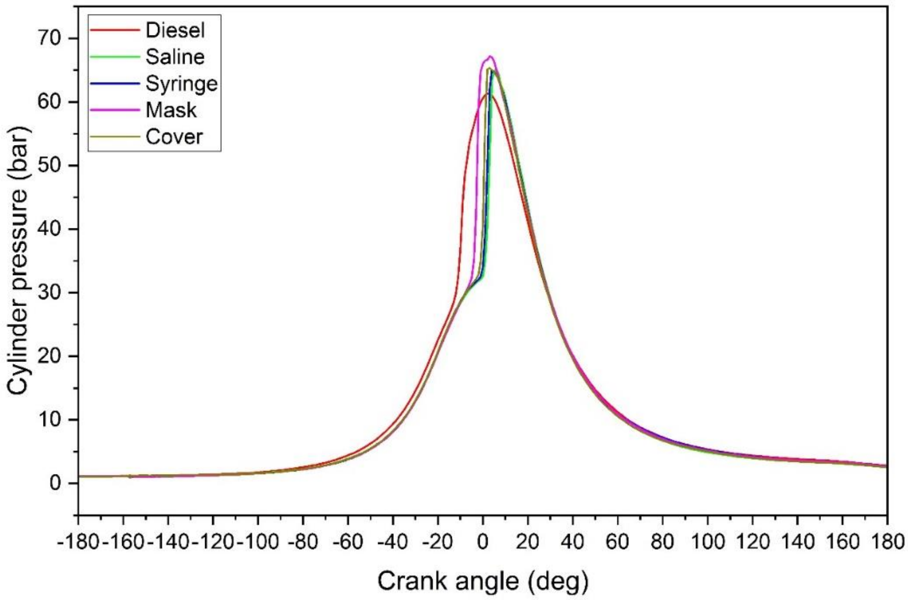

Fig. 2 Crank angle Vs Cylinder pressure

The cylinder pressure for the oils from cover mask, saline, syringe and diesel shown in figure. The figure illustrate that the mask oil produces highest cylinder pressure of 68 bar. This is because of to high calorific value and low viscosity of the fuel. This produces better atomization and vaporization. The chemical analysis of the fuel implies that the presence of alkenes is higher in mask oil. Due to this the fuel produces prolonged combustion and produces high cylinder pressure.

Heat releasee rate

Heat release rate depends on the quantity of carbon and hydrogen weight present in the fuel. Hydrogen rich molecules produce higher heat release rate. From the graph it is found that the mask oil produces a higher heat release rate. The property the oil with high heating value with less viscosity makes heat release rate of 142 kJ/m^3 degree. From the elemental analysis the mask oil has the summation percentage of carbon and hydrogen is 99%. The ratio of carbon to hydrogen is 6. This implies that the oil contains more alkenes. Alkenes are compounds that have double bond structure.

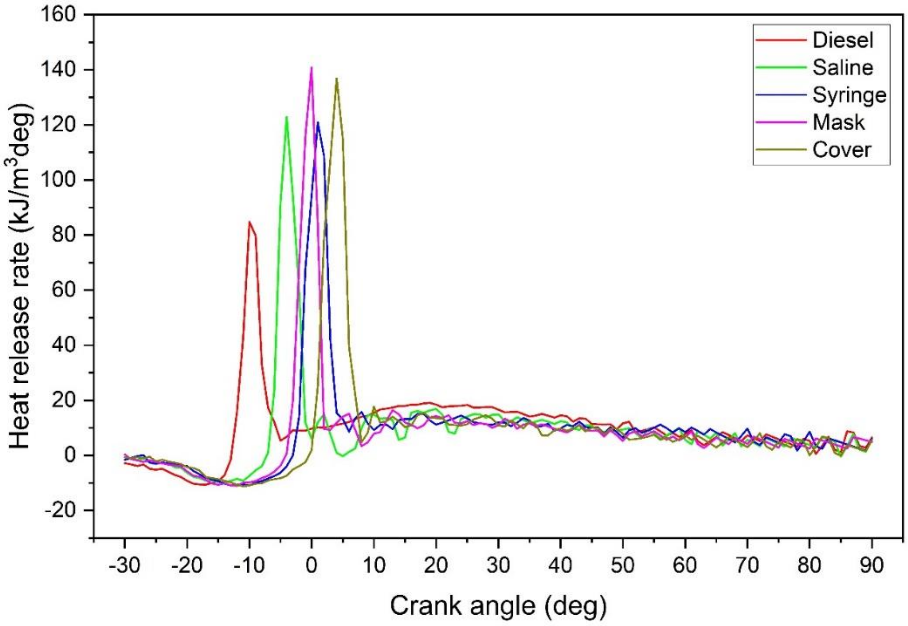

Fig. 3 Crank angle Vs Heat release rate

The summation of carbon and hydrogen is 99% and 1% remaining in oxygen. The 1% oxygen in the fuel makes the combustion clean and produces a high heat release rate of 142 kJ/m^3 degree. Even though the plastic cover oil has high oxygen molecules in the oil. It may not be able to produce more heat release because of the lower percentage of weight in presence of carbon and hydrogen. The heat release rate produced by plastic cover oil is 138 kJ/m^3 degree. The saline and syringe oil also produce less heat release rate because of its low calorific value and high viscosity of the fuel. The ratio of carbon to hydrogen is less than 6. This implies that the oil contains alkenes. The heat release by the saline & syringe oil is 124 & 120 kJ/m^3 degree. Revu et al., [12] reported that the plastic oil blend produces a higher heat release rate than diesel fuel.

3.5 Performance

Brake thermal efficiency

The sequence of brake thermal efficiency (BTE) of cover, masks, syringe, saline oil and diesel is shown in fig. From the fig it is seen that the mask oil produces higher brake thermal efficiency 33%. The because of the physical and chemical properties of the fuel. These properties help the engine to produce more cylinder pressure and heat release rate. Due to this factor the brake thermal efficiency is higher for mask oil. Among the medical waste plastic oils saline produce less brake thermal efficiency of 30 % the injector can inject the low viscosity fuel at a higher pressure inside the engine. Due to this the oil can spread evenly. Since the calorific value of the fuel is high. So, the heat energy dissipation is more and this results in higher brake thermal efficiency.

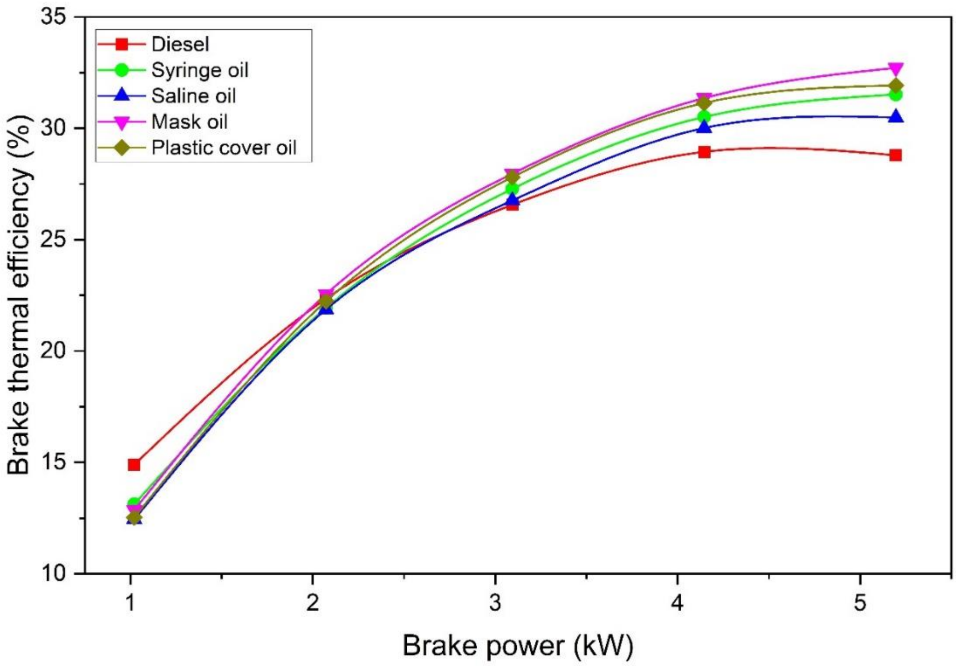

Fig. 4 Brake power Vs Brake thermal efficiency

3.6 Emission Analysis

Oxides of nitrogen

The three main factors with induced the production of NOx are adiabatic flame temperature, response time and oxygen Revu et al., [12]. The cover oil produces more NOx emission though it releases less heating rate. This is due to the higher weight presence of oxygen molecular presence in the cover oil. This results in higher produce of NOx by cover oil. For the plastic cover oil, the weight % of carbon and hydrogen comes as 89.05. This implies that the oil contains a considerable amount of oxygen. The percentage ratio of carbon to hydrogen is above 6. The implies that the oil is having some presence of ester groups. The Ester group contains oxygen. This makes the cover oil produce more NOx. Even though it produce low heat release rate. The ester group in the fuel produces more O_2 during combustion. This results in the cover oil producing 1200 ppm of NOx high load. From the Fig it is seen that diesel produces lower NOx emission of 950 ppm followed next high values produce by mask syringe and saline oil of 1090, 1010 and 820 ppm.

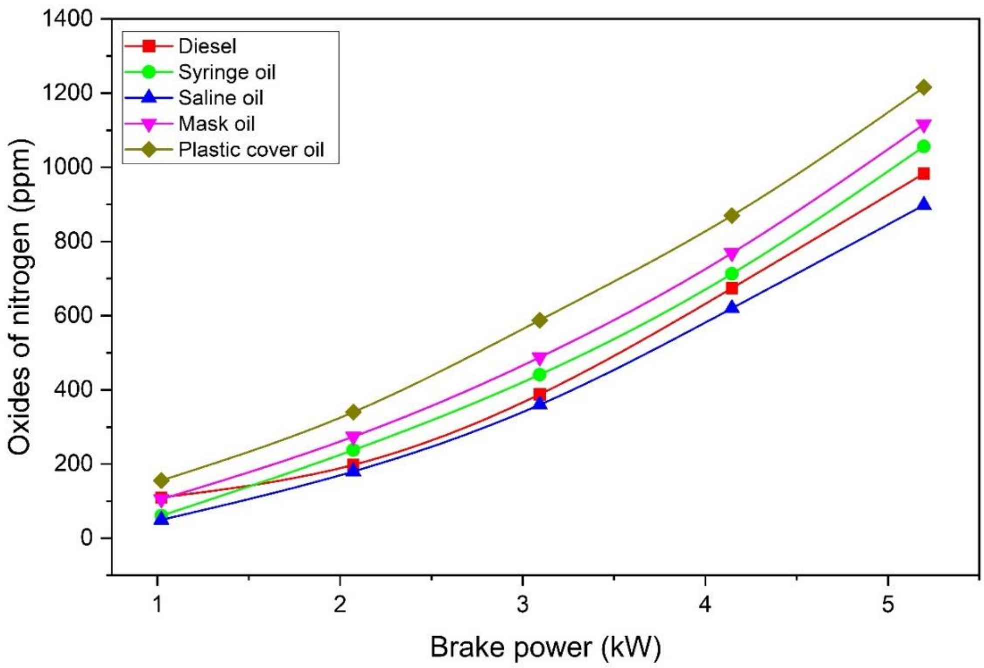

Fig. 5 Brake power Vs Oxides of nitrogen

Smoke Density

Rich fuel zone produces more smoke when the engine is at full load. This is due to the insufficient O_2 present in the combustion zone. At peak load the response time is less. So, the production of smoke is more. The viscosity of the fuel also plays a vital role in the production of smoke. High viscosity fuel produces more smoke Revu et al [12]. From the property table it is seen that the viscosity is less for cover oil is 1.77cst and it produces 54 HSU of smoke at peak load. The mask, syringe and saline oil produce 46, 56 and 69 HSU of smoke. Since all the oil has the viscosity lower than diesel.

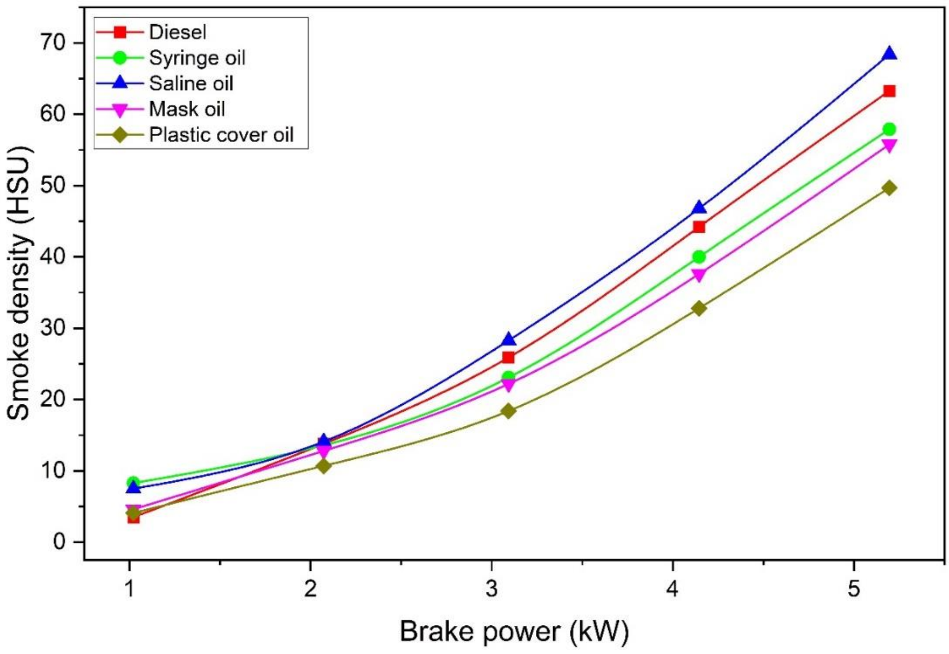

Fig. 6 Brake power Vs smoke density

Hydrocarbon

The release of hydrocarbon emission is higher for diesel fuel and lower for the cover oil. Even though the cover oil produces less heat rate the production of hydrocarbon emission is low. This is due to the less amount of lower boiling alkenes present in the cover oil. In the load and a significant weight percentage of oxygen in the fuel. During the combustion process almost all the hydrocarbons are completely burnt because of the oxygen molecule present in all fuel. The oxygen molecule supports the combustion and makes the cover oil produce less hydrocarbon emission of 36 ppm next to be cover oil the mask produces less hydrocarbon of 30 ppm. The saline and syringe produce 47 and 43 ppm of hydrocarbon emission.

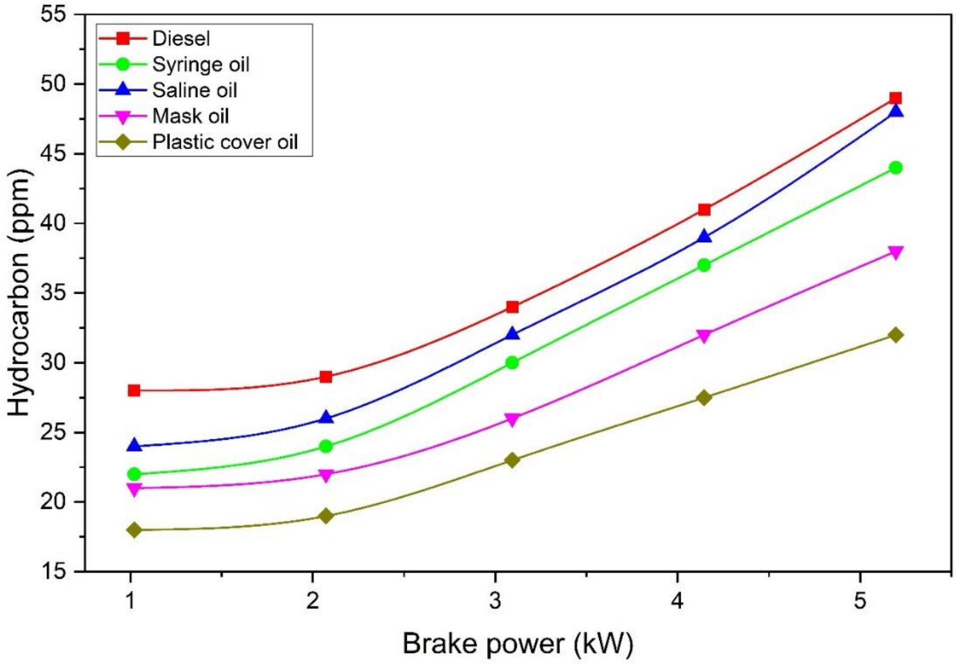

Fig. 7 Brake power Vs Hydrocarbon

4. CONCLUSION

From the experimental studied it is concluded that

1. The mask fractionated oil produces maximum brake thermal efficiency of 33%. When compared to other oil and diesel.
2. Hydrocarbon and smoke are reduced for cover oil. It produces 36 ppm and 54 HSU.
3. The cylinder pressure and heat release rate are higher for the mask oil due to the high calorific value and lower viscosity of the fuel.
4. The NOx is high for mask oil at 1200 ppm when compared to other oil and diesel.

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