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Production, Characterization and Testing of Waste Oil based Biodiesel Blends as an Alternative Fuel in Diesel Engines

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Abstract: Environmental degradation and depleting oil reserve are the matter of great concern around the globe. Diesel being the main transport fuel in India, finding a suitable alternative to diesel is an urgent need. In this context, the biodiesel is receiving much interest as the substitute, but the disadvantage limits its implementation i.e. due to their higher viscosity, high flash and fire point and low volatility. Also, in recent years waste plastic oil has gained attention because of its comparable performance characteristics with that of diesel. But again its higher NOx emissions limit its use. This paper presents the investigation done to eliminate the limitations of both waste plastic oil and biodiesel by blending both with diesel in right proportions and finding the best blend by conducting various tests, which can replace the pure diesel which is used today in almost all of the diesel engines.
Keywords: Biodiesel, Waste plastic oil, Pyrolysis, Transesterification, Load test of biodiesel.

I. INTRODUCTION

India's fuel demand in 2016 grew at its highest pace in at least 16 years as low oil prices for most of the year boosted demand for petrol and aviation fuels, data from the Petroleum Planning and Analysis Cell (PPAC) of the oil ministry showed. Diesel being the most used transport fuel in India, This uncontrolled use of diesel will lead to the depletion of the oil reserves and also cause pollution. In India there is very less oil reserves. So India relays upon foreign imports to suffice its needs. But this will drain the wealth of the nation. To cut the foreign exchange and contribute towards protection of earth from the threat of environmental degradation, bio fuels can be used as a good alternative for diesel for most of the developing countries. Vegetable oils and plastic oil have considerable potential to be considered as appropriate alternative as they possesses fuel properties similar to that of diesel. Vegetable oils can be classified into two types. One is edible oil and the other non-edible oil . Since edible oils are in great demand for domestic consumption, it's a crime to use the food product for the diesel use, as stated by the United Nations. The non-edible oil like oil from jatrophaseed , rubber seed etc are used as a substitute fuel. These days waste cooking oil and ayurvedic waste oil also have come in to focus [6].

Hence this investigation starts with the aim to find the best blend of diesel with waste cooking oil. The use of bio diesel in conventional diesel engine results in substantial reduction of unburnt hydrocarbon, carbon monoxide and particulate matter [but NOx about 2% higher]. Biodiesel has almost no sulfur (0.05%), no aromatics and has about 10 % built in oxygen which helps in better combustion. High viscosity, high flash and fire point and low volatility are main disadvantages of vegetable oils as alternative fuels in IC Engines. Trans-esterification processes are carried out to remove impurities, reduce viscosity and to match most of the properties closely to that of petrol diesel properties [1].

Plastics is a prime materials in the modern world and application in the industrial field as well as the domestic field is continuously increasing. But the plastic after its use become a waste and is often thrown away. The waste plastic being non biodegradable, remains in the soil for upto 100 years causing land pollution. A method commonly used to prevent this is burning if the plastic, but it leads to air pollution. Another solution to the problem is converting the waste plastic into waste plastic oil. The waste plastic oil is obtained from the process called Pyrolysis. Pyrolysis is the thermal decomposition of organic material at elevated temperatures, in the absence of gases such as air or oxygen. This waste plastic oil can be directly used in compression ignition engines due to their comparable characteristics with diesel. But it was found to be giving more NOx emissions. Different methods that are widely used to reduce NOx from diesel engines are exhaust gas recirculation, retarded injection timing, fuel denitrogenation, staged injection of fuel, water injection, exhaust catalysts and reduction of pre-mixed burn fraction by reducing ignition delay. Most of the research work has been done by mixing oil developed from waste plastic disposal with heavy oil for marine application. The results showed that waste plastic disposal oil when mixed with heavy oils reduces the viscosity significantly and improves the engine performance. However, very little has been done to test their use in high speed diesel engines [2,3]

Here in this investigation we intend to mix the biodiesel from waste cooking oil and the waste plastic oil with the diesel to find the best blend of these by load test of each blend considered. Also characterization of these blends are done and finally by comparing both the load test results and also the properties of the fuel, the exact blend with properties similar to thatb of the diesel is found and put forward as an alternate fuel to pure diesel [5].

A. Biodiesel Manufacturing Process

The biodiesel manufacturing process converts oils and fats into chemicals called long-chain mono alkyl esters, or biodiesel. These chemicals are also referred to as fatty acid methyl esters (FAME) and the process is referred to as trans esterification. Figure 3.1 provides a simplified diagram of the trans-esterification process. Roughly speaking, 100 pounds of oil or fat are reacted with 10 pounds of a short-chain alcohol (usually methanol) in the presence of a catalyst (usually sodium hydroxide [NaOH] or potassium hydroxide [KOH]) to form 100 pounds of biodiesel and 10 pounds of glycerin. Glycerin is a sugar, and is a co-product of the biodiesel process.

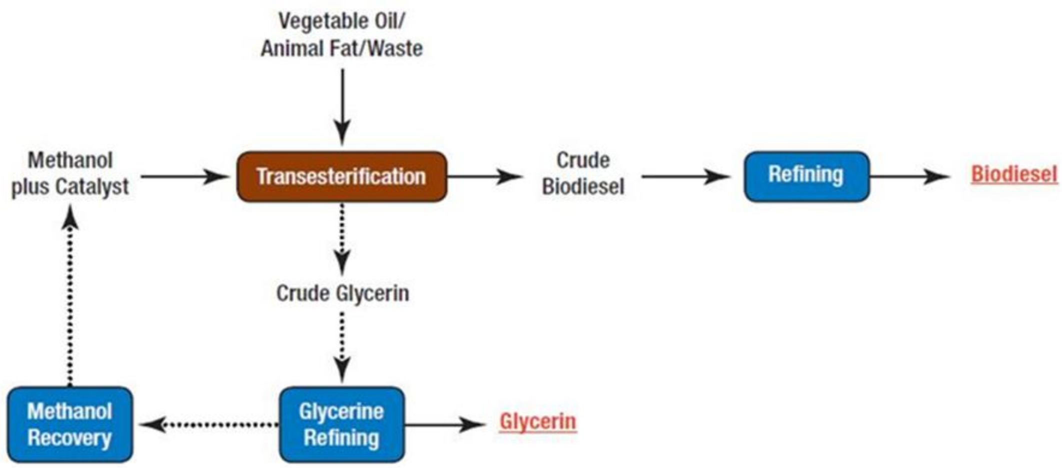

Fig. 1 Transesterification process

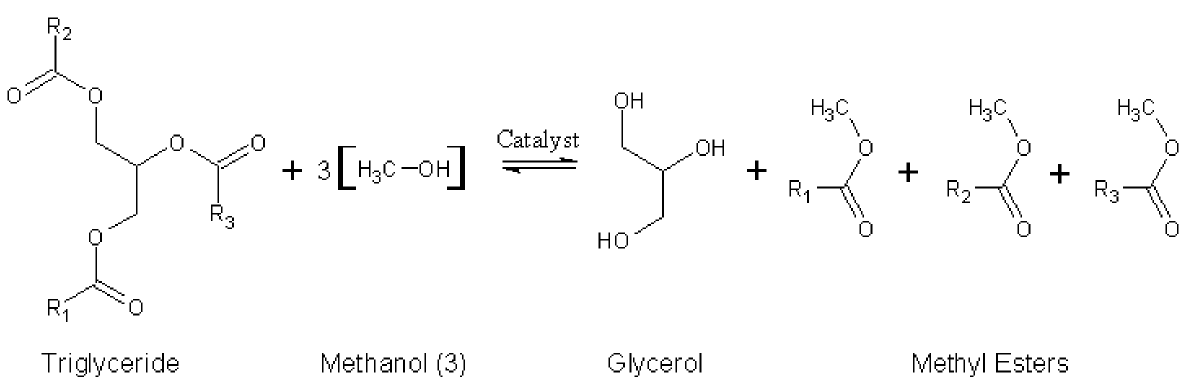

Fig. 2 Transesterification reaction

B. Waste Cooking Oil / Vegetable Oil

The term "waste cooking oil" (WCO) refers to vegetable oil which has been used in food production and which is no longer viable for its intended use. Waste vegetable oil arises from many different sources, including domestic, commercial and industrial. Waste vegetable oil is a potentially problematic waste stream which requires to be properly managed. The disposal of waste vegetable oil can be problematic when disposed, incorrectly, down kitchen sinks, where it can quickly cause blockages of sewer pipes when the oil solidifies. Properties of degraded used frying oil after it gets into sewage system are conductive to corrosion of metal and concrete elements. It also affects installations in waste water treatment plants. Thus, it adds to the cost of treating effluent or polluted waterways. Waste vegetable cooking oil cannot be reused or properly disposed. This waste vegetable oil can be used for biodiesel preparation as raw material. This is one of the important energy resources.

C. Waste Cooking Oil / Vegetable Oil

Pyrolysis process is a better method for converting waste plastics into plastic oil because of their advantages such as self-governing feedstock, least amount of waste produced, low pressure operation and high conversion efficiency in the order of 80%, Plastics can be converted into hydrocarbon fuels since it contains hydrogen and carbon. LDPE (Low Density Polyethylene) is defined by a density range of 0.910–0.940 g/cm^3. It is widely used for domestic as well as industrial applications.

Pyrolysis is the chemical decomposition of organic substances by heating. The word is originally coined from the Greek-derived elements pyro meaning “fire” and lysys meaning “decomposition”. Pyrolysis is usually the first chemical reaction that occurs in the burning of many solid organic fuels, like cloth, wood, and paper, and also of some kinds of plastic. The process involved in the pyrolysis technology is thermal degradation process in the absence of oxygen. Plastic waste is treated in a cylindrical reactor at temperature of 300ºC – 350 ºC.

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 non-condensable gas goes through Water before it is used for burning. Since the plastics waste is processed at about 300ºC – 350ºC 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. Pyrolysis process can also be used to produce liquid fuel similar to diesel from plastic waste.

The oil produced in a pyrolysis process is acidic, with a PH of 1.5-3.8. The acidity may be lessened by the addition of readily available base components.

II. PRODUCTION OF BIODIESEL FROM WASTE COOKING OIL

A. Determination of FFA (Free Fatty Acid)

1) Apparatus Required : Syringes, weigh balance, beakers.

2) Chemicals Required: isopropyl alcohol, NaOH pellets, phenolphthalein indicator.

3) Procedure

a) 1 ml of oil was mixed with 10ml of isopropyl alcohol.

b) To this some drops of phenolphthalein indicator was added.

c) 1g NaOH was mixed with 1L of distilled water which will serve as the known basic solution.

d) Now 10ml of this known basic NaOH solution was taken in a syringe.

e) Add this to the oil-isopropyl alcohol mixture with thorough shaking.

f) Note the amount of NaOH used when solution completely turn pink.

g) Repeat this 3 times.

B. Transesterification

1) Apparatus Required: Magnetic Stirrer, thermometer, beakers

2) Chemicals Required: NaOH pellets, Methanol

3) Procedure

a) 500ml of oil was taken and heated it on magnetic stirrer such that the temperature of the oil is 70ºC and rpm at 700 for 30 min.

b) 100ml of methanol was taken and the calculated amount of NaOH pellets was added to it i.e. here (7+x)/2 for 500ml oil.

c) Mix this for 10 min such that the pellets gets completely dissolved in the methanol.

d) Add this mixture to the pre heated oil.

e) Stir this mixture at about 1000 rpm at 60c for 2 hours. Do not allow the mixture temperature to rise beyond 70º C as the methanol might vaporize.

f) Transfer the mixture to the separating funnel and wait for a much long period of time, say, an overnight.

g) A phase separation occurance is viewed i.e. the oil is found at the upper layer while the glycerin at the bottom layer.

h) Remove glycerin using separating funnel relieving valve.

i) Now the oil obtained is to be washed.

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j) Water Washing Process: After separating of glycerin some small portion of the glycerin and impurities may occur to remove those impurities we must wash the biodiesel with hot water temperature about 55º-65ºC so the sludge of glycerin is dissolved in warm water and settled in bottom of separating funnel. We can separate this wastes and water mixture with the help of the relieving valve of separating funnel.

k) Drying : The drying process is done inorder to remove the moisture content in biodiesel using open beaker, heating unit as heating mantle or magnetic stirrer, thermometer, holding stand for thermometer. In open beaker pour the biodiesel and heat up to 100º-105ºC for about 1hr so that moisture and methanol if any, can be easily removed and then gradually cool the biodiesel.

Fig. 3 Transesterification process

Fig. 4 Water washing process

III.EXTRACTION OF WASTE PLASTIC OIL

A .Selection of the heating element

Thermal analysis was done so as to find the power of the heater required and the dimensions of the furnace.

1) The electric power of the heater was found after the solid works analysis. The volume of the cylinder was calculated based on the volume of the plastic to be stored. A suitable thickness of the furnace was selected and the power developed in heating element was varied and analyzed.

2) Analysis for 3mm thick mild steel chamber under convective condition surrounded by a glass wool in its curved surface and hot air at the upper part was done.

3) The reactor was modeled and a heating element was providing with material as copper.

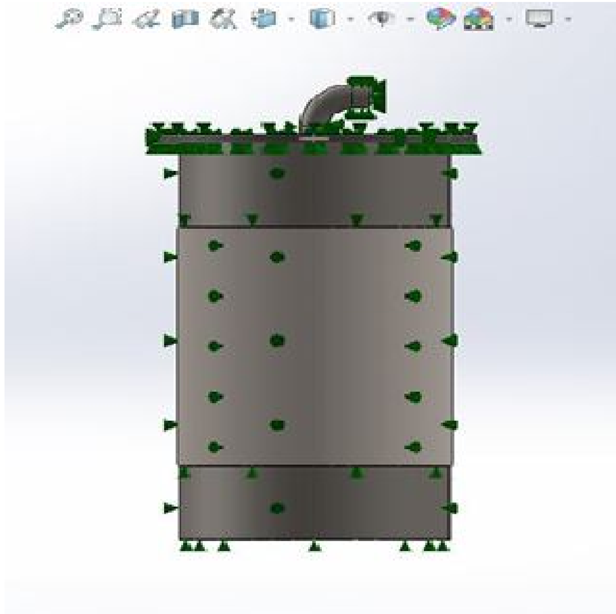

Fig.5 Model of the furnace

B. Thermal analysis of furnace

Convective coefficient of air was given as 1.5 considering the fact that there is small layer of glass wool around the furnace.

Based on above criterion, analysis was done so as to get the pyrolysis temperature in the reactor i.e. 350-450 degree Celsius. The electric power of the heater was varied and it was found that a temperature of around 600-500ºC was developed in the reactor when heater was at 3000W.

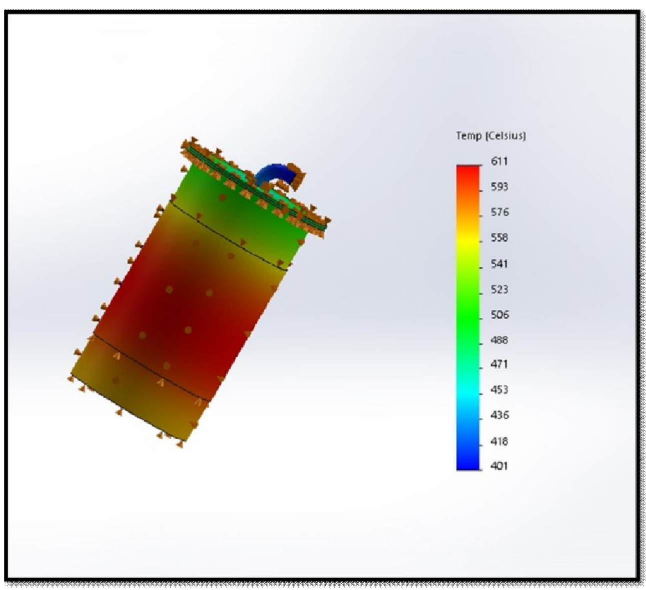

Fig.6 Thermal analysis of furnace

C. Assembly

Assembly of the setup follows the fabrication and testing of the components required for the process. The stand is placed where the setup is to be installed so as to conduct the experiment. The experiment is performed outdoors for safety. The frame is carefully placed on the stand. The next step involves carefully installing the furnace and the insulation. Then carefully place the furnace in the along cylinder. The wires of the electric furnace are sealed in insulating material. Insulations are placed in the rest of the space surrounding the furnace. This ensures minimum heat loss from the furnace in all directions except the top. The frame lid is then used

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to cover the furnace inside the frame. The lid prevents heat loss. The penultimate step is inserting the heating chamber through the lid into the furnace. The final step of the assembly is placing the helical coil heat exchanger assembly on the stand.

Fig.7 Waste plastic oil extraction set up

D. Extraction procedure

For performance of the experiment, the material selected is first added to the heating chamber. The next step is placing the heat sealing gasket between the flanges and fastening the flanges using nut bolting. The fasteners are tightened so that the gasket properly seals the flanges. No air leakage is tolerated as this may result into combustion of the polymers being used. The empty water tank is filled with water before starting the test. The water is filled so that the major part of the coil is immersed under water. This helps to increase the effectiveness in heat exchange. After final inspection the electric supply to the furnace is switched on and the experiment begins. A stopwatch is used so as to keep a track of observations with respect to time. After switching on the apparatus, approximately 15 minutes later it is observed that furnace starts heating considerably. This can be inferred as the hot fumes can be observed rising up from the little gaps in the frame and the heating chamber. Approximately 40 minutes after the start, it is observed that milky fumes are obtained from the outlet. Also the heat sealing gasket is seen to emit some fumes as it heats up. However these observations last for a few minutes until the entire setup attains high temperature (400°C and above). Using 1.5 kg of plastic is used in the experiment.. 85 minutes after the start of the experiment, it is observed that drops of oil start falling from the outlet. A funnel and a flask for oil collection are placed below the outlet.

Fig.8 Waste plastic oil

IV. PERFORMANCE CHARACTERISATION ON ENGINE

The maximum load that can be applied on the engine is calculated. Precautions are taken(No load engine, fuel system check, lubricating system check, cooling system check),engine is started by cranking. Engine is allowed to heat up for, say ‘t’ minutes. At this no load condition, time is noken for 10 cc of fuel consumption using the stopwatch. Engine is loaded up to the maximum load in 5 or 6 equal steps. Time is noted for 10 cc of fuel consumption after each load applied. Observations are tabulated for each fuel, engine is unloaded and stopped by cutting off the fuel supply.

A. Type of engine
1) Single cylinder water cooled
2) Bore: 102mm
3) RPM: 1500
4) BHP: 10
5) Stroke: 110mm
6) Dynamometer Constant: 2000

B. Parameters assessed
1) Brake Power
2) Total Fuel Consumption
3) Specific Fuel Consumption
4) Brake Mean Effective Pressure
5) Brake Thermal Efficiency
6) Indicated Power
7) Indicted Mean Effective Pressure
8) Indicated Thermal Efficiency
9) Mechanical Efficiency

C. Various blends used
1) B20: 20% biodiesel and 80% diesel blend
2) B30: 30% Biodiesel and 70% diesel blend
3) B20+WPO10: 20% Biodiesel 10% Waste plastic oil and 70% diesel blend
4) B20+WPO20: 20% Biodiesel 20% Waste plastic oil and 60% diesel blend

Then the efficiencies and the physiochemical properties of the biodiesel is to be compared with those of diesel and the best blend is to be selected.

V. RESULTS AND OBSERVATIONS

A. Characterisation

1) Characterisation of Diesel: Following were the results obtained in density, specific gravity, cetane number experiment calculations

TABLE I
CHARACTERISATION OF DIESEL

Density	850 Kg/m^3
Specific Gravity	0.850
Cetane Number	47

Properties of diesel were obtained with saybolt viscometer, Pensky marten's flash and fire point apparatus, bomb calorimeter, cloud and pour point apparatus and following observations were made.

TABLE IIPROPERTIES OF DIESEL

Viscosity (mm^2/s)	2.71
Flash Point (ºC)	56
Fire Point (ºC)	62
Cloud Point (ºC)	-6
Calorific Value(J/Kg K)	45208.5

2) Characterisation of Blend using Biodiesel from Waste Cooking Oil: Following were the results obtained in density, specific gravity experiment calculations.

Table iii
Characterisation of blend using biodiesel from waste cooking oil

	B100	B50	B30	B20	B10	B5
Density(Kg/m^3)	890	873	860	857	853	850
Specific Gravity	0.890	0.873	0.860	0.857	0.853	0.850

Properties of biodiesel were obtained with saybolt viscometer, Pensky marten's flash and fire point apparatus , bomb calorimeter and following observations were made.
Hence it was found that the biodiesel of grade B100 cannot be directly used in the engine due to its high fire point and viscosity. By comparing the above properties it was found that biodiesel B20 has the most comparable properties with diesel.

TABLE IV
PROPERTIES OF BIODIESEL

	Flash Point (ºC)	Fire Point (ºC)	Calorific Value (kJ/kgK)	Viscosity (mm^2/s)
B100	>110	-	8945	3.83
B50	65	70	39750	3.41
B30	64	70	41825	3.25
B20	62	67	42090	2.95
B10	60	66	42580	2.81
B5	58	64	42595	2.74

3) Characterisation of Plastic Oil and it's Blends with Biodiesel: Its density was also found by the experiment and properties of blends were obtained with saybolt viscometer, Pensky marten's flash and fire point apparatus, bomb calorimeter and following observations were made

TABLE V
CHARACTERISATION OF PLASTIC OIL AND IT'S BLENDS WITH BIODIESEL

Blends	Density (Kg/m^3)	Specific gravity	Flash Point (ºC)	Fire Point (ºC)	Calorific Value (kJ/kgK)	Viscosity (mm^2/s)
WPO	820	0.821	54	62	44514	2.31
B20 + WPO 10	858	0.858	56	60	44269	2.46
B20 + WPO 20	852	0.852	58	62	43870	2.42

Fig.9 B20

Fig.10 B30

Fig.11 B20 + WPO20

Fig.12 B20+ WPO10

B. Graphs

1)Specific Fuel Consumption: The rate of fuel consumption divided by the rate of power production is termed as Brake specific fuel consumption. Brake specific fuel consumptions descend from lower to higher load conditions. It is related with brake thermal efficiency. At higher load conditions the brake thermal efficiency is decreased and brake specific fuel consumption increased. Figure shows the variation of brake specific fuel consumption (SFC) with load for B20, B30, B20+WPO10, B20+WPO20. As the load increases, SFC decreases for all fuel blends up to part load. The engine will consume more fuel with diesel and waste plastic oil blends than with neat diesel fuel to gain the same power output due to the lower calorific value of blended fuel.

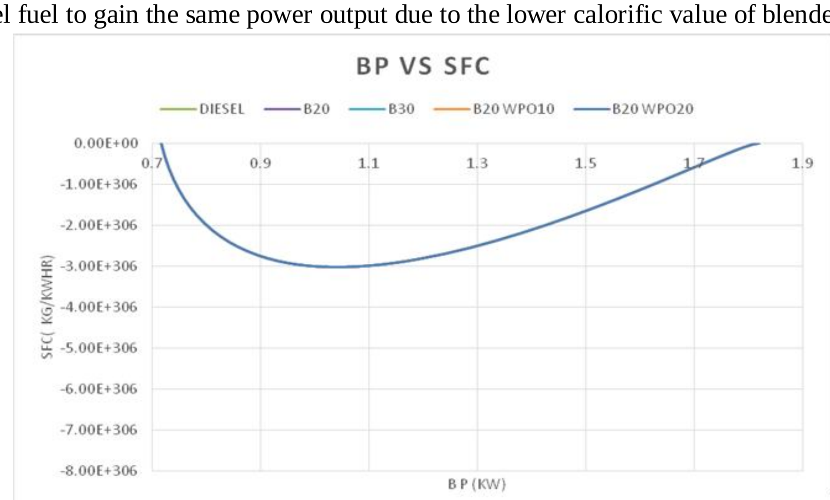

Fig.13 BP Vs SFC

2) Total Fuel Consumption: Fuel consumption is the reciprocal of Fuel Efficiency. Hence, it may be defined as the amount of fuel used per unit distance, expressed in litres/100km. Lower is the value of fuel consumption, more economical is the vehicle. That is, less amount of fuel will be used to travel a certain distance. Hence, here pure diesel itself is the most economic one though the B20 +WPO10 blend is close to it.

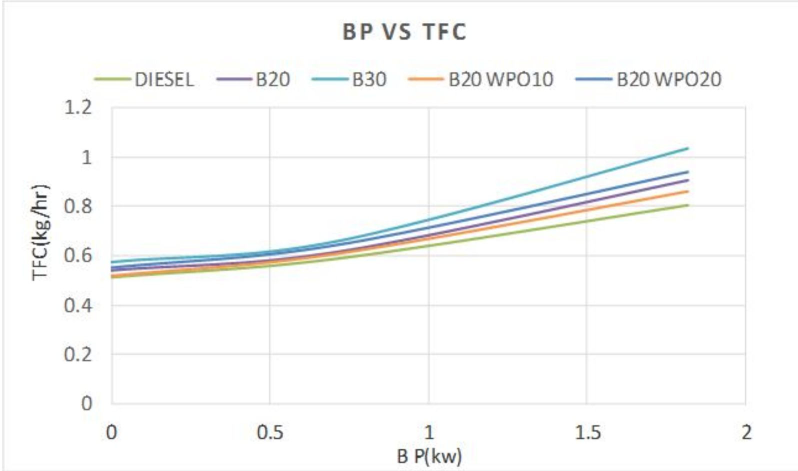

Fig.14 BP Vs TFC

3) Break Thermal Efficiency: The variation of brake thermal efficiency with load for WPPO-Diesel blends is shown in figure. The brake thermal efficiency is lower for the WPO-Diesel blends than diesel at full load. WPO is a mixture of hydrocarbons varying from C10 to C30 having both low and heavy fractions with aromatics. Because of the changes in composition, viscosity, density and calorific value of WPO-Diesel blends, the brake thermal efficiencies of WPPO-Diesel blends are high at part loads. Most closer one with that of diesel is B20 + WPO 10

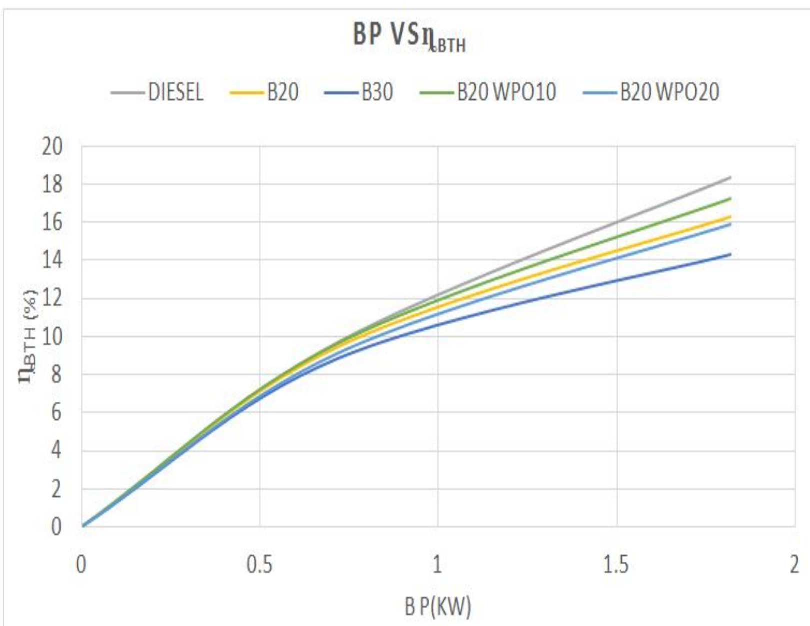

Fig.15 η_{Bth}Vs BP

*4) Indicated Thermal Efficiency:*The indicated thermal efficiency gives an idea of the power generated by the engine (consider zero heat loss) within the cylinder with respect to heat supplied (theoretically calculated chemical energy of fuel) in the form of fuel. It is the ratio between indicated power output and rate of supply of energy in steam. Again it is found that the maximum efficiency is for diesel while B30 and B20 has lesser effiencies.

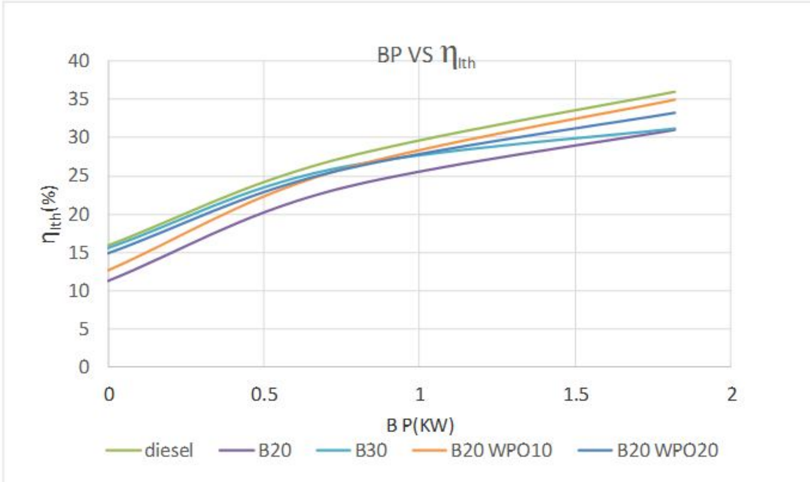

Fig.16 BP Vsη_{Ith}

*5) Mechanical Efficiency:*It is clear that the mechanical efficiency of the engine increases with an increase in load under all operating conditions. On pure diesel mode at full load, the mechanical efficiency is found to be 57.5%. When operated with B20 + WPO10, the corresponding value is 50%. It is found that B20 + WPO10 have the comparable efficiency with diesel though it is much lesser than 7%.

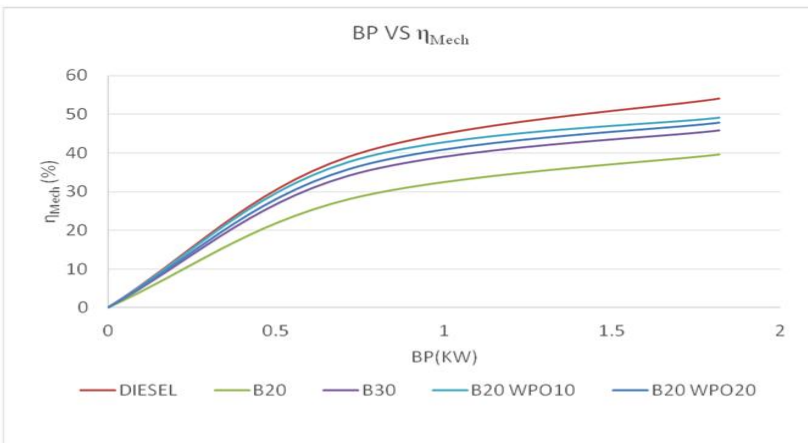

Fig.17BP Vs Mechanical Efficiency

VI. CONCLUSION

This investigation aims at increasing the life of diesel by providing an alternate mixture of waste plastic oil and biodiesel from waste cooking oil which can be blended with the diesel thereby providing an effective solution for the depleting fuel resources.This also helps reduce pollution caused by plastic as its converted into waste plastic oil and then used in diesel engines as blend.

Usually the efficient blend of biodiesel is B10 or B20 because addition of furthermore biodiesel in the blend is not feasible due to their high viscosity, flash point, fire point and lower calorific value. By using the combination of waste plastic oil which has lower viscosity and higher calorific value along with the biodiesel-diesel blend we can reduce the amount of diesel required, thereby increasing the life span of diesel.

The investigation dealt with the production, characterisation and load test of different blend of biodiesel with diesel and also along with waste plastic oil. It was found that out of B20, B30, B20+WPO10, B20+WPO20 bends the B20+WPO10 is the most comparable one with the diesel after all the characterisation and load test. Hence, this paper suggests the use of the blend B20+WPO10 as the suitable substituent for diesel.

A safe method of disposing the waste plastic has not yet been implemented, and dumping of waste plastic underground is hazardous to the environment. Here we can use it as an alternative source of fuel for gasoline and diesel. This will save the environment from hazardous effect as well as to boosting the Indian economy.

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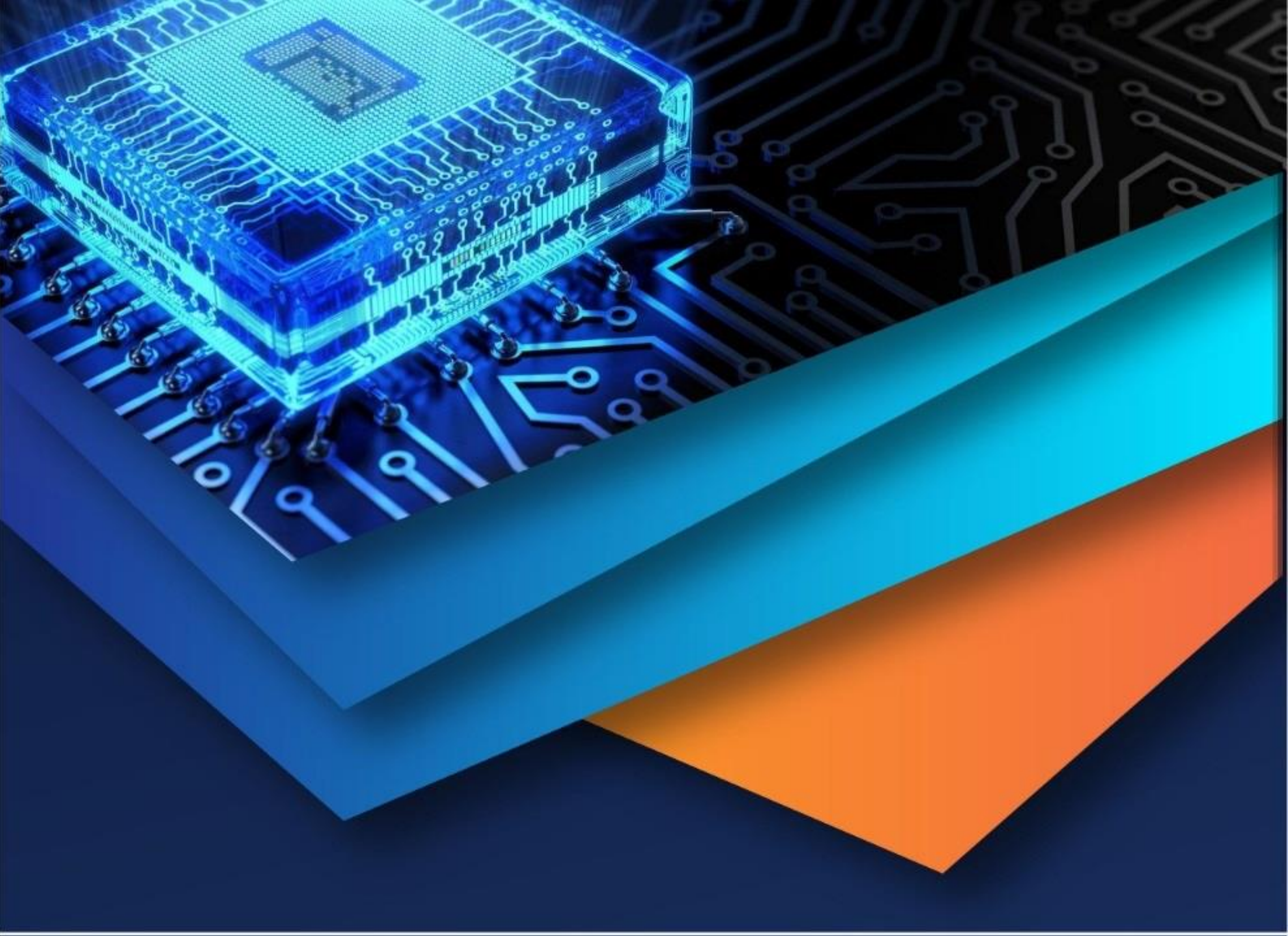

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