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Performance and Emission Analysis of Biodiesel Using Polystyrene Blended With Diesel on Single Cylinder Diesel Engine

J. Dhayanithi[1], Dr.P.Prabhakaran M.E.,Ph.D[2]
ME Student (Thermal Engineering)[1], Professor[2]
Department of Mechanical Engineering
J.J. College of Engineering and Technology, Trichy, India

Abstract:
Waste plastic can be transformed to oil by the pyrolysis and it may be applicable as a fuel for diesel engines. The pyrolysis oil property varies depending on the raw waste plastic and the pyrolysis condition, which is different from that of diesel and gasoline. This alternate should be accessible and reasonable. If this alternate is extracted from waste means its cost will be less and operative. Plastics have been one of the materials with the fastest growth in this world because of their huge applications due to flexibility and relatively low cost. As a result of increase in the consumption of plastics, large amount of plastic wastes are generated from their production and transportation. The need for manage this waste from plastic becomes more important. This leads to pyrolysis, which is a way of making these wastes to become very useful to us by recycling them to produce fuel oil. In this present work, plastic oil is extracted from these plastic wastes through pyrolysis process. It runs without oxygen and in high temperature range of 500 – 530^{o} C with 10 wt. % of Aluminium oxide catalyst in the quantity. The resulting plastic oil is received. Performance and emission tests were carried out for 10%, 30%, and 50% Waste plastic oil (PS) diesel blends. Results confirm that the performance and emission of the engine fuelled with Waste plastic oil their blend with diesel fuel is by and large comparable with pure diesel.

Key words: pyrolysis, waste plastic, diesel, Extracted, Aluminium oxide catalyst, Performance and Emission tests

1. INTRODUCTION

1.1 Alternative fuels

Alternative fuel, also known as non-conventional fuels, is any material that can be used as a fuel, other than conventional fuels like petroleum, coal, propane, hydrogen, and natural gas. Some well-known alternative fuels includes Biodiesel**,** Bioalcohol, Fuel cell**,** Hydrogen**,** Compressed natural gas (CNG)**,** Liquefied natural gas (LNG), Liquefied petroleum gas (LPG) and Vegetable oil.

Benefits of an alternative fuels

- Lower emissions and fewer toxic contaminants than gasoline and diesel. Alternative fuel has inherently lower harmful emissions, including toxic contaminants, compared to gasoline and diesel vehicles
- Reduce dependence on imported oil. Alternative fuels can be extracted and produced domestically, reducing our dependence on a finite supply of imported oil which can be subject to fluctuations in price and supply.
- Renewable fuel source. Many alternative fuels come from renewable sources of energy, providing greater energy efficiency in the development of fuels and reducing dependence on finite sources of energy
- Provide air quality benefits at reasonable cost Alternative fuels have the potential to provide significant air quality benefits at lower costs.
- Reduced potential of environmental damage liability. The use of alternative fuels may reduce the threat of soil and water contamination hat can result from a gasoline or diesel spill or leaking underground storage tanks.

1.2. PLASTICS

Plastics are used on a daily basis throughout the world. The fact that plastic is lightweight, does not rust or rot, low cost, reusable and conserves natural resources is the reason for which plastic has gained this much popularity. The word plastic is a common term that is used for many materials of a synthetic or semi-synthetic nature. The term was derived from the Greek plastikos, which means "fit for molding." Plastics are a wide variety of combinations of properties when viewed as a whole. These are typically polymers of high molecular mass, and may contain other substances to improve performance and reduce costs. Monomers of plastic are either natural or synthetic organic compounds.

1.2.1. Plastics production

Distillation: Most modern plastics are derived from natural materials such as oil; coal and natural gas with crude oil remaining are the most important raw material for their production. The starting point for the production process is the distillation, in petrochemical refineries, of the raw material into fractions. The heavy fractions give us lubrication oils and the heavy oils used for heating fuels. The lighter fractions give us gas, petrol, paraffin and naphtha. The chemical building blocks for making plastics come mainly from naphtha.

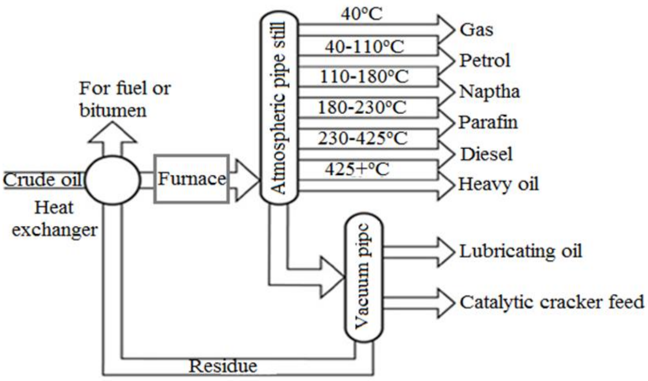


Figure.1.1 Distillation process

Naphtha cracking: The naphtha received from distillation is subjected to a cracking process in which complex organic chemical compounds are separated into smaller molecules, dependent on their molecular weight. These smaller molecules include monomers like ethylene, propylene, butane and other hydrocarbons.

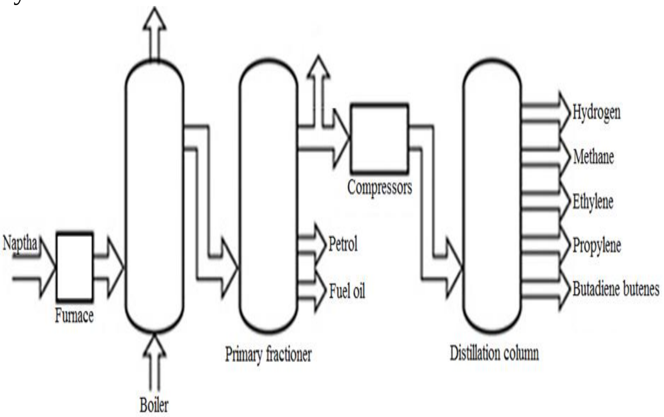


Figure.1.2.Naphtha cracking

Polymerization: Polymerization is the process by which individual units of similar or different molecules combine together by chemical reactions to form large or macromolecules in the form of long chain structures, having altogether different properties than those of starting molecules. Several hundreds and even thousands of monomers are combining together to form the macromolecules, polymers.

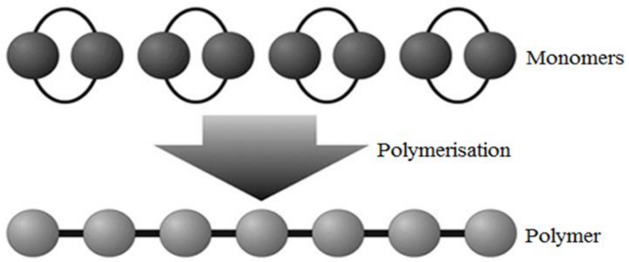


Figure.1.3.Polymerization

1.2.2. Types of plastics

There are mainly two types of plastics are there

1.2.2.1 Thermoplastics

1.2.2.2 Thermosetting plastics

1.2.2.1. Thermoplastics

Thermoplastics are those, which once shaped or formed, can be softened by the application of heat and can be reshaped repeatedly, till it loses its property. Example: Polyethylene, Polypropylene, Nylon, Polycarbonate etc. Applications: Polyethylene Buckets, Polystyrene cups, Nylon ropes etc.

1.2.2.2. Thermosetting plastics

Thermosetting Plastics are those, which once shaped or formed, cannot be softened by the application of heat. Excess heat will char the material. Example: Phenol formaldehyde, Urea Formaldehyde, Melamine Formaldehyde, Thermosetting Polyester etc. Applications: Bakelite melamine Cutlery etc.

1.2.3. Plastics number classification and its description

Many consumer products, such as water bottles and product containers, are made from various types of plastic. The Society of the Plastics Industry (SPI) established a classification system in 1988 to allow consumers and recyclers to properly recycle and dispose of different types of plastic. Manufacturers follow a coding system and place an SPI code, or number, on each plastic product, which is usually molded into the bottom. Although you should always verify the plastic classification number of each product you use, this guide provides a basic outline of the different plastic types associated with each code number.

1.2.4. Plastic waste generation

Plastics usage throughout the world is increasing day by day because of its advantages like light weight, low cost, reusability and conservation of energy. So, plastic production has increased by an average of almost 10 % every year on a global basis since 1950. The total global production of plastic has grown from 1.3 million tonnes in 1950 to 245 million tonnes. The growth of the Indian plastic industry has been remarkable equal to 17% is higher than for the plastic industry elsewhere in the world. The rapid rate of plastics production and consumption throughout the world has led to the generation of increasing amounts of waste and this turn in poses greater difficulties for disposal. Plastic wastes can be classified as industrial and municipal wastes according to their origins. Municipal plastic wastes (MSW) normally remain a part of municipal solid wastes as they discarded and collected as household wastes the various sources of MSW includes domestic items such as food containers, packaging foam, CD, fridge liners, electronic equipment cases, drainage pipes, plumbing pipes etc., agricultural items and automobile wrecking. Industrial plastic wastes are those arising from the large plastics manufacturing, processing and packaging industry. The industrial waste plastic mainly constitute plastic from construction and demolition companies, electrical and electronics industries and the automotive industries spare parts for cars such as fan blades, seat coverings, battery containers and front grills.

1.2.5 Plastic waste management

There are several methods are used for plastic waste management. The following figure shows the methods of plastic waste management.

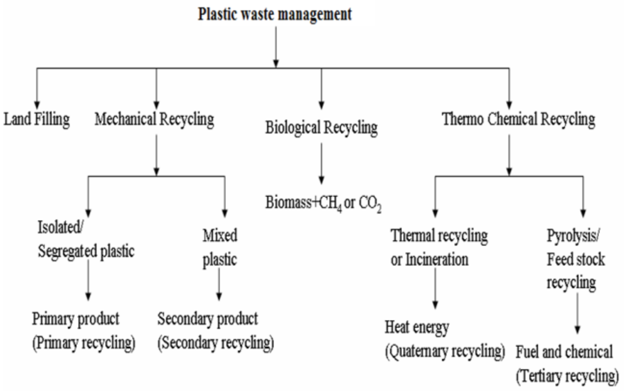


Figure. 1.4 Plastic waste management

1.2.5.1 Land filling

Highest portion of solid waste including plastics have been subjected to landfill. However, disposing of the waste to landfill is becoming undesirable due to legislative pressures, rising costs, the generation of explosive greenhouse gases and the poor biodegradability of commonly used packaging polymers. Since waste plastics have a high volume to weight ratio, appropriate landfill space is becoming both scare and expensive.

1.2.5.2 Mechanical recycling

Mechanical recycling is reprocessing of the used plastics to form new similar products. This is a type of primary and secondary recycling of plastic where the homogeneous waste plastics are converted into products with nearly same or less performance level than the original product. Mechanical recycling of household waste plastics is particularly difficult when they are contaminated with biological residues or as is usually the case when they are a mixture of different kinds of plastics.

1.2.5.3 Thermal recycling

It is also known as incineration. Energy generation by incineration of plastic waste is in principle a viable use for recovered waste polymers since hydrocarbon polymers replace fossil fuels and thus reduce the CO2 burden on the environment. Incineration is the preferred energy recovery option of local authorities because there is financial gain by selling waste plastic as fuel. Co-Incineration of plastic wastes with other municipal solid wastes may be increasingly practiced, because the high calorific value of plastic can enhance the heating value of MSW and facilitate an efficient incineration, while their energy content can also be recovered.

1.2.5.4 Chemical recycling

Chemical recycling is also known as feedstock recycling or tertiary recycling. This process converts polymers into original monomers or other valuable chemicals. These products are useful for a variety of downstream industrial processes or as transportation fuels. There are three main approaches depolymerisation, partial oxidation and pyrolysis. Condensation polymers which include materials such as polyamides, polyesters, nylons and polyethylene terephthalate can be depolymerised via reversible synthesis reactions to initial diacids and dicols or diamines. The direct combustion of polymer waste, which has a good calorific value, may be detrimental to the environment because of the production of noxious substances such as light hydrocarbons, NO_x, sulphur oxides and dioxins. Partial oxidation could generate a mixture of hydrocarbon and synthesis gas, the quantity and quality being dependent on the type of polymer used. In cracking process polymer chains are breakdown into useful molecular weight compounds. The products of plastic pyrolysis process could be utilized as fuels or chemicals. Three different cracking processes such as hydrocracking, thermal cracking and catalytic cracking are reported.

2. PROBLEM DESCRIPTION

Now a day usage of fuel is increasing along with evolution of vehicles. Therefore the fuel demand and price is increasing rapidly. On the other hand, plastics have been the one of the materials with the fastest growth in this world because of its huge applications due to flexibility and relatively low cost. Today about 129 million tonnes of plastics are produced annually all over the world out of which 77 million tonnes are produced from petroleum. As a result of increase in the consumption of plastics, large amount of plastic wastes are generated from their production, transportation and consumption. The need for manage this waste from plastic becomes more important. The largest amount plastic waste is disposed by landfilling and incineration. But this creates serious effects in the environment. This leads to pyrolysis, which is a way of making these wastes to become very useful to us by recycling them to produce fuel oil.

3. MATERIALS

3.1 POLY STYRENE

In this present work Poly styrene (PS) plastic is used to obtain fuel range hydrocarbon by pyrolysis. Poly styrene (PS) waste plastics have been considered for the experiments. Poly styrene (PS) is a thermoplastic material which is made from petroleum. This thermoplastic is available in a range of flexibilities depending on the production process. High density materials are the most rigid. The polymer can be formed by a wide variety of thermoplastic processing methods and is particularly useful where moisture resistance and low cost are required. It is stronger than standard polyethylene, acts as an effective barrier against moisture and remains solid at room temperature. It resists insects, rot and other chemicals. It is easily recyclable and can be used again and again. Recycled PS creates no harmful emissions during its production or during its use by the consumer. Also, PS leaks no toxic chemicals into the soil or water. In general, high density grades of polyethylene have densities up to $0.97 g/cm^3$. Low density grades are as low as $0.91 g/cm^3$. Typically, the high-density material is more linear and consequently more crystalline. As might be expected, this higher crystallinity permits use at temperatures upto 130^oC with somewhat better creep resistance below that temperature. Low density polyethylene has less stiffness than the high density polyethylene. A linear polymer, Poly styrene (PS) is prepared from ethylene by a catalytic process. The absence of branching results in a more closely packed structure with a higher density and higher chemical resistance than LDPE. PS is also harder and more opaque and it can withstand rather higher temperatures.

3.1.1 Physical properties of Poly styrene (PS)

Plastics have some physical characteristics, which need to be considered when processing any Product. The following table contains the physical properties of High density polyethylene.

Table 3.1 Physical properties of PS

PROPERTY	VALUE
Density	$0.958 g/cm^3$
Viscometer number	380ml/g
Melt flow rate	0.23g/10min
Specific gravity	0.95
Melting point	120^oC
Yield stress	$26 N/mm^2$
Flexural stress	$20 N/mm^2$
Stiffness in torsion	$180 N/mm^2$
Hardness	$41 N/mm^2$
Impact strength at 23^0C	$20 kJ/m^2$

3.1.2 Benefits of PS Recycling

1. PS Recycling will remove the PS plastic from the waste stream which means waste disposal costs can be reduced.
2. PS Recycling can help with workplace safety and neatness such as the reduction of fire hazards.
3. PS Recycling can lower waste processing labour costs (that are required for handling the trash destined for the landfill).
4. PS Recycling can be instrumental is streamlining overall waste processing operations.

3.1.3 Advantages of Poly styrene

1. Food Contact is Acceptable
2. Process ability is good
3. Copolymer
4. ESCR is High (Stress Crack Resist.)
5. Antioxidant
6. Density is high
7. Impact Resistance is good
8. Toughness is good

3.1.4 Disadvantage of Poly styrene

1. High thermal expansion
2. Poor weathering resistance
3. Subject to stress cracking
4. Poor temperature capability
5. Low strength/stiffness

3.2 CATALYST

Aluminium oxide or alumina oxide neutral has been used as a catalyst this process to enhance the reaction. Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3.It is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point. Alumina has been used as a catalyst in a wide variety of industrial processes for many years. Even modest improvements in alumina catalysts can have a significant impact on efficiencies of production of a very wide variety of chemical compounds. There is continuing commercial need for new tailored alumina catalyst that can more efficient produce existing chemical compounds, or that lend themselves to the production of new compounds. luminium oxide (alumina Al_2O_3) has advantages such as its thermal, chemical, and physical properties when compared with several ceramics materials, and is widely used for firebricks, abrasives and integrated circuit (IC) packages. Industrially, more than about 45 million tons of Al_2O_3 are produced in the world, which are mainly manufactured by the Bayer method using bauxite, and about 40 million tons are consumed for refining aluminium Furthermore about 5 million tons of Al_2O_3 are produced as chemical grade and used for various purposes. Moreover about 1.5 million ton Al_2O_3 is used as raw powder in the world. The amount of Al_2O_3 powder used in Japan is about 350,000 tons, what is about 20% of the total quantity produced in the world. In order to produce Al_2O_3 powder with the quality necessary to be used as ceramic material, various manufacturing methods besides the Bayer method have been developed.

3.2.1 Properties of aluminium oxide

Catalysts have some physical and thermal properties, which need to be considered when processing any Product. The following table contains the physical properties of aluminium oxide or alumina.

Table 3.2 Physical properties of aluminium oxide

Property	Value
Atomic composition	>99%
Crystalline structure	Corundum
Grain size	1-5 microns
Density	3.95 g/cm^3
Water absorption	0%

Table 3.3 Thermal properties of aluminium oxide

Property	Value
Dilation co-efficient(20-2000°C)	8.4x10^{-6} /°C
Specific heat	930 J/kg.k
Thermal conductivity	40 W/m.K
Thermal shock resistance	200°C

3.2.2 Benefits of aluminium oxide

Low cost: The compositions can be prepared from low cost aluminium salts and non-toxic surfactants.

Selectivity: The invention provides an improved ability to determine pore size and some characteristics of pore shape, including ability to obtain uniformity in the selected pore size and connectivity between pores. The result is significantly improved ability to control which chemical reactions will be catalysed at the alumina surface, with accompanying reduction of unwanted by products due to the higher catalytic selectivity.

Reactivity: The improved performance of the alumina catalysts means that catalytic production efficiencies could be higher than current levels by substantial factors for a wide variety of chemical compounds. The improved control on pore size and shape also enables reductions in unwanted by production.

3.2.3 Application of aluminium oxide

Al_2O_3 could be used for a wide variety of applications as a catalyst substrate. Major examples include chemical production using petroleum as a feedstock, catalytic converters for clean up equipment, and adsorbent's and alumina catalysts for industrial application.

1. It is used in hydrodesulphurization and some Ziegler-Natta polymerization.
2. Aluminium oxide is the catalyst in the Claus process for converting hydrogen sulphide waste gases into elemental sulphur in refineries. It is also useful for dehydration of alcohols to alkenes.

4. EXPERIMENTATION

4.1 Experimental setup

The pyrolysis setup used in this experiment consists of the reactor, condenser, thermocouple and submersible pump. Reactor made of stainless steel tube (length- 320 mm, internal diameter- 150 mm and outer diameter- 158 mm) sealed at one end and an outlet tube at other end for obtaining the volatile gas products of the reaction.

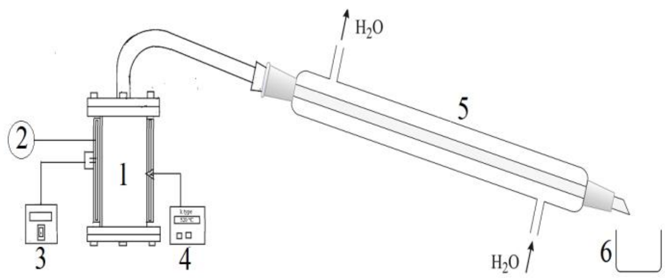


Fig 5.1.Pyrolysis experimental set up-line diagram

1. Reactor
2. Heating coil
4. Thermocouple
5. Condenser

3. Power source 6.Receiver

The SS tube is externally wounded by an electric coil for heating purpose. The coil is made up of ceramic material. The reactor is insulated by glass wool and sheet metal to avoid heat loss. Chromel - Alumel (K type) thermocouple is connected to the inner wall of the reactor to measure temperature. Liebig condenser is connected to the outlet tube. It is made up of borosilicate glass tube (Length -150cm, outer diameter -5cm, inner diameter -1.4cm). Submersible pump of 1650WP is connected to the condenser to circulate the water through the outer tube.

4.2 Experimental procedure

Initially the plastic wastes are sliced manually. Then these sliced plastic wastes were washed and dried to remove dusts. 750g of dried plastic wastes (High density of polyethylene) were fed into reactor with 75g (10% wt. of plastic) of Aluminium oxide (Al_2O_3) catalyst. Water is circulated through the condenser by using submersible pump. The coil is switched ON. The temperature is increased gradually inside the reactor. After 2hrs temperature is reached 500°C. Reactions were maintained in the temperature range of 500-530 °C. At this temperature range hot gas comes out from reactor and this hot gas is condensed by condenser. The waste plastic oil (WPO) is collected from condenser. The collected oil is become denser in atmospheric temperature. So, the oil is preheated and blended with diesel in 10 %, 30 %, 50 %, for performance test.

5. PROPERTIES OF WASTE PLASTIC OIL

Table 5.1 Properties of Waste Plastic Oil

S.No	PARAMETERS	RESULT OBTAINED FOR WPO	DIESEL
1.	Flash point by PMCC	70 °C	52 °C
2.	Fire point by PMCC	80 °C	56 °C
3.	Kinematic viscosity @ 40°C	2.60 cst	2.60 cst
4.	Density @15°C	0.8460 gm/ml	0.850 gm/ml
5.	Gross calorific value	9900 Kcal/ kg	4392 Kcal/ kg
6.	Conrad son carbon residue	0.05 %	0.17 %
7.	Ash content	0.01%	0.01%

6. PERFORMANCE TEST

Engine performance is an indication of the degree of success with which it does its assigned job *i.e.*, conversion of chemical energy contained in the fuel into useful work.In evaluation of engine performance certain basic parameters are chosen and effect of various operating conditions and modifications on these parameters are studied.

6.1 BASIC PERFORMANCE PARAMETERS

1. Power and mechanical efficiency
2. Mean effective pressure
3. Volumetric efficiency
4. Thermal efficiency
5. Specific fuel consumption

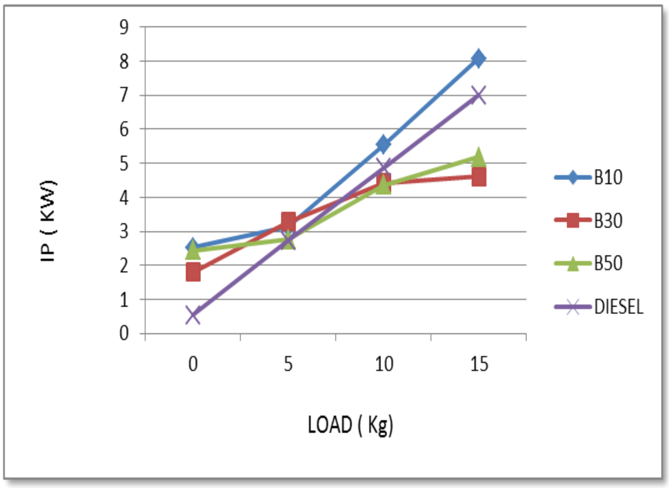
Figure 6.1 Test rig VCR research engine

6.2 DATA COLLECTION

There are five test fuels were used during performance test includes 100 % diesel, 10 % WPO blend with diesel, 30% WPO blend with diesel, 50 %WPO blend with diesel. The following tables shows the obtained data's from performance tests for various WPO diesel blends such as Brake power, Indicated power, Mechanical efficiency, brake mean effective pressure, brake thermal efficiency, indicated thermal efficiency, specific fuel consumption.

Table 6.1 Indicated power for various WPO Diesel blends

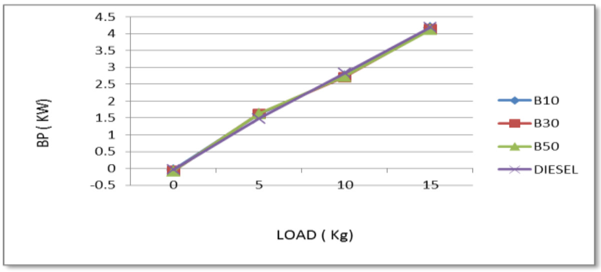
LOAD (kg)	INDICATED POWER (kW)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	2.52	1.79	2.43	0.54
5	3.13	3.28	2.76	2.72
10	5.53	4.42	4.35	4.86
15	8.08	4.61	5.18	7



This graph shows how the indicated power is varies for 10 %, 30 %, 50% Waste plastic oil diesel blends and pure diesel. Indicated power for diesel at 15kg is 7 kW. Indicated power for 10 %, 30 %, and 50 % of Waste plastic oil diesel blend is 8.08, 4.61, and 5.18 kW respectively. It clear that indicated power is decreases if the WPO percentage in fuel is increased

Table 6.2 Brake power for various WPO Diesel blends

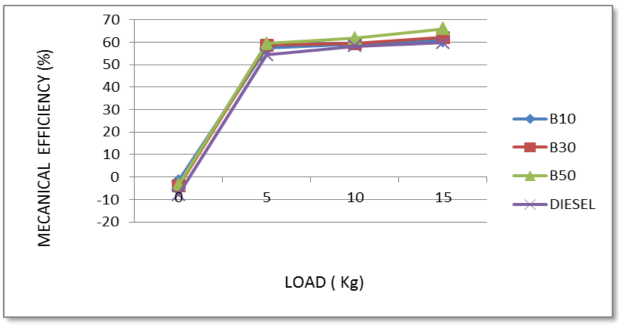
LOAD (kg)	BRAKE POWER (kW)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	-0.05	-0.07	-0.08	-0.04
5	1.61	1.62	1.62	1.48
10	2.74	2.71	2.73	2.83
15	4.17	4.13	4.11	4.19



This shows how the brake power is varies for 10 %, 30 %, 50% Waste plastic oil diesel blends and pure diesel. Brake power for diesel at 15kg is 4.19 kW. Indicated power for 10 %, 30 %, and 50 % of Waste plastic oil diesel blend is 4.17, 4.11, and 4.23 kW respectively. It is observed that brake power for different blends is higher as compared to pure diesel.

Table 6.3 Mechanical efficiency for various WPO Diesel blends

LOAD (kg)	MECHANICAL EFFICIENCY (%)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	-1.86	-4.07	-3.44	-7.86
5	57.35	58.78	59.5	54.32
10	59.18	59.45	61.83	58.29
15	60.79	62.1	65.99	59.77



The comparisons of WPO diesel blends with pure diesel are shown in figure. Mechanical efficiency for pure diesel at 15kg load is 59.77 %. The same for 10 %, 30 %, and 50 % WPO diesel blends are 60.79 %, 62.1%, and 65.99% respectively. It is observed that for all WPO diesel blends mechanical efficiency is higher when compared to pure diesel. It is also observed that the mechanical efficiency is increased from 60.79 to 62.1 % for 30 % WPO diesel blend from 10 % WPO diesel blend and again it is increased to 65.99 % for 50 % WPO diesel blend.

Table 6.4 Brake mean effective pressure for various WPO Diesel blends

LOAD (kg)	BRAKE MEAN EFFECTIVE PRESSURE (%)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	-0.06	-0.09	-0.1	-0.05
5	1.74	2.12	2.74	1.78
10	3.5	3.37	4.78	3.46
15	5.45	5.95	6.98	5.19

The variation of brake mean effective pressure for various WPO diesel blend and pure diesel is shown in figure. Mean effective pressure for pure diesel at 15kg load is 5.19 bar. The same for 10 %, 30 %, and 50 % WPO diesel blends are 5.45, 5.95, and 6.98 bar respectively. It is observed that for 50 %WPO brake mean effective pressure is higher as compared to diesel after that it is decreases for 10 % and 30 % WPO gradually.

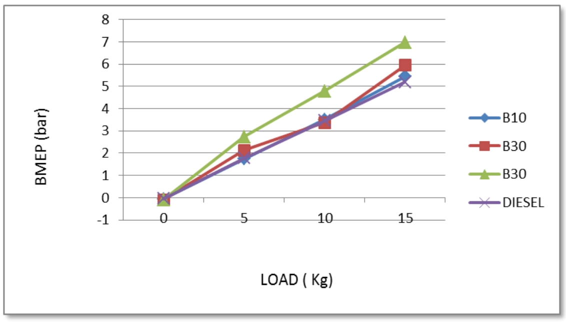
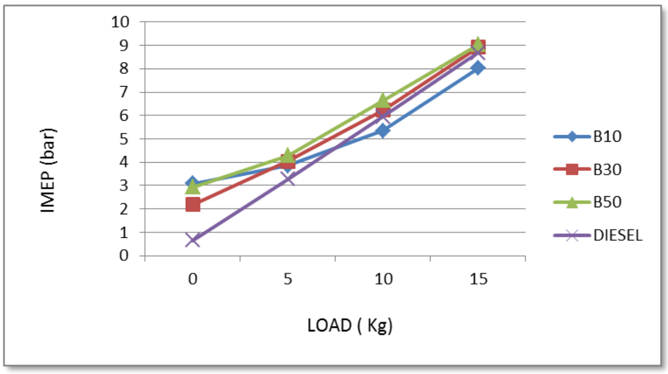


Table 6.5 Indicated mean effective pressure for various WPO Diesel blends

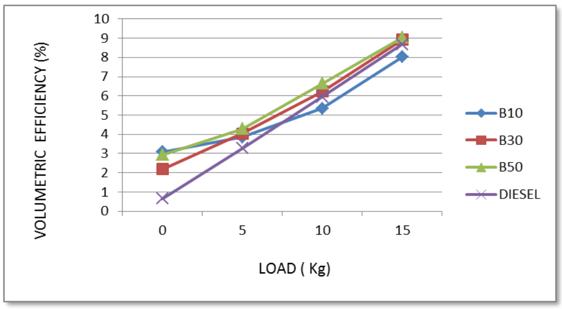
LOAD (kg)	INDICATED MEAN EFFECTIVE PRESSURE (kW)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	3.08	2.19	2.93	0.64
5	3.84	4.04	4.28	3.27
10	5.34	6.23	6.63	5.94
15	8.02	8.92	9.03	8.68



The variation of indicated mean effective pressure for various WPO diesel blend and pure diesel is shown in figure. Indicated mean effective pressure for pure diesel at 15kg load is 8.68 bar. The same for 10 %, 30 %, and 50 % WPO diesel blends are 8.02, 8.92, and 9.03 bar respectively. It is observed that indicated mean effective pressure is decreases if WPO diesel blend is increases.

Table 6.6 Volumetric efficiency for various WPO Diesel blends

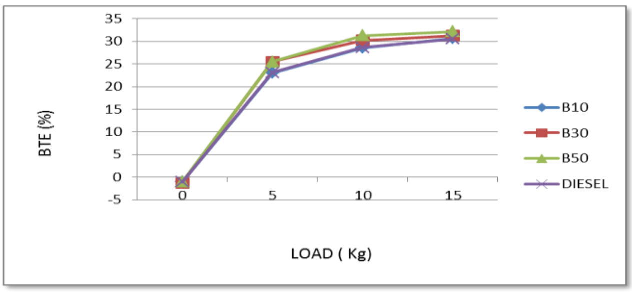
LOAD (kg)	VOLUMETRIC EFFICIENCY (%)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	81.16	81.77	82.54	79.03
5	81.07	81.75	81.74	78.13
10	80.98	81.58	81.79	77.14
15	80.7	81.24	81.73	75.89



The variation of volumetric efficiency with load is shown in Figure. It can be observed from the figure that the volumetric efficiency is 75.89 % at 15kg for diesel. However when the engine is fuelled with WPO-diesel blends such as 10% WPO, 30% WPO, and 50% WPO, It gives the volumetric efficiency of 80.7%, 81.24% and 81.73%, respectively at full load. It is observed that the volumetric efficiency of the Waste plastic oil blend is closer or slightly higher to diesel except 30 % WPO diesel blend.

Table 6.6 Brake thermal efficiency for various WPO Diesel blends

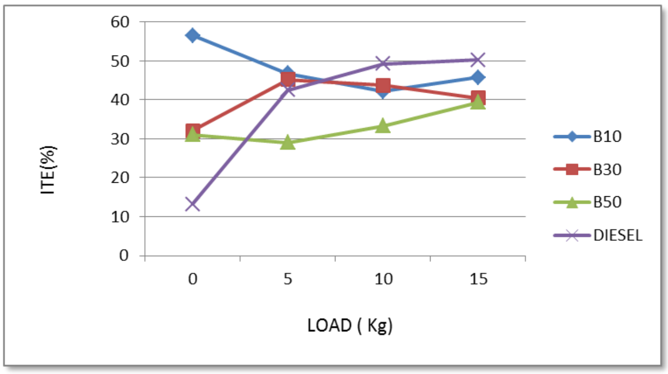
LOAD (kg)	BRAKE THERMAL EFFICIENCY (%)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	-1.05	-1.31	-1.07	-1.04
5	23.06	25.5	25.53	23.11
10	28.59	30.2	31.28	28.68
15	30.66	31.25	32.16	30.56



The variation of brake thermal efficiency with load is shown in Figure. It can be observed from the figure that the thermal efficiency is 30.56% at 15kg load for diesel. However when the engine is fuelled with WPO-diesel blends such as 10% WPO, 30% WPO, 50% WPO, it gives the thermal efficiency of 30.66%, 31.25%, 32.16 % respectively at 15kg load. It is also observed that brake thermal efficiency is higher for 10%, 30 % and 50% WPO when compared to pure diesel.

Table 6.7 Indicated thermal efficiency for various WPO Diesel blends

LOAD (kg)	INDICATED THERMAL EFFICIENCY (%)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	56.53	32.09	31.05	13.17
5	46.82	45.24	29.05	42.53
10	42.22	43.77	33.35	49.21
15	45.74	40.46	39.42	50.2

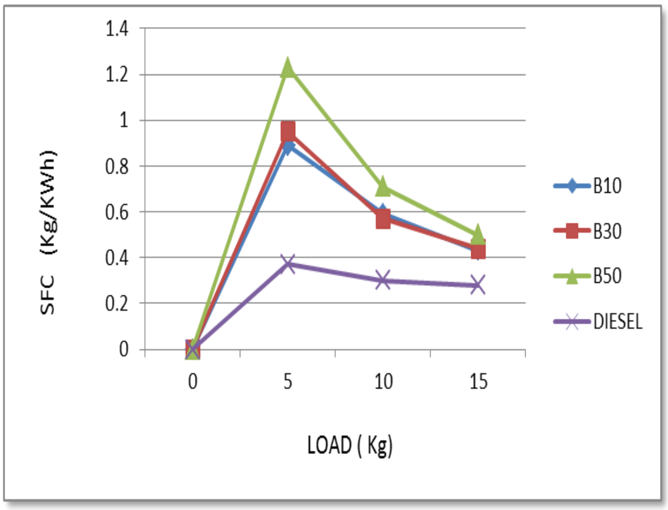


The variation of indicated thermal efficiency with load is shown in Figure. It can be observed from the figure that the indicated thermal efficiency is 25.2 % at 15kg load for diesel. When the engine is fueled with WPO diesel blends such as 10% WPO, 30% WPO, and 50% WPO, it gives the thermal efficiency of 41.99%, 128.78%, and 45.86% respectively at 15 kg load. It is also observed that indicated thermal efficiency is also higher for 30% and 50% blends and it is slightly lower for 10% WPO Diesel blend when compared to pure diesel.

Table 6.8 Specific fuel consumption for various WPO Diesel blends

LOAD (kg)	SPECIFIC FUEL CONSUMPTION (kg/kWh)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	0	0	0	0.00
5	0.89	0.95	1.23	0.37
10	0.59	0.57	0.71	0.30
15	0.43	0.44	0.5	0.28

The variation of specific fuel consumption with load is shown in Figure. It can be observed from the figure that the specific fuel consumption is 0.28kg/kWh at 15kg load for diesel. When the engine is fueled with WPO diesel blends such as 10% WPO, 30% WPO and 50% WPO, its specific fuel consumption is 0.43 and 0.44 kg/kWh, and 0.5 kg/kWh respectively at 15kg load. It is also noted that the specific fuel consumption is increased for 10 %, 30 % and 50% WPO Diesel blends when compared to pure diesel.



7. EMISSION TEST

7.1 Types of Emission

1. Carbon monoxide (CO)
2. Hydrocarbons (HC)
3. Carbon dioxide (CO_2)
4. Oxygen (O_2)
5. Nitrogen oxide (NO_X)

Table 7.1 carbon monoxide (CO) for various WPO Diesel blends

LOAD (kg)	CARBON MONOXIDE (CO)(% BY VOLUME)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	0.07	0.08	0.08	0.09
5	0.07	0.08	0.09	0.09
10	0.08	0.08	0.09	0.07
15	0.11	0.12	0.12	0.12

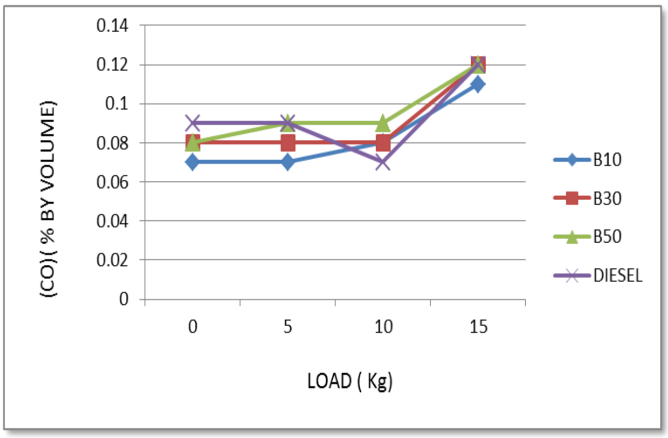


Table 7.2 hydrocarbons (HC) for various WPO Diesel blends

LOAD (kg)	HYDROCARBONS (HC) (ppm)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	48	49	49	35
5	52	65	66	70
10	52	63	65	83
15	63	68	68	100

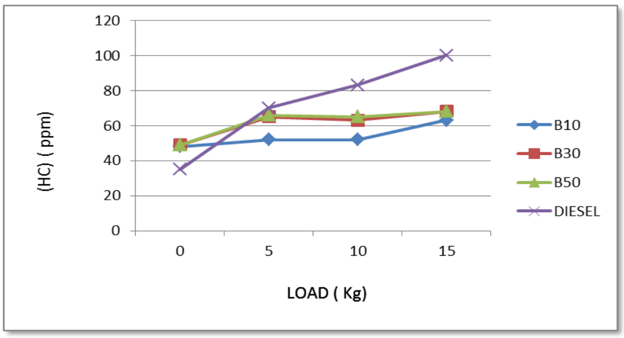


Table 7.3 Carbon dioxide (co_2) for various WPO Diesel blends

LOAD (kg)	CARBON DIOXIDE (CO_2) (% BY VOLUME)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	2.3	2.5	2.7	2.40
5	3.2	3.4	3.6	3.30
10	3.6	4.9	4.9	3.90
15	5.6	6.3	6.1	6.40

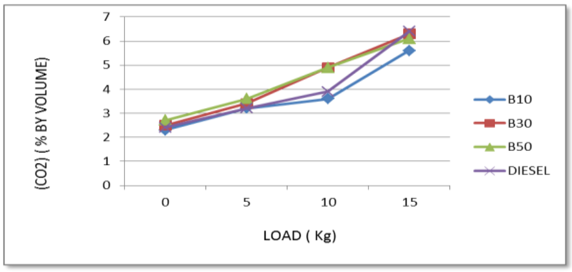


Table 7.4 Oxygen (O_2) for various WPO Diesel blends

LOAD (kg)	OXYGEN (O_2) (% BY VOLUME)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	16.1	16.6	16.9	18.26
5	15.5	15.7	16.2	17.04
10	14.48	14.46	15.1	10.04
15	13.02	13.2	13.2	14.81

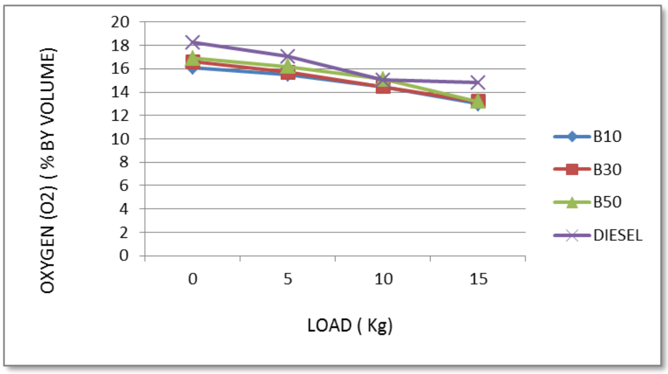
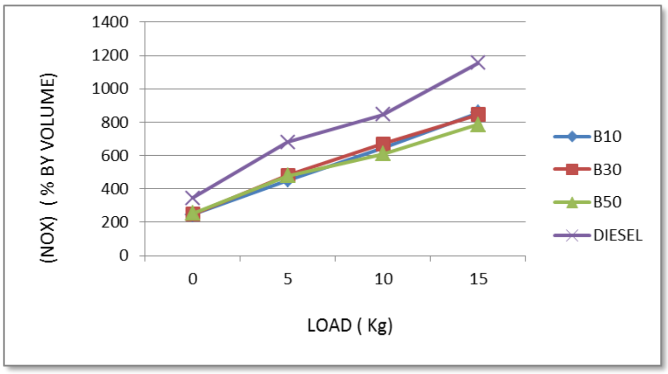


Table 7.5 Nitrogen oxide (NO_X) for various WPO Diesel blends

LOAD (kg)	NITROGEN OXIDE (NO_X) (% BY VOLUME)			
	10 %WPO Diesel blend	30 %WPO Diesel blend	50 %WPO Diesel blend	Diesel
0	245	248	254	346
5	452	482	478	680
10	645	670	610	845
15	856	845	784	1104



8. CONCLUSION

In our work the pyrolysis of the polystyrene was investigated in batch reactor in the temperature range 500-530°C. To ensure the cracking reaction Aluminium oxide (Al_2O_3 – neutral) catalyst was used. The received oil is blend with diesel in different proportions 10 %, 30 % and 50%. The blends are subjected to performance and emission tests. From the test conducted with waste plastic oil blend with diesel and pure diesel on a diesel test rig engine, the conclusions are arrived:

- Engine was able to run with 50% waste plastic oil-diesel blend
- Engine fuelled with 50 % waste plastic oil-diesel blend exhibits higher brake thermal efficiency (32.16%) when compared to pure diesel (30.56%).
- Engine fuelled with 10 % waste plastic oil-diesel blend exhibits lower indicated thermal efficiency (45.74%) when compared to pure diesel (56.2%).
- Brake specific fuel consumption 50% waste plastic oil-diesel blend exhibits higher indicated thermal efficiency (0.5kg/ kw-hr) when compared to pure diesel (0.2822 kg/ kw-hr)
- Emission level is less compare to pure diesel. So, it's more suitable for alternate fuel in diesel engines.

9. FUTURE SCOPE

From the results it can be concluded that aluminium oxide is work well for pyrolysis of high density polyethylene terephthalate. The following are the recommendations for future works.

- Aluminium oxide can be used as a catalyst for other types of plastics.
- Develop a continuous process for plastic pyrolysis using suitable catalyst.
- By distillation process polyethylene terephthalate oil can be fueled.
- Study on the yield of oil for different plastics using different catalyst.
- The oil content can be analyzed by Gas chromatography/ mass spectrometer (GC/ MS) and details hydrocarbon analyzer (DHA)

10. REFERENCES

[1].Emilio B. Espinosa (2017) 'Performance Evaluation of Waste Plastic Oil Converter' Vol. 5 No.2, 58-63.

[2]. Kanika Mathur, Chaudhari Shubham, Hegde Sunadh, Pawar Aditya, and Kakad Hardeep Singh (2016) 'Extraction of Pyrolysis oil from Waste Plastics' Volume: 03 Issue: 04, pp. 08-94

[3]. Raj Kumar Yadav and Yogesh Kumar Tembhurne (2016) 'Waste Plastic Fuel Used In Petrol Engine' Volume 7, Issue 1, Jan-Feb 2016, pp. 01-04.

[4]. Harsha Vardhan Reddy T, Aman Srivastava, Vaibhav Anand and Saurabh Kumar (2016) 'Fabrication and Analysis of a Mechanical System to Convert Waste Plastic into Crude Oil' Volume 6, Issue 1, pp 23-82.

[5].Elmo C. Rapsing (2016) 'Design and Fabrication of Waste Plastic Oil Converter' Vol. 4, Issue 2, pp: (69-77).

[6].Yasha Shukla, Hemant Singh, Shiwangi Sonkar and Deepak Kumar (2016) 'Design of Viable Machine to Convert Waste Plastic Into Mixed Oil for Domestic Purpose' Volume 12, Issue 4 (April 2016), PP.09-14.

[7].Hariram V, Seralathan S, Vagesh Shangar R and Yoga Narasimhulu K. (2015) 'Combustion characteristics of waste pyrolytic plastic oil at full load operation in a direct injection compression ignition engine' Volume 7, Issue 5, pp 673-676.

[8].Dianta Mustofa Kamal and Fuad Zainuri (2015) 'Green Product of Liquid Fuel from Plastic Waste by Pyrolysis at 900 °C' Vol. 9, Issue 2, pp: 40-44.

[9].Sunbong Lee1, Koji Yoshida and Kunio Yoshikawa (2015) 'Application of Waste Plastic Pyrolysis Oil in a Direct Injection Diesel Engine: For a Small Scale Non-Grid Electrification' Vol. 5, No. 1, pp 05-69.

[10].Dipak Kumar Shaw and Pranav Sahni (2014) ' Plastic to oil' vol 4 issue 4 PP 46-48.

[11].Nilamkumar. S. Patel and Keyur D. Desai (2013) 'Waste Plastic Oil as a Diesel Fuel in the Diesel Engine' Vol. 2 Issue 3, pp 51-03.

[12].Deshpande, D.P., Warfade V.V., Amaley, S.H. and Lokhande, D.D. (2012) 'Petro-Chemical Feed stock from plastic waste' Res.J.Recent Sci., vol.1 (3), pp.63-67.

[13].Sudhir Kumar, J., Joshua Prasad, V.J., Venkata Subbaiah, K. and Prasada Rao, V.V. (2012) ' Experimental studies on a DI-CI Engine using blends of diesel fuel with plastic diesel derived from plastic waste at 250 bar injection pressure', International Journal of Current Engineering and Technology, ISSN : 2277-4106, Vol. 2, No. 1.