Experimental Investigation of Waste Plastic Oil Blended with Diesel as an Alternative Fuel in Diesel Engines

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Abstract:
Evolutions of vehicles lead to the increase in the usage of fuels. Therefore demand and price of fuel is increasing day by day. This led to find an alternative fuels for internal combustion engines. If this alternative fuel is extracted from waste means its cost will be less and operative. Plastic is the major waste all over the world. It creates very serious environmental challenge because of their huge quantities and their disposals. In this study, these plastic wastes were subjected to pyrolysis process mainly consists of three units such as reactor, condenser and receiver. In this process plastic wastes were melted and cracked without oxygen at very high temperature range of 500 – 530°C with 10% wt. of Aluminum oxide (Al₂O₃) neutral catalyst. The resulting waste plastic oil is received and this waste plastic oil is blended with diesel. Performance and emission tests were carried out for 25%, 50%, 75%, and 100% waste plastic oil (WPO) diesel blends. Results indicated that the brake thermal efficiency, indicated thermal efficiency and specific fuel consumption is increase with the use of waste plastic oil diesel blends as compared to diesel alone.

Key words: pyrolysis, catalyst, waste plastic oil, performance, emission

1. INTRODUCTION

1.1 Alternative fuels

Alternative fuel, also known as 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, Bio alcohol, Fuel cell, Hydrogen, Compressed natural gas (CNG), Liquefied natural gas (LNG), Liquefied petroleum gas (LPG) and Vegetable oil.

Benefits of an alternative fuels
- Fewer toxic contaminants than gasoline and diesel.
- 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.

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.

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.

Fig 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.
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.

1.2.2. Types of plastics

There are mainly two types of plastics are there
- Thermoplastics
- Thermosetting plastics

<table>
<thead>
<tr>
<th>Plastic no</th>
<th>Plastic</th>
<th>Tm °C</th>
<th>Tg °C</th>
<th>Tensile (Pa)</th>
<th>Compressive (Pa)</th>
<th>Density Kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PET</td>
<td>245</td>
<td>73</td>
<td>48263301</td>
<td>75842330.2</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>265</td>
<td>80</td>
<td>72394951.5</td>
<td>103421359.3</td>
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<tr>
<td>2</td>
<td>HDPE</td>
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<td></td>
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<td>-</td>
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<td>24821126.2</td>
<td>965</td>
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<tr>
<td>3</td>
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<td>-</td>
<td>75</td>
<td>40679068</td>
<td>55158058.3</td>
<td>1300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>105</td>
<td>51710679.6</td>
<td>89631844.8</td>
<td>1580</td>
</tr>
<tr>
<td>4</td>
<td>LDPE</td>
<td>98</td>
<td>-25</td>
<td>82737087.7</td>
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<td></td>
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<td>-</td>
<td>31371145.6</td>
<td>-</td>
<td>932</td>
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<td>5</td>
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<td>900</td>
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<tr>
<td></td>
<td></td>
<td>175</td>
<td>-</td>
<td>41368543.7</td>
<td>55158058.3</td>
<td>910</td>
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<tr>
<td>6</td>
<td>PS</td>
<td>-</td>
<td>74</td>
<td>35852737.9</td>
<td>82737087.5</td>
<td>1040</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>105</td>
<td>51710679.6</td>
<td>89631844.8</td>
<td>1050</td>
</tr>
</tbody>
</table>

Table 1.2 Physical properties of plastics

1.2.5. 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 tones in 1950 to 245 million tones. 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 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 are 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.

1.2.6 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**

1.2.6.1 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.

1.2.6.2 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.

1.2.6.3 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.

1.2.6.4 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, NOx, sculpture 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 hydro cracking, thermal cracking and catalytic cracking are reported.

1.2.7 Advantages of plastics

1. Plastic are light in weight.
2. They can be easily molded and have excellent finishing.
3. They possess very good strength and toughness.
4. They possess good shock absorption capacity.
5. Corrosion resistant and chemically inert.
6. They have low thermal expansion of co-efficient and possess good thermal and electrical insulating property.
7. They are very good water resistant and possess good adhesiveness.
8. Plastic is strong, good and cheap to produce.
9. Plastic is a recycling process and it does not decompose.
10. Plastic bottles can be reused and restored over again and again.
11. Plastic is one of the unbreakable.
12. Plastic is an odorless.
13. Plastic is used for building, construction, electronics, and packaging.

1.2.8 Disadvantages of plastics

1. Produces toxic fumes when it is burnt.
2. Plastics are low heat resistant and poor ductility.
3. Plastics are deformation under load.

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 tones of plastics are produced annually all over the world out of which 77 million tones 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
3. MATERIALS

3.1 Polyethylene Terephthalate

In this present work Polyethylene Terephthalate (PET) plastic is used to obtain fuel range hydrocarbon by pyrolysis.

Polyethylene Terephthalate (PET) waste plastics have been considered for the experiments. Polyethylene Terephthalate (PET) is a thermoplastic material which is made from petroleum. This thermoplastic is available in a range of flexibilities depending on the production process. 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 PET creates no harmful emissions during its production or during its use by the consumer. Also, PET leaks no toxic chemicals into the soil or water.

In general, high density grades of polyethylene terephthalate have densities up to 1.2g/cm$^3$- 1.4g/cm$^3$. Typically, the Polyethylene Terephthalate material is more linear and consequently less crystalline. As might be expected, this lesser crystalline permits use at temperatures up to 245°C with somewhat better creep resistance below that temperature. Polyethylene Terephthalate has less stiffness than the high density polyethylene. A linear polymer, Polyethylene Terephthalate (PET) is prepared from ethylene by a catalytic process. The absence of branching results in a more closely packed structure with a low density and low chemical resistance than LDPE. PET is also lighter and more thin and it can withstand rather low temperatures.

3.1.1 Physical properties of Polyethylene Terephthalate (PET)

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 terephthalate.

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>1.2g/cm$^3$</td>
</tr>
<tr>
<td>Viscosity number</td>
<td>380mL/g</td>
</tr>
<tr>
<td>Melt flow rate</td>
<td>0.23g/10min</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>0.95</td>
</tr>
<tr>
<td>Melting point</td>
<td>120°C</td>
</tr>
<tr>
<td>Yield stress</td>
<td>26N/mm$^2$</td>
</tr>
<tr>
<td>Flexural stress</td>
<td>20N/mm$^2$</td>
</tr>
<tr>
<td>Stiffness in torsion</td>
<td>180N/mm$^2$</td>
</tr>
<tr>
<td>Hardness</td>
<td>41N/mm$^2$</td>
</tr>
<tr>
<td>Impact strength at 23°C</td>
<td>20kJ/m$^2$</td>
</tr>
</tbody>
</table>

Table 3.1 Physical properties of PET

3.1.2 Benefits of PET Recycling

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

3.1.3 Advantages of Polyethylene Terephthalate

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 Polyethylene

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

3.2 Catalyst

Aluminum oxide or alumina oxide neutral has been used as a catalyst this process to enhance the reaction. Aluminum oxide is a chemical compound of aluminum and oxygen with the chemical formula Al$_2$O$_3$. It is significant in its use to produce aluminum 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 efficiently produce existing chemical compounds, or that lend themselves to the production of new compounds.

Aluminum oxide (alumina Al$_2$O$_3$) 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$_2$O$_3$ are produced in the world, which are mainly manufactured by the Bayer method using bauxite, and about 40 million tons are consumed for refining aluminum. Furthermore about 5 million tons of Al$_2$O$_3$ are produced as chemical grade and used for various purposes. Moreover about 1.5 million ton Al$_2$O$_3$ is used as raw powder in the world. The amount of Al$_2$O$_3$ 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$_2$O$_3$ 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 aluminum 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 aluminum oxide or alumina.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic composition</td>
<td>&gt;99%</td>
</tr>
<tr>
<td>Crystalline structure</td>
<td>Corundum</td>
</tr>
<tr>
<td>Grain size</td>
<td>1-5 microns</td>
</tr>
<tr>
<td>Density</td>
<td>3.95 g/cm³</td>
</tr>
<tr>
<td>Water absorption</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 3.2 Physical properties of aluminium oxide

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilation co-efficient(20-2000°C)</td>
<td>8.4x10⁻⁶/°C</td>
</tr>
<tr>
<td>Specific heat</td>
<td>930 J/kg.k</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>40 W/m.K</td>
</tr>
<tr>
<td>Thermal shock resistance</td>
<td>200°C</td>
</tr>
</tbody>
</table>

Table 3.3 Thermal properties of aluminum oxide

3.2.2 Benefits of aluminum oxide

**Low cost:** The compositions can be prepared from low cost aluminum 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 catalyzed 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 aluminum oxide

Al₂O₃ 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. Aluminum oxide is the catalyst in the Claus process for converting hydrogen supplied 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.

![Pyrolysis experimental set up-line diagram](http://ijesc.org/)

1. Reactor 4. Thermocouple
2. Heating coil 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 - 1.4cm, 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 (polyethylene Terephthalate) were fed into reactor with 75g (10% wt. of plastic) of Aluminum oxide (Al₂O₃) 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.

4.3 Polyethylene Teraphthalate Properties:

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>RESULT OBTAINED FOR WPO</th>
<th>DIESEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinematic viscosity @ 40 Deg. C</td>
<td>2.09est</td>
<td>2.6 est</td>
</tr>
<tr>
<td>Density @ 15 Deg.c</td>
<td>0.8134gm/cc</td>
<td>0.850gm/cc</td>
</tr>
<tr>
<td>Conrad son carbon residues</td>
<td>0.04%</td>
<td>0.17%</td>
</tr>
<tr>
<td>Flash point by PMCC method</td>
<td>22Deg.c</td>
<td>52 Deg.c</td>
</tr>
<tr>
<td>Fire point by PMCC method</td>
<td>32Deg.c</td>
<td>56 Deg.c</td>
</tr>
<tr>
<td>Gross calorific value in kcal/kg</td>
<td>10630kcal/kg</td>
<td>4392kcal/kg</td>
</tr>
<tr>
<td>Calculate cetane index</td>
<td>58</td>
<td>47.982</td>
</tr>
<tr>
<td>Sediments (insoluble’s in hexane)</td>
<td>0.09%</td>
<td>0.015%</td>
</tr>
<tr>
<td>Sediments (insoluble’s in benzene)</td>
<td>0.01%</td>
<td>0.01%</td>
</tr>
</tbody>
</table>
5. PERFORMANCE AND EMISSION 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.

5.1 Basic performance parameters

5.1.1 Power and mechanical efficiency

Indicated power. The total power developed by combustion of fuel in the combustion chamber is called indicated power.

\[ \text{I.P.} = \text{BP} + \text{FB} \text{ kW} \]

Brake power. The power developed by an engine at the output shaft is called brake power.

\[ \text{B.P.} = \frac{2\pi \text{Re}NT}{60 \times 1000} \text{ kW} \]

Mechanical efficiency. The ratio of brake power and indicated power is called mechanical efficiency = B.P. / I.P.

5.1.2 Mean effective pressure

It is defined as the hypothetical pressure which is thought to be acting on the piston throughout the power stroke. If it is based on indicated power it is indicated mean effective pressure. If based on brake power it brake mean effective pressure.

5.1.3 Volumetric efficiency

It is defined as the ratio of actual volume of the charge drawn in during the suction stroke to swept volume of the piston.

\[ \text{volumetric efficiency} = \frac{V_s}{V_a} \]

5.1.4 Thermal efficiency

It is the ratio of indicated work done to energy supplied by the fuel.

\[ \text{Indicated thermal efficiency} = \frac{\text{I.P.}}{\text{Fe/Cv}} \times 10 \]

\[ \text{Brake thermal efficiency} = \frac{\text{B.P.}}{\text{Fe/Cv}} \times 1 \]

5.1.5 Specific fuel consumption (SFC)

It is the mass of the fuel consumed per kW developed per hour, and is a criterion of economic power production.

\[ \text{SFC} = \frac{F_C}{\text{B.P.}} \text{ kg/kWh.} \]

5.2 Internal combustion research engine

The performance tests were carried out in IC research engine for various proportions of waste plastic oil diesel blends. The specifications of the research engine are given in the table.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Parameters</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Engine type</td>
<td>Single cylinder vertical water cooled 4 stroke Diesel Engine</td>
</tr>
<tr>
<td>2</td>
<td>Power</td>
<td>5.2 Kw (7HP)</td>
</tr>
<tr>
<td>3</td>
<td>Rated speed</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>4</td>
<td>Cylinder bore</td>
<td>87.5 mm</td>
</tr>
<tr>
<td>5</td>
<td>Stroke length</td>
<td>110 mm</td>
</tr>
<tr>
<td>6</td>
<td>Connecting rod length</td>
<td>195 mm</td>
</tr>
<tr>
<td>7</td>
<td>Compression ratio</td>
<td>17.5</td>
</tr>
</tbody>
</table>

5.3 Data collection

There are five test fuels were used during performance test includes 100 % diesel, 25 % WPO blend with diesel, 50% WPO blend with diesel, 75 %WPO blend with diesel, 100% 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.

5.4 Types of Emission

1. Carbon monoxide (CO)
2. Hydrocarbons (HC)
3. Carbon dioxide (CO₂)
4. Oxygen (O₂)
5. Nitrogen oxide (NOₓ)

6. RESULT AND DISCUSSION

The performance and emission was compared with pure diesel from the obtained performance and emission graphs. The basic performance and emission parameters were presented against brake power for all plastic oil diesel blends.

6.1 Brake thermal efficiency

The variation of brake thermal efficiency with brake power is shown in Figure 7.1. It can be observed from the figure that the thermal efficiency is 28.67% at 5.19KW brake power for diesel. However when the engine is fuelled with WPO-diesel blends such as 25% WPO, 50% WPO, 75% WPO, and 100% WPO, it gives the thermal efficiency of
31.16%, 30.82%, 27.90%, and 26.40% respectively at 5.19KW brake power. It is also observed that brake thermal efficiency is higher for 25% and 50% WPO Diesel blends and it is slightly lower for 75% and 100% WPO Diesel blend when compared to pure diesel.

6.2 Indicated thermal efficiency

The variation of indicated thermal efficiency with load is shown in Figure 7.2. It can be observed from the figure that the indicated thermal efficiency is 34.30% at 5.19KW brake power for diesel. When the engine is fueled with WPO diesel blends such as 25% WPO, 50% WPO, 75% WPO, and 100% WPO, it gives the thermal efficiency of 37.27%, 36.86%, 33.37% and 31.57% respectively at 5.19KW brake power. It is also observed that indicated thermal efficiency is also higher for 25% and 50% blends and it is slightly lower for 75% and 100% WPO Diesel blend when compared to pure diesel.

6.3 Brake specific fuel consumption

The variation of brake specific fuel consumption with load is shown in Figure 7.3. It can be observed from the figure that the brake specific fuel consumption is 0.282 kg/kWh at 5.19KW brake power for diesel. When the engine is fueled with WPO diesel blends such as 25% WPO, 50% WPO, 75% WPO, and 100% WPO, its brake specific fuel consumption is 0.2597 kg/kWh, 0.2626 kg/kWh, 0.29 kg/kWh and 0.3066 kg/kWh respectively at 5.19KW brake power. It is also noted that the brake specific fuel consumption is decreased for 25% and 50% WPO Diesel blends and it is slightly increased for 75% and 100% WPO Diesel blend when compared to pure diesel.

6.4 Indicated specific fuel consumption

The variation of indicated specific fuel consumption with load is shown in Figure 7.4. It can be observed from the figure that the indicated specific fuel consumption is 0.236 kg/kWh at 5.19KW brake power for diesel. When the engine is fueled with WPO diesel blends such as 25% WPO, 50% WPO, 75% WPO, and 100% WPO, its indicated specific fuel consumption is 0.2171 kg/kWh, 0.2195 kg/kWh, 0.2485 kg/kWh and 0.2563 kg/kWh respectively at 5.19KW brake power. It is also noted that the indicated specific fuel consumption is decreased for 25% and 50% WPO Diesel blends and it is slightly increased for 75% and 100% WPO Diesel blend when compared to pure diesel.

6.5 Carbon monoxide (CO)

The variation of carbon monoxide (CO) with brake power is shown in Figure 7.5. It can be observed from the figure that carbon monoxide (CO) is 0.36% at 5.19KW brake power for diesel. However when the engine is fueled with WPO-diesel blends such as 25% WPO, 50% WPO, 75% WPO, and 100% WPO, it gives the carbon monoxide (CO) of 0.32%, 0.24%, 0.27%, and 0.34% respectively at 5.19KW brake power. It is also noted that carbon monoxide (CO) is lower for 25%, 50%, 75% and 100% WPO Diesel blends when compared to pure diesel.
The variation of hydrocarbons (HC) with brake power is shown in Figure 7.6. It can be observed from the figure that a hydrocarbon (HC) is 154ppm at 5.19KW brake power for diesel. However when the engine is fuelled with WPO-diesel blends such as 25% WPO, 50% WPO, 75% WPO, and 100% WPO, it gives the hydrocarbons (HC) of 67ppm, 69ppm, 69ppm, and 67ppm respectively at 5.19kw brake power. It is also observed that hydrocarbons (HC) is lower for 25%, 50%, 75% and 100% WPO Diesel blends when compared to pure diesel.

The variation of Carbon dioxide (CO\textsubscript{2}) with brake power is shown in Figure 7.7. It can be observed from the figure that Carbon dioxide (CO\textsubscript{2}) is 7% at 5.19KW brake power for diesel. However when the engine is fuelled with WPO-diesel blends such as 25% WPO, 50% WPO, 75% WPO, and 100% WPO, it gives the Carbon dioxide (CO\textsubscript{2}) of 5.1%, 6.8%, 5.4% and 6.1% respectively at 5.19kw brake power. It is also observed that Oxygen (O\textsubscript{2}) is lower for 25%, 50%, 75% and 100% WPO Diesel blends when compared to pure diesel.

The variation of Nitrogen oxide (NO\textsubscript{X}) with brake power is shown in Figure 7.5. It can be observed from the figure that Nitrogen oxide (NO\textsubscript{X}) is 1230ppm at 5.19KW brake power for diesel. However when the engine is fuelled with WPO-diesel blends such as 25% WPO, 50% WPO, 75% WPO, and 100% WPO, it gives the Nitrogen oxide (NO\textsubscript{X}) of 940ppm, 934ppm, 818ppm and 801ppm respectively at 5.19KW brake power. It is also observed that Nitrogen oxide (NO\textsubscript{X}) is lower for 25%, 50%, 75% and 100% WPO Diesel blends when compared to pure diesel.
In our work the pyrolysis of the high density polyethylene was investigated in batch reactor in the temperature range 500-530°C. To ensure the cracking reaction Aluminum oxide (Al₂O₃-neutral) catalyst was used. The received oil is blend with diesel in different proportions 25 %, 50 %, 75% and 100%. 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 (30.815%) when compared to pure diesel (28.673%).
- Engine fuelled with 50% waste plastic oil-diesel blend exhibits higher indicated thermal efficiency (36.85%) when compared to pure diesel (34.30%).
- Brake specific fuel consumption 75% and 100% waste plastic oil-diesel blend exhibits higher indicated thermal efficiency (0.3066kg/ 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.

8. 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)

9. REFERENCES


