Pyrolysis of Polyethylene Waste Material – Analysis and Comparison of Pyrolysis Oil with Diesel

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Abstract-*Millions of plastics are being produced annually for various applications. If not properly disposed they cause harm to birds and sea life. Even if properly disposed it takes thousands of years to decompose. In this modern world shortage of fuel is the major concern of many. To overcome this fuel shortage and to eliminate the harmful effect of plastics, pyrolysis of plastics pose as a viable solution. Our paper deals with pyrolysis of polyethylene waste plastics, analysis and comparison of obtained fuel with diesel. The pyrolysis reactor is made using simple equipments to cut the cost. To improve the engine performance and exhaust emission datas our fuel is blended with diesel. The blended fuel is prepared in the ratio of 15:18(15% of pyrolysis fuel and 85% of diesel). For this blend performance test and emission test were done in Kirloskar TV1 test engine and compared with diesel.*

Key Words: **Plastics, Disposal Methods Of Plastics, Pyrolysis Of Polyethylene Waste, Properties Of Pyrolysis Oil, Blending Of Pyrolysis Oil, Comparison Of Performance And Emission Test.**

INTRODUCTION

Due to the depletion of fossil fuels in past decades mankind is forced to look for other type of energy sources. Different type of energy sources are being developed such as bio – fuels, solar energy, tidal energy and more. On the other side due to rapid expansion of the global market tons of plastics are being produced and consumed annually but these plastics are not properly disposed.

Major portion of the waste plastics are dumped in oceans and landfills which causes major threat to the environment. Worldwide, our factories now produce approximately 400 million tonnes of plastic per year[1]. Around 91% of these plastics are not properly recycled. Most of all plastics takes more than 400 years to degrade, so most of it still exist in some form[2]. The petroleum and plastics are crude oil derived products both contain hydrocarbon in common. So these waste plastics can be used to derive fuels by using a process called as pyrolysis.

PLASTICS

Plastics were invented by Alexander parkes in 1862. Plastics are called as polymers. Polymer is a molecule made up by repetition of simple unit. Polymers are made by chains of carbon atoms with the help of other molecules such as N_2 and O_2. Structure of polyethylene can be written as

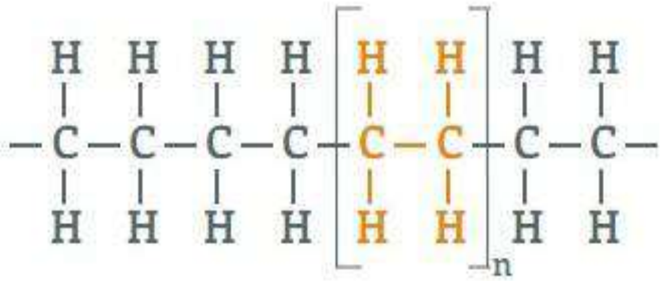

Fig -1: Structure of polyethylene

The repeating unit of the polymer is in the brackets with a subscript 'n', to represent the number of the unit in this polymer molecule.

Types of Plastic and its Characteristics

Plastics are classified in many ways based on their chemical properties. For easy identification and recycling society of plastic industry has classified the plastics based on their chemical structure.

1. Polyethylene terephthalate (PETE)
2. High density polyethylene (HDPE)
3. Polyvinyl chloride (PVC)
4. Low density polyethylene (LDPE)
5. Polypropylene (PP)
6. Polystyrene (PS)
7. Others (eg– acrylic, nylon)

Fig -2: Classification of plastic

Table -1: Types of plastics and its application

Types of plastics	Applications
PETE	Soft Drink Bottles, Mineral Water Bottles, Fruit Juice Containers
HDPE	Milk Jugs, Shampoo Bottles, Shower Soaps, Cleaning Agents
PVC	Food Foils, Tray For Sweets, Fruits Packing
LDPE	Crushed Bottles, Shopping Bags and Most of the Packing
PP	Furniture, Luggages, External Border of the Cars
PS	Toys, Refrigerator Trays, CD Cases
Others	Fiberglass, Nylon, Acrylic

Disposal method of waste plastics

Ocean dumping: It is the process of dumping the waste plastics and trashes into the depth of the oceans. It has adverse effect on marine life. It is one of the inexpensive method among others. The major disadvantage of using this method is destruction of food source and killing of sealife.

Landfills: It is the process of dumping plastics wastes in the land. It requires large area to dump plastics in landfills. It serves as the major reason for the soil pollution. The land which are filled can be reused community purposes.

Incineration: It is process of burning the plastic wastes. The remained ashes are either dumped in landfills or spread over water bodies. This type of disposal causes land, air and water pollution. It has negative effects on humans such as breathing problems.

PYROLYSIS

Pyrolysis is a Greek word in which pyro means heat and lysis means breakdown. Pyrolysis of the plastics is a chemical reaction in which the waste plastics are converted into the pyrolysis fuel. It is the thermal cracking of larger particle into smaller particle. The molecules are always in a continuous vibrating state at any particular temperature. This molecular vibration is directly proportional to the temperature of the molecules. When the temperature is increased the molecules tends to vibrate very fastly, due to this vigorous vibrations the particles starts to break into smaller molecules. This is known as pyrolysis.

A simple example of pyrolysis is cooking of food. When vegetables are cooked in high temperature and high pressure due to their molecular vibration the complex food particles are pyrolyzed into smaller and simpler molecules which are easily digestible.

METHODOLOGY

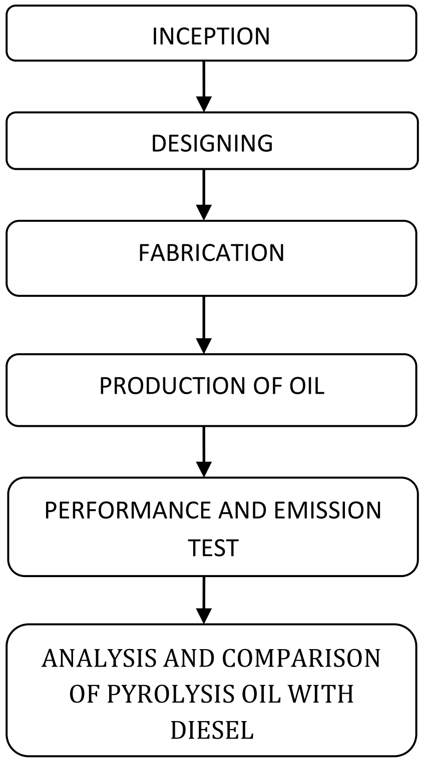

Chart -1: Methodology

EXPERIMENTAL SETUP

Components

A simple pyrolysis plant requires the following components. They are

- Heating element
- Reactor
- Condenser
- Temperature gauge
- Pressure gauge
- Ball valve
- Steel pipe

Heating element – pressurized kerosene stove is used as a heating element. The pressure created in the nozzle makes the kerosene to flow through the pipe and with air. This air fuel mixer is ignited by using flame sticks. The pressure in the tank can be controlled with the help of the air screw located in the filler cap.

Reactor - We used a 5 litre specially modified pressure vessel as a reactor for this process. The lid of the reactor has a hole for pipe to transport vapour from the inside of the reactor to the condenser.It also has two holes for temperature and pressure gauge.

Fig -2: Pyrolysis reactor

Condenser - It cools the entire hot vapour coming out of the reactor. It has an inlet and outlet pipe for cold water to pass through its outer surface of inner pipe. The hot gases at the temperature of about 350℃ are condensed to 30 – 35℃.

Fig -3: Condenser

3-D Model of the experimental setup

The below figure shows the 3 dimensional assembled model of our experimental setup designed using Catia

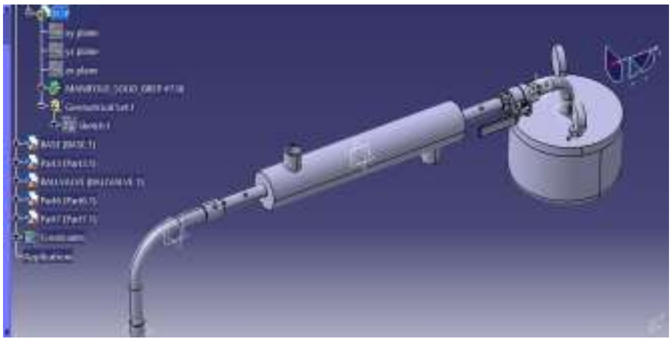

Fig -4: 3-D Model of experimental setup

PROCEDURE

Polyethylene plastics are selected for this experiment. Plastics are collected from the environment. Then they are segregated and made into pieces of size 3 to 5 centimeters to fit into the reactor easily. This pieces are then washed with detergent and scrubbed to remove any remaining impurities. Then they are dried. The experiment is carried out in batches each batch consists of 1 kg of polyethylene and the catalyst are added in the ratio of 10:1. The catalyst is the mixture of silica and alumina at the ratio of 83% silica and 17% of alumina.

The reactor is preheated to temperature of 100^{0}C. Then the plastic pieces are added along with the catalyst. At the early stages of this process the gball valve is kept closed to build pressure inside the reactor and to prevent gases from escaping. At the temperature of 250^{0}C plastics starts to melt. When the temperature is at 450^{0}C, conversion of melted plastics into gases takes place. These gases are then passed through the condenser to obtain pyrolysis oil.

Fig -5: Extracted pyrolysis oil

PHYSICAL PROPERTIES OF PYROLYSIS OIL

Table -2: Physical properties of pyrolysis oil

Physical Properties	Pyrolysis oil
Kinematic viscosity @40℃ in cSt	3.28
Flash point ℃	340C
Fire point ℃	390C
Gross calorific value in kJ/kg	39,847.90
Density in kg/m3	928

PERFORMANCE TEST OF DIESEL

To improve the engine performance and exhaust emission datas, our fuel is blended with diesel. The pyrolysis oil is blended with diesel in the ratio of 15% of pyrolysis oil and 85% of diesel. For this blend, performance test and emission test were done in Kirloskar TV1 test engine and compared with diesel

The test results are expressed in the form of both tables and graphs.

Table -3: Indicated and brake thermal efficiency of diesel

Speed (rpm)	Load (kg)	IThEff (%)	BThEff (%)
1548.00	0.12	53.87	0.98
1525.00	4.51	50.46	20.23
1503.00	9.10	47.22	27.63
1481.00	13.52	47.63	32.36
1450.00	18.21	45.46	34.14

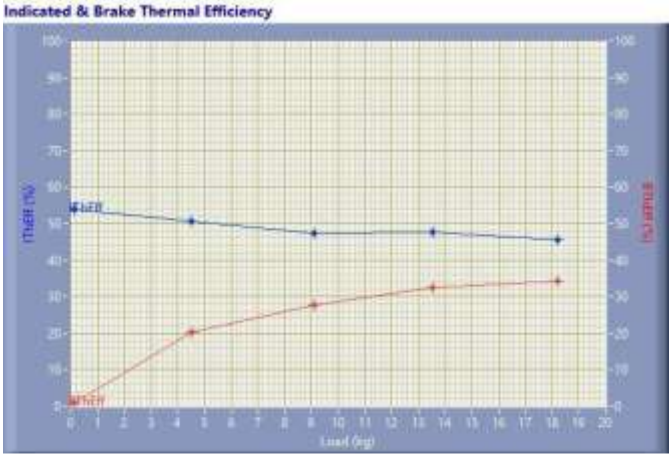

Chart -2: Indicated and brake thermal efficiency of diesel

Table -4: Specific Fuel consumption of diesel

Speed (rpm)	Load (kg)	SFC (kg/kWh)	Fuel (kg/h)
1548.00	0.12	8.61	0.30
1525.00	4.51	0.42	0.55
1503.00	9.10	0.31	0.80
1481.00	13.52	0.26	1.00
1450.00	18.21	0.25	1.25

Chart -3: Specific Fuel consumption of diesel

PERFORMANCE TEST OF BLENDED PYROLYSIS OIL

Table -5: Indicated and brake thermal efficiency of blended Pyrolysis oil

Speed (rpm)	Load (kg)	IThEff (%)	BThEff (%)
1602.00	0.12	53.67	1.01
1504.00	4.53	51.48	19.98
1477.00	9.05	45.17	26.96
1460.00	13.63	45.45	32.12
1446.00	18.21	41.91	32.69

Chart - 4: Indicated and brake thermal efficiency of blended Pyrolysis oil

Table -5: Specific fuel consumption of blended pyrolysis oil

Speed (rpm)	Load (kg)	SFC (kg/kWh)	Fuel (kg/h)
1602.00	0.12	8.45	0.30
1504.00	4.53	0.43	0.55
1477.00	9.05	0.32	0.80
1460.00	13.63	0.27	1.00
1446.00	18.21	0.26	1.30

Chart - 5: Specific fuel consumption of blended pyrolysis oil

EMISSION TEST OF DIESEL

Table -6: Emission Test of Diesel

SI NO	Load %	CO (%)	HC (PPM)	CO_2(%)	NO_X (PPM)
1	00	0.061	9	2.15	185
2	25	0.109	99	4.39	688
3	50	0.105	112	6.13	1141
4	75	0.126	134	8.32	1539
5	100	0.611	183	11.3	1658

EMISSION TEST OF BLENDED PYROLYSIS OIL

Table -7: Emission Test of Blended Pyrolysis Oil

SI NO	Load %	CO (%)	HC (PPM)	CO_2(%)	NO_X (PPM)
1	00	0.051	24	1.98	180
2	25	0.074	63	4.11	639
3	50	0.115	113	6.09	1115
4	75	0.146	161	8.24	1535
5	100	0.681	242	11.6	1641

COMPARISON OF PERFORMANCE TEST RESULTS FOR BLENDED PYROLYSIS OIL AND DIESEL

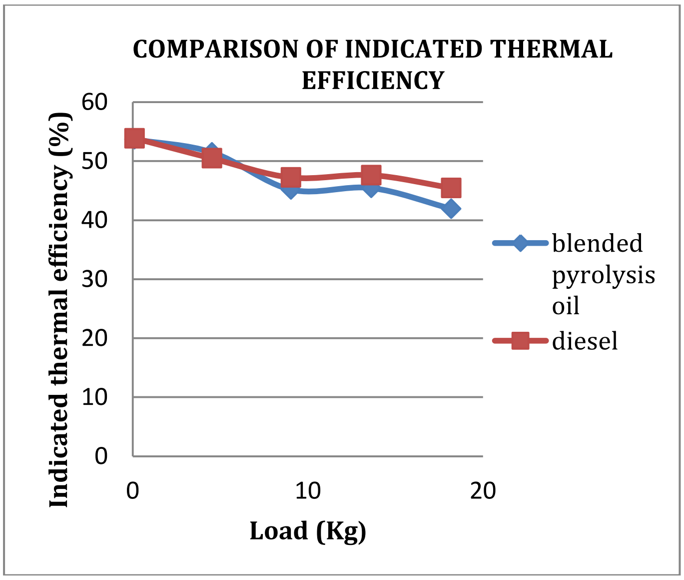

Chart - 6: Comparison Of Indicated Thermal Efficiency

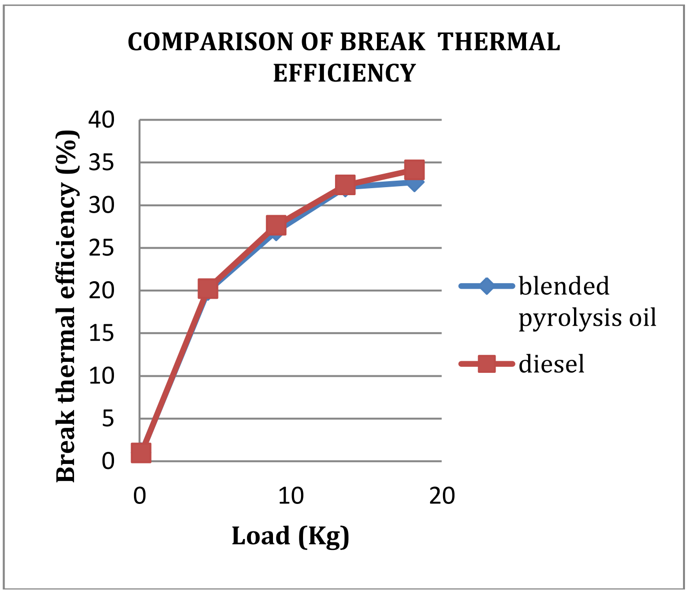

Chart - 7: Comparison Of Break Thermal Efficiency

COMPARISON OF EMISSION TEST RESULTS FOR BLENDED PYROLYSIS OIL AND DIESEL

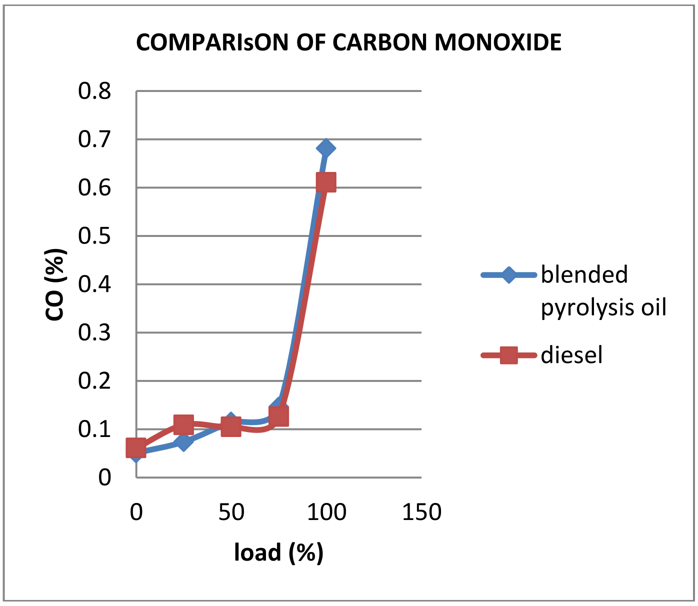

Chart - 8: Comparison Of Carbon Monoxide

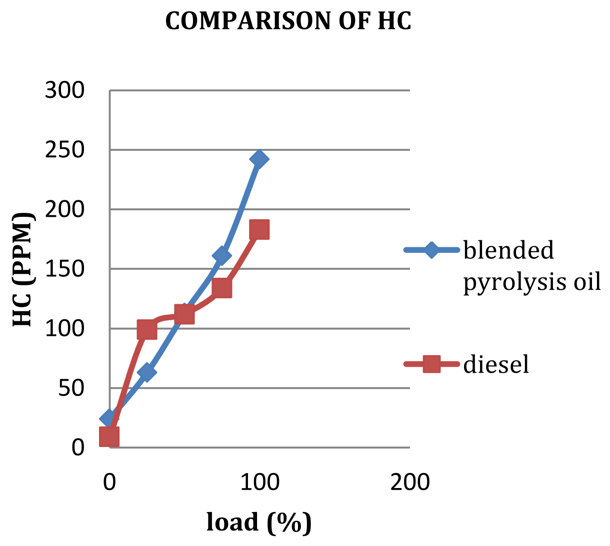

Chart - 9: **COMPARISON OF HC**

CONCLUSIONS

This work represents the process of pyrolysis and analysis of blended pyrolysis oil (polyethylene plastic oil).In this project, the reactor for pyrolysis was fabricated. In the reactor the pyrolysis oil was extracted at 350^{o}c temperature.

Moreover for 1kg of polyethylene waste plastic, we obtained 650ml of pyrolysis oil.

The comparison graph was discussed in earlier sections. From this, it is concluded that the performance and emission test results of the diesel and the blended pyrolysis oil were nearly similar and it is believed that the efficiencies can be further improved by various blends of plastoil and diesel.

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