TITLE OF THE PROJECT

WASTE PLASTIC PYROLYSIS

PROJECT REFERENCE NO.: 39S_BE_0707

COLLEGE : **BLDEA College of Engineering and Technology, Vijaypur.**

BRANCH : **DEPARTMENT OF CIVIL ENGINEERING**

GUIDE : **Prof. A.S. Tanksali**

STUDENTS : **Mr. Runal Desai**

Mr. Hannan Ahmed

Mr. Sachin Pawar

Mr. Basavaraj Balkunde

INTRODUCTION : **Attached Below**

OBJECTIVE: **Attached Below**

METHODOLOGY: **Attached Below**

CONCLUSION: **Attached Below**

FUTURE WORK: **Attached Below**

SYNOPSIS

The present rate of economic growth is unsustainable without saving of fossil energy like crude oil, natural gas, or coal. There are many alternatives to fossil energy such as biomass, hydropower, and wind energy. Also, suitable waste management strategy is another important aspect. Development and modernization have brought about a huge increase in the production of all kinds of commodities, which indirectly generate waste. Plastics have been one of the materials because of their wide range of applications due to versatility and relatively low cost.

Some **299 million** tons of plastics were produced in **2013**, representing a **4 percent increase** over **2012**. Recovery and recycling, however, remain insufficient, and millions of tons of plastics end up in landfills and oceans each year

Approximately **10–20 million tons of plastic** end up in the **oceans each year**. A recent study conservatively estimated that **5.25 trillion plastic** particles weighing a total of 268,940 tons are currently **floating in the world's oceans**.

And since plastic being a non-biodegradable material it remains into the soil, thereby polluting the environment.

Our Project deals with the extraction of **OIL/DIESEL** from the **waste plastics** termed as **PLASTIC PYROLYZED OIL** which can be marketed at much cheaper rates compared to that present in the market. As we know that both Plastics and Petroleum derived fuels are Hydrocarbons that contain the elements of Carbon & Hydrogen. **Pyrolysis** process becomes an option of waste-to-energy technology to deliver bio-fuel to replace fossil fuel. The advantage of the pyrolysis process is its ability to handle unsort and dirty plastic. The pre-treatment of the material is easy. Plastic is needed to be sorted and dried. Pyrolysis is also non toxic or non environmental harmful emission unlike incineration.

CHAPTER: 01

INTRODUCTION

Due to the fossil fuel crisis in past decade, mankind has to focus on developing the alternate energy sources such as biomass, hydropower, geothermal energy, wind energy, solar energy, and nuclear energy. The developing of alternative-fuel technologies are investigated to deliver the replacement of fossil fuel. The focused technologies are bio-ethanol, bio-diesel lipid derived bio-fuel, waste oil recycling, pyrolysis, gasification, dimethyl ether, and biogas. On the other hand, appropriate waste management strategy is another important aspect of sustainable development since waste problem is concerned in every city.

The waste to energy technology is investigated to process the potential materials in waste which are plastic, biomass and rubber tire to be oil. Pyrolysis process becomes an option of waste-to-energy technology to deliver bio-fuel to replace fossil fuel. Waste plastic and waste tire are investigated in this research as they are the available technology. The advantage of the pyrolysis process is its ability to handle un-sort and dirty plastic. The pre-treatment of the material is easy. Tire is needed to be shredded while plastic is needed to be sorted and dried. Pyrolysis is also no toxic or environmental harmful emission unlike incineration

Economic growth and changing consumption and production patterns are resulting into rapid increase in generation of waste plastics in the world. For more than 50 years the global production of plastic has continued to rise.

Some 299 million tons of plastics were produced in 2013, representing a 4 percent increase over 2012. Recovery and recycling, however, remain insufficient, and millions of tons of plastics end up in landfills and oceans each year

Approximately 10–20 million tons of plastic end up in the oceans each year. A recent study conservatively estimated that 5.25 trillion plastic particles weighing a total of 268,940 tons are currently floating in the world‟s oceans.

And since plastic being a non-biodegradable material it remains into the soil, thereby polluting the environment.

On the other hand, appropriate waste management strategy is another important aspect of sustainable development since waste problem is concerned in every city. As we know that both Plastics and Petroleum derived fuels are Hydrocarbons that contain the elements of Carbon & Hydrogen. Pyrolysis process becomes an option of waste-to-energy technology to deliver bio-fuel to replace fossil fuel. The advantage of the pyrolysis process is its ability to handle unsort and dirty plastic. The pre-treatment of the material is easy. Plastic is needed to be sorted and dried. Pyrolysis is also no toxic or non environmental harmful emission unlike incineration.

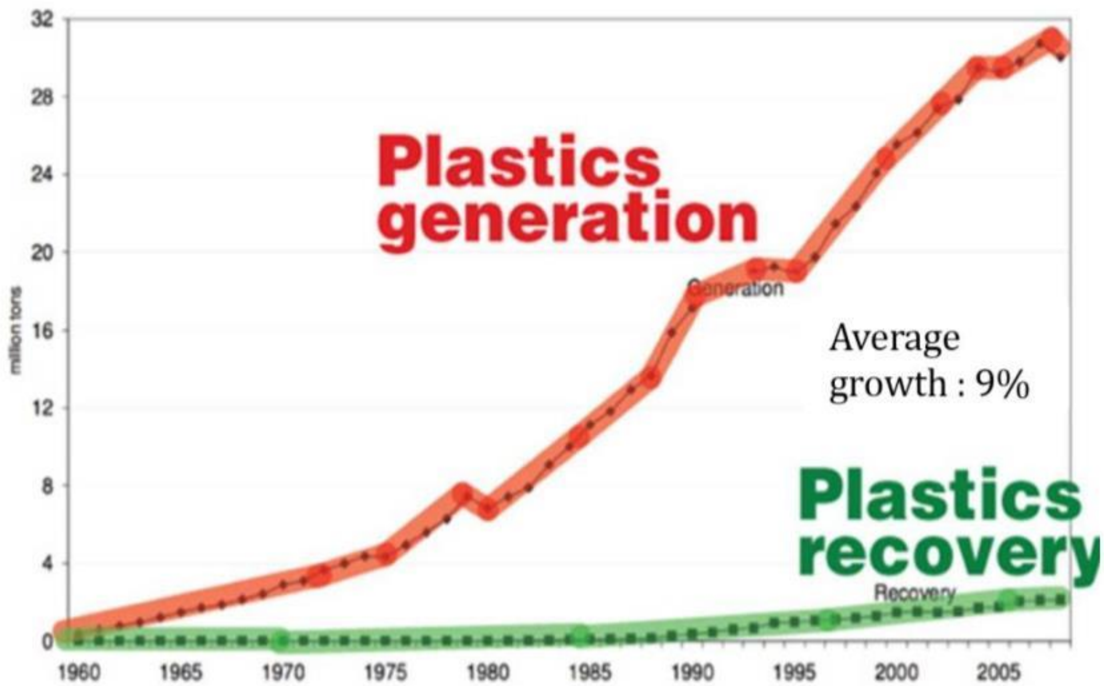


Fig. 1

The above graph shows the plastic generation and the amount of plastic that is subjected to recycling.

Disposal methods of waste plastics & their advantages and disadvantages:

OCEAN DUMPING	
Advantages: • convenient • inexpensive • source of nutrients, shelter and breeding	**Disadvantages:** • ocean overburdened • distruction of food sources • killing of plankton • desalination
SANITARY LANDFILL	
Advantages: • volume can increase with little addition of people/equipment • filled land can be reused for other community purposes	**Disadvantages:** • completed landfill areas can settle and requires maintenance • requires proper planning, design, and operation
INCINERATION	
Advantages: • requires minimum land • can be operated in any weather • produces stable odor-free residue • refuse volume is reduced by half	**Disadvantages:** • expensive to build and operate • high energy requirement • requires skilled personnel and continuous maintenance • unsightly - smell, waste, vermin
OPEN DUMPING	
Advantages: • inexpensive	**Disadvantages:** • health-hazard - insects, rodents etc. • damage due to air pollution • ground water and run-off pollution
RECYCLING	
Advantages: • key to providing a liviable environment for the future	**Disadvantages:** • expensive • some wastes cannot be recycled • technological push needed • separation of useful material from waste difficult

CHAPTER: 02

OBJECTIVES

The main objectives of this project are:

1. To establish the basis for the development and implementation of waste plastics recycling with the application of environmentally sound technologies (EST) to promote resource conservation and green house gases (GHG).
2. To raise awareness in developing countries like INDIA on plastic waste and its possible reuse for conversion into diesel or fuel, this could be generated and marketed at cheaper rates compared to that of the available diesel or oil in the market.
3. To reduce the dependency on gulf countries for fossil fuels, thereby contributing to the Economic growth of the country.

CHAPTER: 03

LITERATURE SURVEY

1. **M.fAli** reported that the high yields of liquid fuels in the boiling range 100°C–480°C and gases were obtained along with a small amount of heavy oils and insoluble material such as gums and coke. The results obtained on the co-processing of polypropylene with coal and petroleum residues are very encouraging as this method appears to be quite feasible to convert plastic materials into liquefied coal products and to upgrade the petroleum residues and waste plastics.

2. **Miskolczi** Investigated the pyrolysis of real waste plastics (high-density polyethylene and polypropylene) in a pilot scale horizontal tube reactor at 520 °C temperature in the presence and absence of ZSM-5 catalyst. It was found that the yields of gases, gasoline and light oil could be increased in the presence of catalyst. They also concluded that the plastic wastes could be converted into gasoline and light oil with yields of 20–48% and 17–36% respectively depending on the used parameters.

3. **F murfyk** from the recent literature, it is evident that the process of converting waste plastic to reusable oil is a current research topic, preparation of blends of diesel with varying proportions of waste plastic oil produced from the thermal pyrolysis and the analysis of viscosity and density of these blends is presented. The feasibility of the waste plastic oils derived from PVC plastics as an alternate fuel for transportation is also checked by conducting performance test on a single cylinder Kirlosker diesel engine equipped with electrical loading at 50% of the engine maximum load i.e., at 3.7 kW.

CHAPTER: 04

TYPES OF PLASTICS AND ITS PROPERTIES AND USES

Plastic Type	General Properties	Common Household Uses
1 PETE Polyethylene Terepthalate	Good gas & moisture barrier properties High heat resistance Clear Hard Tough Microwave transparency Solvent resistant	Mineral Water, fizzy drink and beer bottles Pre-prepared food trays and roasting bags Boil in the bag food pouches Soft drink and water bottles Fibre for clothing and carpets Strapping Some shampoo and mouthwash bottles
2 HDPE High Density Polyethylene	Excellent moisture barrier properties Excellent chemical resistance Hard to semi-flexible and strong Soft waxy surface Permeable to gas HDPE films crinkle to the touch Pigmented bottles stress resistant	Detergent, bleach and fabric conditioner bottles Snack food boxes and cereal box liners Milk and non-carbonated drinks bottles Toys, buckets, rigid pipes, crates, plant pots Plastic wood, garden furniture Wheeled refuse bins, compost containers
3 V Polyvinyl Chloride	Excellent transparency Hard, rigid (flexible when plasticised) Good chemical resistance Long term stability Good weathering ability Stable electrical properties Low gas permeability	Credit cards Carpet backing and other floor covering Window and door frames, guttering Pipes and fittings, wire and cable sheathing Synthetic leather products
4 LDPE Low Density Polyethylene	Tough and flexible Waxy surface Soft – scratches easily Good transparency Low melting point Stable electrical properties Good moisture barrier properties	Films, fertiliser bags, refuse sacks Packaging films, bubble wrap Flexible bottles Irrigation pipes Thick shopping bags (clothes and produce) Wire and cable applications Some bottle tops
5 PP Polypropylene	Excellent chemical resistance High melting point Hard, but flexible Waxy surface Translucent Strong	Most bottle tops Ketchup and syrup bottles Yoghurt and some margarine containers Potato crisp bags, biscuit wrappers Crates, plant pots, drinking straws Hinged lunch boxes, refrigerated containers Fabric/ carpet fibres, heavy duty bags/tarpaulins
6 PS Polystyrene	Clear to opaque Glassy surface Rigid or foamed Hard Brittle High clarity Affected by fats and solvents	Yoghurt containers, egg boxes Fast food trays Video cases Vending cups and disposable cutlery Seed trays Coat hangers Low cost brittle toys
7 OTHER	There are other polymers that have a wide range of uses, particularly in engineering sectors. They are identified with the number 7 and OTHER (or a triangle with numbers from 7 to 19).	Nylon (PA) Acrylonitrile butadiene styrene (ABS) Polycarbonate (PC) Layered or multi-material mixed polymers

CHAPTER: 05

CHARACTERISTICS OF PLASTICS AND OIL PRODUCTS

Before looking at the process options for the conversion of plastic into oil products, it is worth considering the characteristics of these two materials, to identify where similarities exist, and the basic methods of conversion. The principal similarities are that they are made mostly of carbon and hydrogen, and that they are made of molecules that are formed in „chains" of carbon atoms.

Crude oil is a complex mixture of hydrocarbons, which are separated and purified by distillation and other processes at an oil refinery. The majority of the crude oil is used for the production of fuels for transportation, heating and power generation. These oil products are not single components, but are a blend of components used to meet the relevant fuel specifications in the most economic manner, given the composition of the crude oil and the configuration of the oil refinery. These components have a wide range of chain lengths: gasoline has compounds with a chain length of between three and 10 carbon atoms, and diesel has compounds with a chain length of between five and 18 carbon atoms, but both contain only hydrogen and carbon.

Plastic is a generic term for a wide range of polymers produced using highly refined fractions of crude oil, or chemicals derived from crude oil, known as monomers. Polymers are formed by the reaction of these monomers, which results in chain lengths of tens or hundreds of thousands of carbon atoms. Some polymers also contain oxygen (e.g. polyethylene terephthalate (PET)), whereas others contain chlorine (polyvinyl chloride (PVC)). It is worth noting that only a small proportion (< 5%) of the crude oil processed in the world is used to produce the monomers (e.g.ethane,propene) used in the manufacture of polymers (e.g. polyethene, polypropylene).

The similarity between oil products and plastics is illustrated in Figure 2 . The figure demonstrates where the atomic composition in most plastics is similar to those in gasoline and diesel derived from crude oil.

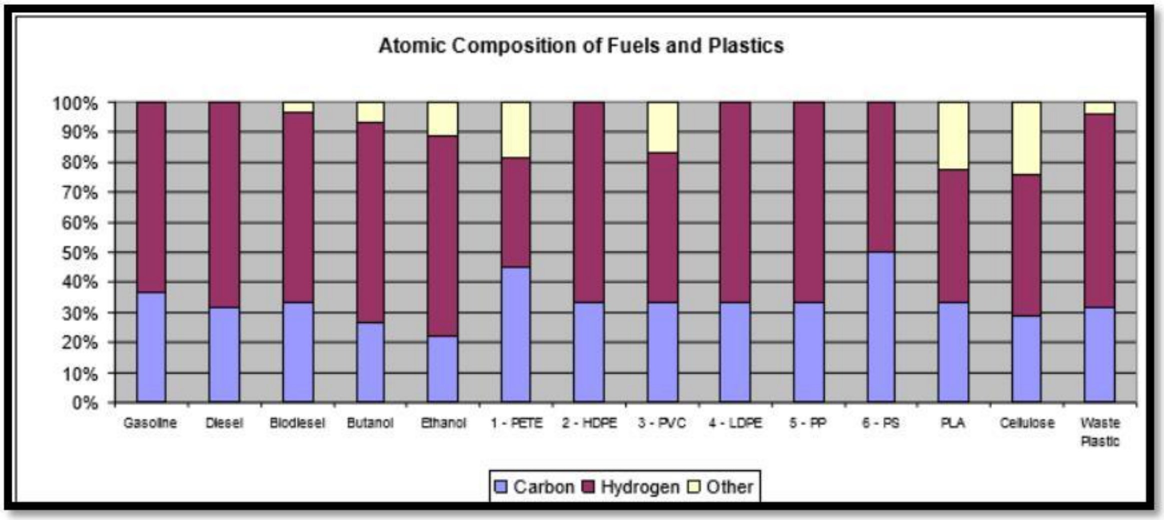

Atomic Composition of Fuels and Plastics
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Gasoline
Diesel
Biodiesel
Butanol
Ethanol
1 - PETE
2 - HDPE
3 - PVC
4 - LDPE
5 - PP
6 - PS
PLA
Cellulose
Waste Plastic
Carbon
Hydrogen
Other

Fig. 2


Waste Plastic Recycling- Indian Scenario
VENTAN
"We are sitting on plastic time bomb"..................................Supreme Court to CPCB in April 2013.
CPCB Report to SC...2013
5.6 Million Tons of Waste Plastic per annum
Delhi ....689.5 TPD
Chennai.......429.5 TPD
Kolkata.......425.7 TPD
Mumbai... .. 408.3 TPD

Fig. 3

CHAPTER: 06

METHODOLOGY

1.Identification of waste plastics. (PE/PP/PS/LDPE/HDPE)

2.Subjecting the waste plastic for pyrolysis process.

3.Condensation of the gas to obtain raw fuel.

4.Conversion of raw fuel into its pure form (diesel etc) by the process of distillation.

6.1. COLLECTION & IDENTIFICATION OF WASTE PLASTIC :

Fig. 4

- The collection of waste plastic is quite an easy task as compared to other wastes , the plastic wastes are abundant and can be obtained in large quantities from the households, roadsides, hospitals, hotels etc.

Fig. 5

Fig. 6

- This plastics are usually termed as

  POLYETHYLENE (PE)

  POLYPROPYLENE (PP)

  HIGH DENSITY POLYETHYLENE (HDPE)

  LOW DENSITY POLYETHYLENE (LDPE)

Usually they are manufactured in the form of plastic bags, saline bottles, plastic tools, chairs and other components which we usually come across in our day to day life.These plastics could be collected or usually purchased at Rs.10 to 15/kg after being shredded and washed properly.

6.2. SUBJECTING THE WASTE PLASTIC FOR PYROLYSIS PROCESS:

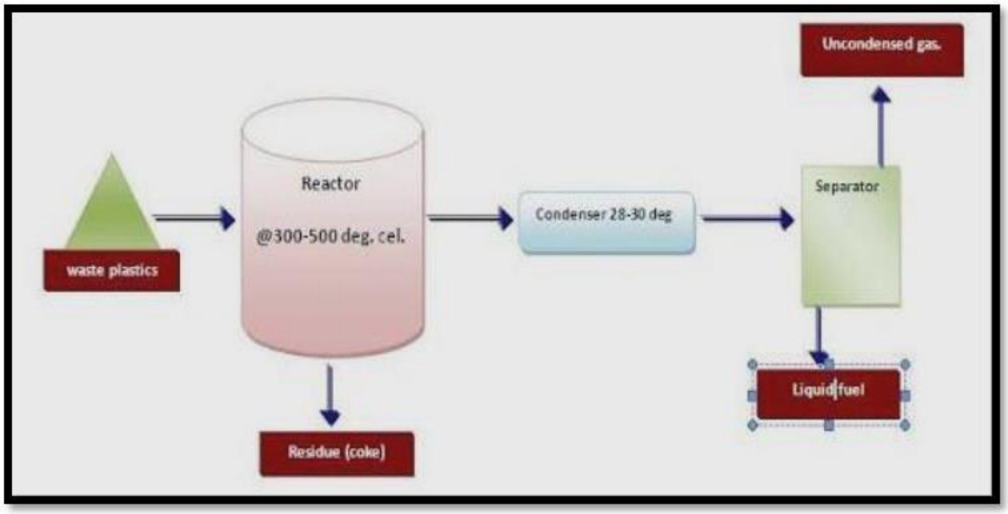


Fig. 7

The pyrolysis is a simple process in which the organic matter is subjected to higher temperature about 300ºC to 500ºC in order to promote thermal cracking of the organic matter so as to obtain the end products in the form of – liquid, char and gas in absence of oxygen.

6.2.1. WHY WE ADOPT PYROLYSIS PROCESS:

Comparison of Green House Gas (GHG) Emissions by Pyrolysis process with other processes: [11]

- Emissions associated with manufacture of other raw materials (excluding the waste plastic stream) are 13.0kgCO_2. For the case of pyrolysis these are owing to hydrogen that is consumed within the process.
- Site emissions from incineration of pyrolysis gases, distillation residues and 3% of the diesel product generated are 56kgCO_2
- Emissions associated with all elements of transport (products and waste) are 197kgCO_2
- Based on these figures the emissions associated with pyrolysis are 266kgCO_2
- Displacement savings associated with replacing fossilised diesel production are 426kgCO_2.
- Overall the net emissions for pyrolysis are –160kgCO_2.

6.2.2 GHG emissions for different disposal process:

	GHG emissions ($kgCO_2(e)$ per tonne of mixed plastic)				
	Input materials	Transport	Processing	Displacement savings	Net emissions
Landfill	0.0	15.1	55.7	0.0	**70.8**
Incineration	0.0	15.1	2408.0	-565.5	**1857.6**
Pyrolysis	13.0	197.2	55.6	-425.5	**-159.7**
Gasification w/MTG	153.7	153.7	995.5	-261.7	**1041.2**
Gasification w/F-T	153.7	139.3	285.2	-147.1	**431.1**
Gasification w/Bio	153.7	187.7	1217.1	-454.9	**1103.6**
Catalytic depolymerisation	16.0	197.5	51.0	-397.4	**-132.8**

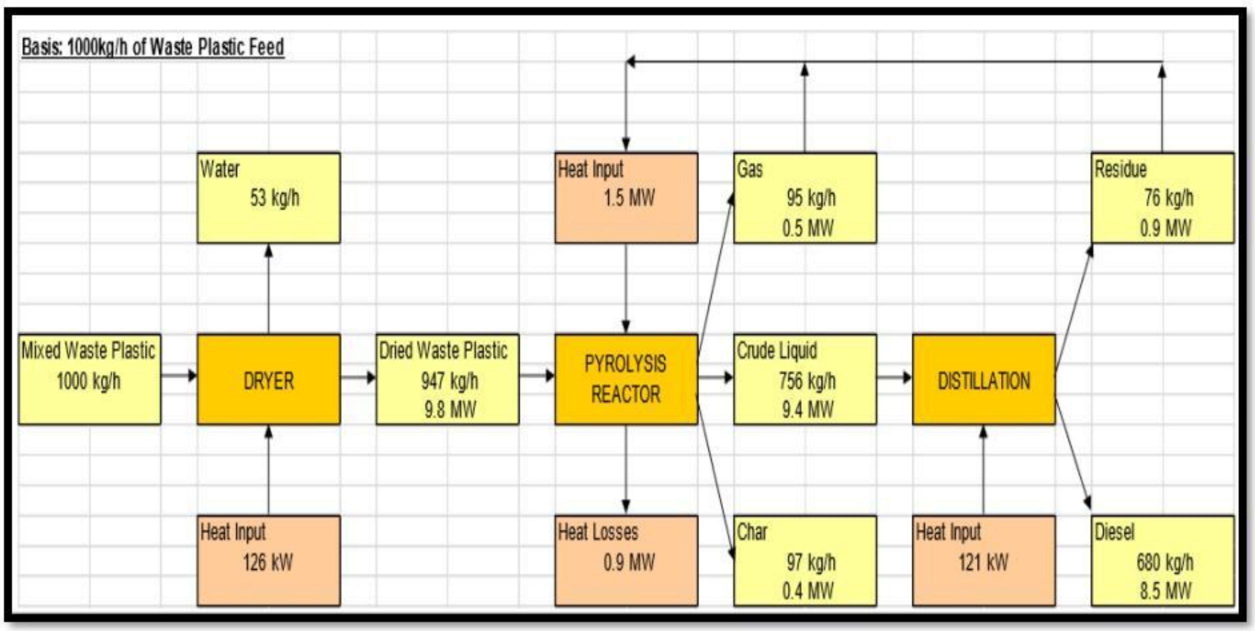


Fig. 8

6.2.3. SETUP FOR TRIAL EXPERIMENT:

Fig. 9
Experimental setup of trial test conducted, wherein 380 grams of plastic was dumped into a closed container and heated.

Fig. 10

Semi liquid fuel obtained after burning the waste plastic, which can be further processed into diesel.

Fig. 11

Efficient burning of the obtained fuel with a clear blue flame and minimum emission of CO_2.

6.2.4. EXTRACTION PROCESS IN A SPECIALLY DESIGNED MOULD(PYROLYZER):

The below picture shows the mould prepared by us so as to serve as a **pyrolyzer device**.

Fig. 12

6.2.5. DESIGN DETAILS OF THE INSTRUMENT

- Material = Stainless Steel
- Top diameter = 25 cm
- Bottom diameter = 25 cm
- Depth = 40 cm
- Volume = 19634 cm^3
- Diameter of outlet = 2.54 cm
- Weight of mould = 14 kg
- Digital thermometer (upto 2000°C)
- Silicon visor

Fig. 13

Fig. 14

6.3. CONDENSATION OF GAS TO OBTAIN RAW FUEL:

After heating the waste plastic at a temperature of about 300 ^{0}C to 500 ^{0}C in the pyrolyzer the gas is allowed to escape through the outlet dipped into the water containing jar so as to condense the fumes to obtain the RAW FUEL floating over the surface as shown in picture above, Which is further taken out through the outlet provide to the water containing jar.

Fig.15 Initial condition before Condensation.

Fig.16 A layer of oil formed at the top surface after Condensation of the gases.

Fig. 17
7 litres of Raw fuel collected from about 7.5kg of Plastic.

6.4. CONVERSION OF RAW FUEL INTO ITS PURE FORM (DIESEL,Kerosine etc) BY THE PROCESS OF DISTILLATION :

Once the RAW FUEL is obtained it is further subjected to distillation process so as to obtain the fuel i.e. diesel in its pure form by removing the impurities present in it which can be then tested into diesel engines for its efficiency.

Fig. 18

CHAPTER: 07

PHYSICAL PROPERTIES OF DIESEL GRADE OF WASTE PLASTIC [10]

Sl no.	Characteristics	Diesel Grade Fuel
1	Flash point in ^{o}C	87
2	Fire point ^{o}C	92
3	Viscosity @40 ^{o}C	3.8
4	Density kg/m^3	800
5	Calorific value kj/kg	46988

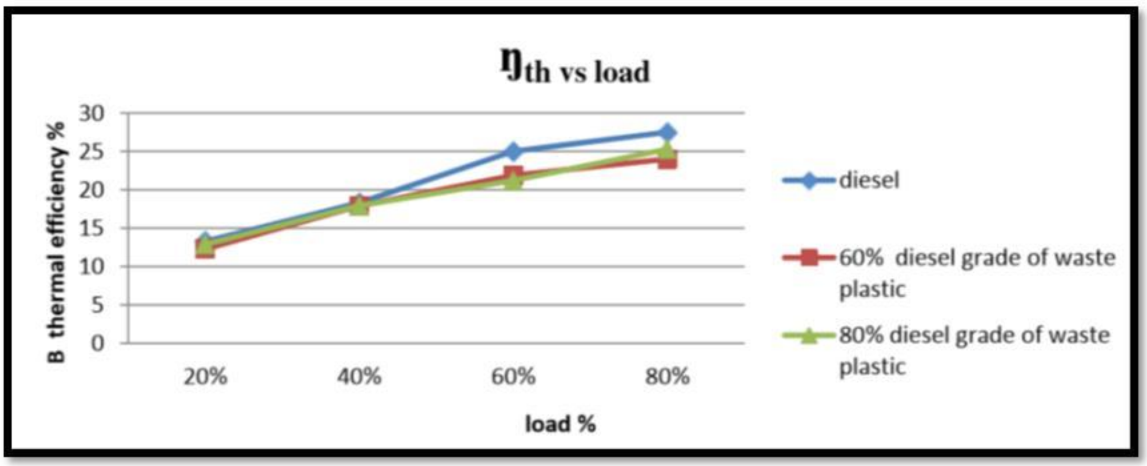
Fig.20
Test conducted at Mahila University,Vijayapura.

CHAPTER: 08

PERFORMANCE CHARACTERISTICS [10]

8.1.BRAKE THERMAL EFFICIENCY:

The experimental study on a single cylinder, four-stroke, air cooled DI diesel engine and air-cooled spark ignition engine with waste plastic oil, At full load, the efficiency is higher for diesel and petrol fuel. This is due to the fact that at full load, the exhaust gas temperature and the heat release rate are marginally higher for waste plastic oil compared to diesel.

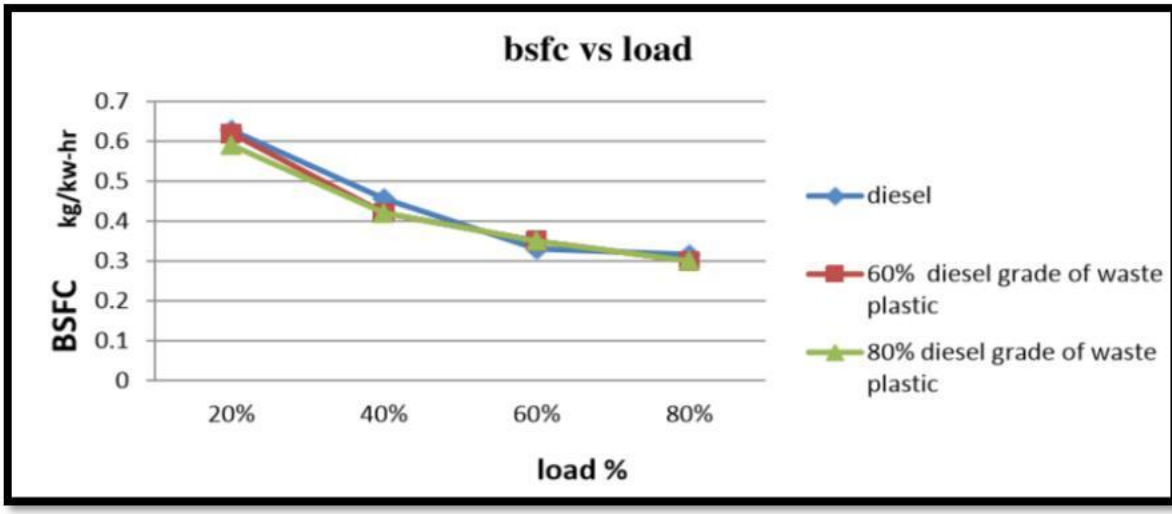


Graph:1 Brake thermal efficiency

Graph shows that an experimental study on waste plastic oil and diesel fuel blends in compression ignition engine proved that the thermal efficiency is 27.5% at full load. It is observed that the engine fuelled WPO60 and WPO80 of diesel grade gives brake thermal efficiency of 24% and 25.3% respectively at full load. The total heat release for each WPO-DF blends is lesser than diesel. Hence, the brake thermal efficiency is lower for the WPO-DF blends than diesel.

8.2.BRAKE SPECIFIC FUEL CONSUMPTION:

Brake specific fuel consumption measures how efficiently an engine is using the fuel supplied to produce work. It is inversely proportional to thermal efficiency as shown in the graph below.

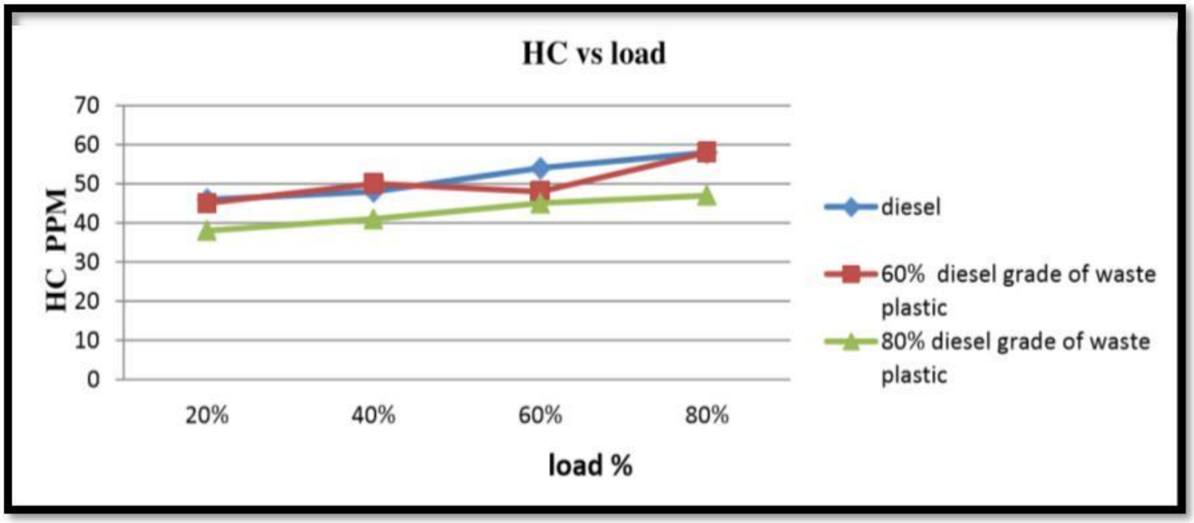


Graph:2 Brake specific fuel consumption

CHAPTER: 09

EMISSION CHARACTERISTICS [10]

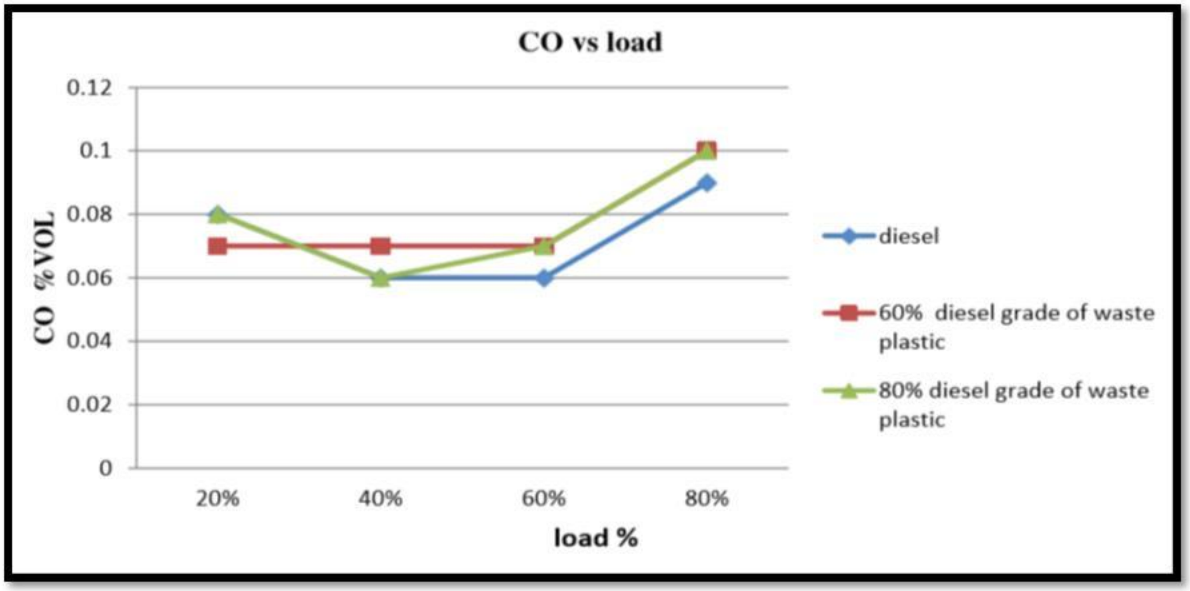
9.1. HYDROCARBON EMISSION:



Graph:3 Hydrocarbon emission

Above graph shows that an experimental study on diesel grade fuel of waste plastic oil shows that, unburned hydrocarbon varies from 36 ppm at low load to 58 ppm at full load, It is noticed that the concentration of the hydrocarbon of waste plastic oil is little higher than diesel; the reason behind increased unburned hydrocarbon in waste plastic oil may be due to higher fumigation rate and non-availability of oxygen relative to diesel.

9.2. CARBON MONOXIDE EMISSION:



Graph:4 Carbon monoxide emission

Graph shows that, CO_2 varies from 2.40% vol. at low load to7.60 % vol. at full load for different blends,An experimental study on diesel grade fuel of waste plastic oil shows that, CO varies from 0.08% vol. at low load to 0.10 % vol. at full load for different blends.Here the CO emission of waste plastic oil is higher than diesel. The reason behind increased CO emission is incomplete combustion due to reduce in cylinder temperatures.

CHAPTER: 10

COST ANALYSIS

Reported by: Department of Mechanical Engineering, Faculty of Engineering, Rajamangala University of Technology Phra Nakhon, Bangkok, Thailand.

Type of Cost	Unit	Plastic Oil
Total Capital Cost	Baht	9,000,000
Capital cost	Baht/Day	24,658
Expenses:		
Feedstock Expenses	Baht/Day	30,000
Operation Expense	Baht/Day	3,000
Maintenance Expenses	Baht/Day	1,000
Labor Expense	Baht/Day	3,000
Utilities Expense	Baht/Day	1,000
Taxes, Insurance	Baht/Day	450
Total Expenses	Baht/Day	38,450
Profit 30%	Baht/Day	11,535
Total production	**Baht/Day**	**74,643**
Oil production	Liter/Day	4,500
Production cost	**Baht/Liter**	**16.59**

1Baht = 1.90 Indian Rupee
16.59Baht = 31.52 Indian Rupee

CHAPTER: 11

APPLICATION OF PROJECT & FUTURE WORK

1. The obtained fuel could be utilized in diesel generators, vehicles such as tractors and also passenger vehicles such as cars.
2. The fuel has to be refined at the industrial establishments, based on the results of which small scale industry can be established.
3. As there is a high demand of crude oil and due to its sky reaching prices , we could take up this project to setup large or small scale industries and produce the fuel locally at much cheaper rates directly benefiting the National economy and also a step towards SWAACH BHARAT by recycling the waste plastic.
4. The application of this project could help in reducing the dependency on the gulf countries and promote a step towards innovation.

CHAPTER: 12

RESULTS AND DISCUSSIONS

1. Through our experimentation we concluded that about 600 to 750ml of diesel fuel could be obtained by burning 1Kg of plastic. Burning 1Kg of plastic in an open environment produces 3Kg of CO_2, whereas by converting it into fuel and burning it reduces 80% of CO_2 emissions , which results in to be quite environmentally friendly.
2. Lesser emission of unburnt HYDROCARBONS in waste plastic pyrolysis oil compared to that of diesel.
3. The diesel or oil thus obtained has a higher efficiency with around 30 to 40% low production cost compared to that available in the market.

CHAPTER: 13

LIMITATIONS

1. High Carbon monoxide emissions compared to that of currently available diesel in the market.
2. High emissions at lesser loads compared to that of higher load working engines.
3. For efficient use of diesel grade fuel of waste plastic, blending it with normal diesel is necessary.

CHAPTER: 14

CONCLUSION

It is very difficult to find out alternative of plastic. Even plastic´s demand is increasing every day as well as their waste. This project analysis has observed the use of waste plastics, a factory planning and its feasibility in Metropolitan City. It is easily assumed that, when the use of waste plastic will increase then the solid waste management will search more ways to find out to collect them.

The implementation of this project can develop so many opportunities in the city. It can be a solution to control waste plastic, develop a new technique or idea, and detect the source of diesel for the country. Bangladesh is such a country where this kind of project could be very promising and effective in the future

The use of plastic pyrolysis oil in diesel engine in the aspect of technical and economical is compared and found that oil is able to replace the diesel oil.Though the plastic pyrolysis oil offers lower engine performance, the plastic waste amount is enormous and it needed to be process to reduce the environmental problems. Moreover, the engine can be modify follow the combustion condition of plastic pyrolysis oil. The waste plastic used in the process must be PE or PP or LDPE in order to protect the contamination of chlorine in the oil.

REFERENCES:

1. J. Walendziewski, Engine fuel derived from plastics by thermal treatment, fuel 81 (2002) 473-481
2. M. Mani, G. NagarajaN, Influence of injection timing on performance, emission and combustion characteristics of a DI diesel engine running on waste plastic oil Energy 34 (2009) 1617–1623
3. F. Murphy, K. M. Donnell, E. Butler, G. Devlin, The evaluation of viscosity and density of blends ofCyn-diesel pyrolysis fuel with conventional diesel fuel in relation to compliance with fuel specifications EN 590:2009.
4. N. Miskolczi, A. Angyal, L. Bartha, I. Valkai, Fuels by pyrolysis of waste plastics from agricultural and packaging sectors in a pilot scale reactor Fuel Processing Technology 90 (2009) 1032–104
5. M. N. Siddiqui, H.H. Redhwi, Catalytic coprocessing of waste plastics and petroleum residue into liquid fuel oils, Journal of Analytical and Applied Pyrolysis 86 (2009) 141–147
6. A.K. Panda, R.K. Singh, D.K. Mishra, Thermolysis of waste plastics to liquid fuel A suitable method for plastic waste management and manufacture of value added Products-A world prospective, Renewable and Sustainable Energy Reviews 14 (2010) 233–248
7. A. Demirbas, Waste management, waste resource facilities and waste conversion processes, Energy Conversion and Management 52 (2011) 1280–1287
8. M. F. Ali, S. Ahmed, M. S. Qureshi, Catalytic coprocessing of coal and petroleum residues with waste plastics to produce transportation fuels Fuel Processing Technology 92 (2011) 1109–1120
9. Mitusuhara, waste plastics to produce transportation fuels Fuel Processing Technology 72(2011)
10. Anup T J1,et.al "*Waste Plastic Pyrolysis Oil as Alternative For SI and CI Engines*" International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 7, July 2014.
11. Sam Haig,et.al Plastic to oil IFM002 final report "Zero Waste Scotland".