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Manufacturing and Production of Thermo-Fuel Plant from Waste Plastic

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Abstract
Now-a-days there is a huge increase in consumption as well as production of plastics day by day and all the reasoning and arguments for and against plastics finally land up on the fact i.e. plastics are non-biodegradable. The disposal and decomposition problem leads to number of research regards this. Pyrolysis, is a way of making these plastics waste to become useful to us by converting them to fuel oil, called Thermofuel. Thermo-fuel is a process that converts waste plastic into valuable liquid hydrocarbon product that can be utilized as energy source for many purposes such as diesel engine, generator, vehicle etc. The present work involves disposal of waste plastic into petroleum based fuel using Pyrolysis of polyethylene (we are using plastic water bottles)that has the almost same physical properties as fuel used in aviation industries (JP-4).The experiment is carried out in Catalytic Pyrolysis(presence of catalyst).The catalyst used for experiment is Silica-alumina and Zeolite in proportion of 1:1. In Pyrolysis process plastic is burnt in the absence of oxygen and in a high temperature range of approximately 450°C that's why a reactor is constructed with furnace for reaction and to achieve required temperature. To yield the highest quantity of hydrocarbon plastic requires a temperature of about 430°C and catalyst to plastic waste ratio of 1:10.This study involves complete design of furnace,condenser, reactor and comparison with other conventional fuels with their miscellaneous properties. The study only focuses on Manufacturing and Productionof plastic waste fuel plant.

Keywords
Waste Plastics, Polyethylene, Pyrolysis, Catalyst, Production, Alternative fuel

Introduction

Waste plastic has become a very serious environmental issue due to increase in use of plastic day by day. Plastic waste being non decomposable which possess disposal problems and also it is not be easy to recycle and it results in it quality Deteriorationduring recycling process. Plastic waste goes through total photo degradation and turns into plastic dust which enters in food chain and causes multiple health problems to Habitats. Waste plastic is mostly discarded in landfills and ocean which results in land pollution and water pollution.

Plastic Production and its use had increase at a rapid rate in the span in last few decades of global production. It was 1.3 M Tones in 1951 and it reached nearly about 245 M Tones in 2006. The maximum demand of polyethene in market is 4.4% annually. Now-a-days the disposal method employ are land filling, mechanicalrecycling, biological recycling, thermal and chemical recycling. Asia accounts for 36.5% of the world-wide consumption and has been world's largest plastic consumer from several years. In last fewyear remarkable growth in the consumption of plastic globally has been due to introduction of plastic in areas such as automotive field, transport, medical, electronics, infrastructure and furniture.

Due to shortage of conventional fuel, the price of automobile fuel was increasing day by day which will lead to shortage of conventional fuel in future. There are various problems affecting to environment by excessive plastic waste. All plastic need to dispose after their use. By taking into account these problems, we are going to make alternative fuel for automobile from the waste plastic.

Thermo fuel is a process of converting waste plastic into useful fuel. The process by which we are converting waste plastic into fuel is Pyrolysis. Pyrolysis is process of chemical decomposition of organicmaterials at elevated temperature in absence of oxygen. Many researchers have been done on this with and without the use of catalyst. Also they did the analysis of output fuel at different temperature. They did analysis for various quantities of catalysts to find out the maximum fuel output. They compared properties of output fuel with Petrol and Diesel on various parameters. Also they did analysis for minimizing temperature by using various combination of the catalyst.

Literature Survey

Dr. P.V.Thorat et.al: "Pyrolysis of waste plastic to produce Liquid Hydrocarbons"He had concluded that thermofuel is a truly sustainable waste solution, diverting plastic waste from landfills, utilizing the embodied energy content of plastics and producing a highly usable commodity that, due to its cleaner burning characteristics, is in itself more environmentally friendly than conventional distillate.

Christine Cleetus et.al: "Synthesis of Petroleum-Based Fuel from Waste Plastics and Performance Analysis in a CI Engine" In the recent research during 2013 they had concluded most crucial points:

i) A petroleum based fuel has been produced fromwaste plastic (polythene).

(ii) The optimum catalyst and reactions for catalyticpyrolysis of polythene have been found. Based on theyield and thermophysical properties, the combinationof silica alumina and zeolite was selected as the optimum catalyst.

(iii) In the performance analysis in engine, even thoughthe plastic oil shows inferior results as compared todiesel, the lower blends percentage oils show resultsclose with that of diesel (B10, B20, and B30). Thismakes it a strong competitor in the area of alternatefuels. Also the blend B20 has low CO emissions thanfor diesel.

(iv). If the gaseous products and solid can be used, then theeffective cost will come down even further.

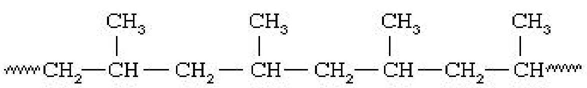
(v) Rather than considering it just as an alternate fuel, thepractical importance of this method in waste plasticmanagement adds its value as an alternate fuel.

Objectives

1) Design and Fabricate the Model.
2) Manufacturing and Production of Thermo-fuel in the Fabricated Model.
3) Compare the properties of fuel with other conventional fuels.
4) To find the miscellaneous properties of plastic fuel.

Plastic And Its Types

Plastic is a material consisting of a wide range of synthetic or semi synthetic organics that can be molded into solid objects of various shapes. Plastics are generally organic polymers of high molecular mass. Most plastics contain organic polymers. The vast majority of these polymers are based on chains of carbon atoms alone or with oxygen, sulphur, or nitrogen. The important thing is that part of the chain on the main "path" linking a large number of repeat units together. The structure of polypropylene can serve as an example here attached to every other carbon atom is a pendant methyl group (CH_3):



Due to their relatively low cost, ease of manufacture, versatility, and imperviousness to water, plastics are used in an enormous and expanding range of products. They have already displaced many traditional materials, such as wood, stone, horn and bone, leather, paper, metal, glass and ceramic, , in most of their former uses. In developed countries, about a third of plastic is used in packaging and another third in buildings such as piping used in plumbing or vinyl siding. Other uses include automobiles, furniture, and toys. In the developing world, plastics have many uses in the medical field.

What Kind of Plastics Used

SELECTION OF PLASTIC RESIN	THERMO FUEL SYSTEM SUITABILITY
Polyethylene	Very good
Polypropylene	Very good
Polystyrene	Very good (gives excellent properties)
ABS resin(ABS)	Good ,requires off-gas counter measure
Polyvinylchloride(PVC)	Not suitable, should be avoided
Polyurethane(PUR)	Not suitable, should be avoided
Fibber reinforced plastic(FRP)	Fair, Pre-treatment required to remove fibers
PET	Not suitable, should be avoided

Methods For Conversion

Pyrolysis is the process of thermal degradation of plastic without oxygen. In this method we heat the plastic in a chamber. Due to absence of oxygen plastic is directly convert into the gas andgases which were produced are cooled by condensation. For this process we need temperatures about 400°C to 450°C and suitable catalyst is used for the quick reaction.

Pyrolysis of plastic method has followed steps:
i) Removing oxygen from furnace.
ii) Heat the plastic evenly by increasing heating range.
iii) Pyrolising the plastic.
iv) Catalytic conversion of the gases to specific carbon chain lengths.
v) Condensation of gases (vapor) which are come from the furnace by suitable cooling method for better quality.

Design Of Model

Experimental Setup

The following diagram shows the setup model of the experiment. The Pyrolysis process includes the heating of plastic components in required condition of temperature and pressure in vacuum. In the setup we need furnace which can withstand and control the temperature range from 300^0c to 600^0c. Due to constant heating the plastic in the furnace it can be converted into vapour form. Hence we need the huge pipes to carry the vapours into the collecting tank. The hot pipes must carry the very hot gases with little amounts of thermal errors. Then we need condenser for cooling the exit gases which is filled by coolant e.g. water and connecting pipe which carries hot vapours from furnace to condenser. The whole setup is placed on the table approx. 2-3 ft. from ground. It helps to easy working as well as reducing the thermal errors.

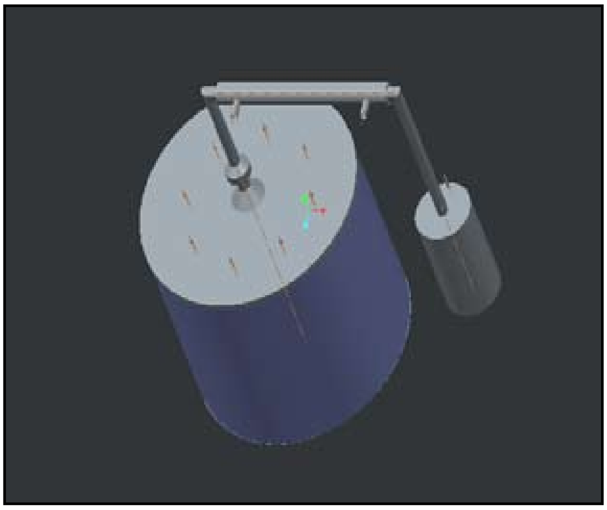


Fig. 1: 3-D view of Model

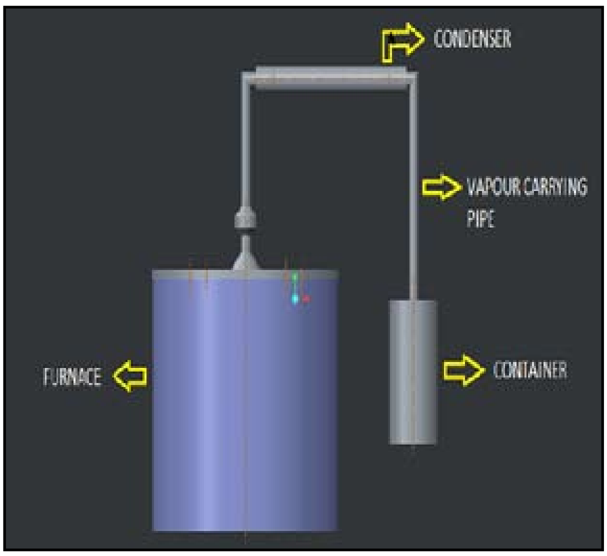


Fig. 2: Side view of Model

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Analytical Calculations:

1. Inner Cell

Material = Stainless Steel (S_{yt} = 215 MPa)

Allowable stress = S_{yt} / N_f

Taking $N_f = 2$

Allowable stress, 6_{all} = 215 / 2 =107.5 MPa

Maximum pressure, p_{max} = 15bar

Thickness, t = (p_{max} x d)/ 2 6_{all}

t =1.5 x 200 / (2 x 107.5)

t = 1.395 ~ 1.4 mm

Thickness of Inner cell is 1.4mm. But for Considering safety and availability of Material we have taken thickness of 5mm.

2. Outer Cell

Material = Mild Steel (S_{yt} = 370 MPa)

Allowable stress = S_{yt}/N_f

Taking $N_{f=}$ 2

Allowable stress, 6_{all} = 370/2 =185 MPa

Maximum pressure, p_{max} =15bar

Thickness, t = (p_{max} x D)/ 2 6_{all}

t =1.5 x 380 / (2 x 185)

t = 1.59mm ~ 1.6mm

Thickness of Outer cell is 1.6mm. But for Considering safety and availability of Material we have taken thickness of 5mm.

3. Flange

Thickness of Flange = 1.3 t

= 1.3 x 10 = 13mm

4. Top Cover

Material = Mild Steel (S_{yt} = 370 MPa)

Allowable stress = S_{yt} / N_f

Taking $N_{f=}$ 2

Allowable stress, 6_{all} = 370/2 =185 MPa

Maximum pressure, p_{max} = 15bar

Thickness t = K1 x D x $(p_{max} / 6_{all})^{1/2}$

= 0.3 x 400 x $(1.5/185)^{1/2}$

= 9.67 mm ~10mm

Actual Fabricated Model

Specifications of Components

(a) REACTOR
- Height = 300mm,
- Internal Diameter (I.D.) = 200mm,
- Outer Diameter (O.D.) 210mm
- Thickness (t) = 5mm

(a) FURNACE
- Inner Diameter = 380mm
- Outer Diameter = 390mm
- Thickness = 5mm
- Outer Diameter of Flange = 265mm
- Inner Diameter of flange = 260mm

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- Thickness of Flange = 10mm

(c) CONDENSER
- Type of Condenser = Water cooled Condenser
- Diameter of condenser = 100mm

(d) HEATING COIL
- Material = Stainless Steel
- Max operating pressure
- Max operating Temperature = $1800^{o}C$
- Length = 6000mm (9 rounds)
- Resistance = 170 ohm
- Max Power = 33 KW

(e)TEMPERATURE CONTROLLER
- Paragon autocontrol
- Input voltage = 230 V
- For 2 wire RTD or Thermocouple
- Range = $1200^{0}C$
- Control = On-Off Type

(f) THERMOCOUPLE
- Type = 'K' type Thermocouple
- Sensing device = Probe sensor
- Max Temperature Range = -250 to $1200^{0}C$
- Cr-Al Type

Production of Thermo Fuel

PREPROCESSING WORK**:**

In the pre-processing work, we need to collect require type of plastic material which can easily found in the surrounding. We need 1 kg of plastic for the 950ml of plastic fuel. According to our requirement collect required amount of plastic material for the process. Make the instruments ready for the process. Collect the required catalyst for the process. We are using silica alumina and zeolite in proportion of 1:1 for greater efficiency of the process. Check the measuring and controlling devices of model such as thermostat, heating coil etc. Confirm the setup is ready and go for process.

PRODUCTION PROCESS OF PLASTIC FUEL

The production process of the model is shown in below figure:-

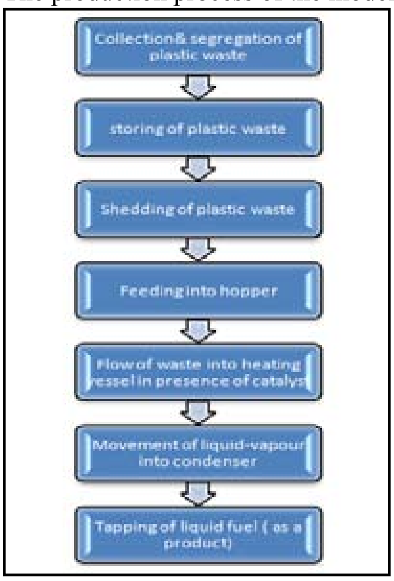

Fig No 3: Flow Chart For Steps of Production Process of Plastic Fuel

Steps for Production Process:

1. To collect and segregate waste plastic suitable for Pyrolysis process preferably polyolefin's polyethylene, polypropylene & polystyrene.
2. Then the collected waste plastic is stored in a storing tank.
3. Then the waste plastic is shredded into small flakes of plastics.
4. Then it is feed into heating vessel in presence of catalyst.
5. The liquid vapours are allowed to flow into the condenser.
6. In condenser the liquid vapours cools and liquid fuel is tapped which can be used for various purposes.

Step 1: Collection of plastic material: A rough rule of thumb is to take a representative sample of the flaked waste plastic and add it to a jar of water. If more plastic floats than sinks then the plastic scrap is acceptable feedstock for Thermo Fuel. The floatable fraction represents mainly polyolefin's and polypropylene and expanded polystyrene. Polyolefin's give the best yield of distillate due to their straight-chain hydrocarbon structure. Polystyrene is beneficial in the mix since it contributes aromatic character to the distillate and improves the pour point properties. Suitable Plastic Material for Treatment as a rule of thumb, approximately 950ml of oil can be recovered from 1kg of plastics such as Polyolefin's including Polyethylene (PE) and polypropylene (PP), or polystyrene (PS).

The raw materials include following:

1) Polyethylene: Buckets, drums, Chapels, sandal, bottles, plastic parts, carry bags etc.
2) Polypropylene: Pipe fitting, filter cloths etc.
3) Polyamide: Nylon ropes
4) Polyvinyl Chloride (PVC): PVC pipes and fittings
5) Polystyrene: Cloths and fibre
6) Rubber: Tires, automobile parts
7) Electronic Goods: Telephone sets, computers, keyboards, monitors laptops, electronic devices etc.

Step2: Cleaning and drying the plastic components: Plastic is a man-made substance with meant to withstand dirt and hard use. As there are various uses of plastic in industries so many impurities, dirt and unwanted material present in the mixture. So we have to remove that unwanted materials. There are so many methods of cleaning the plastic material. Use warm water or sprinkle baking soda into bottles, or plastic bags for cleaning. And use the preheated steam to dry the components. It is very suitable method and do not required extra cost for cleaning and drying the plastic.

Step3: Shredding & crushing of plastic components: As we are using used plastic, they are of various size and shape. This occupies whole size of reactor. Hence it is important to reduce its shape by crushing and pressing method. For this we can use manual method for soft plastic such as plastic bottle, polyethene bags. But the hardened plastic crushed by the crusher machines. The crusher machine cuts the plastic in small parts that can we use easily in reaction. Also reaction need in presence of catalyst. Due to its big shape catalyst cannot reached to whole part of plastic material. It may cause to the reaction. That's why we crush the plastic before using into the process.

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Step 4: Pyrolysis Process: The Pyrolysis is a main process of conversion of plastic fuel. In Pyrolysis process, we start the heating coil. The heating coil heats the internal part of the reactor. The ignition temperature of the process reaches above 350^{o}C. The plastic starts melting. Due to vacuum inside the reactor chamber plastic cannot burnt but only continuous heated by heating coil. Due to this the plastic is converted into the superheated steam. The larger bond between the carbon particles breaks in to smaller carbon component. The catalyst (Silica alumina and zeolite) controls the whole process of formation of apparatus. The vapour's come out from the nozzle at the upper side and enter into the pipe. The pipe is heat resistant and material of pipe has high melting temperature. The hot and high velocity gas goes through the condenser to collecting tank or coolant tank (Here we are using water) which helps to condense the gases. It forms the layer of fuel on the surface of coolant in the tank.
Step 5: Condensation of the vapours: The hot and high velocity gases enters into the condenser. The condenser use water as a coolant to cool the hot vapours. Due to this the gases convert into the fuel. The fuel forms separate layer on the surface of collecting tank. We can separate the fuel from the condenser. The formed fuel is known as "Plastic fuel". If we want to separate the petrol diesel or other gases from the plastic crude oil we have to allow it to fractional distillation chamber. But it is very costly method hence we are using the crude oil fuel directly in the use.
Step 6: Testing and Analysis of Properties of the fuel: The collected plastic fuel shows the properties near to conventional fuel. The output fuel tested under the various methods to check their properties. It can be seen that the properties of plastic fuel is better than the diesel and petrol which we are using in daily life. Hence it is seen that the plastic fuel is good replacement of conventional fuel.

PRECAUTIONS:
1. Do not touch the furnace and its assembly during working condition.
2. Check the connection of heating coil before starting the operation.
3. Place the setup on levelled surface.
4. Check whether the temperature measuring device i.e. thermostat is in working condition.
5. Remove all the components of setup carefully after operation.

CATALYST USED
Here we are using catalyst Silica alumina and Zeolite in 1:1 proportion.

There are two types of Pyrolysis:
i) Normal Pyrolysis
ii) Catalytic Pyrolysis.
The catalyst is used to:
1. Increase the rate of reaction
2. Increase the yield of product
3. Reduce the waste after Pyrolysis
The polymer- catalyst ratio plays important role in the production waste plastics oil.

- If we use polymer to catalyst ratio 3:1-
  -the amount of solid product is more
  -the weight of gaseous product is medium
  -the weight of liquid product is more
- If we use polymer to catalyst ratio 6:1-
  -the amount of solid product is medium
  -the weight of gaseous product is high
  -the weight of liquid product is medium
- If we use polymer to catalyst ratio10:1-
  -the amount of solid product is less
  -the weight of gaseous product is less
  -the weight of liquid product is high

We can use catalyst blend for increasing more efficiency of the catalyst in production process. It combines properties of both catalyst and gives efficient results than using single pure catalyst. Here we are using catalyst *Silica alumina*and *Zeolite*.
If we use 100% Zeolite as catalyst then the temperature of reaction is comparatively high for high production of fuel oil.
If we use 50% Zeolite & 50% silica alumina, silica alumina reduces the temperature of reaction for maximum production of fuel oil and Zeolite helps in increasing the rate of reaction.
Therefore, we used catalyst ratio as1:1.

Comparison with Conventionnal Fuel

Table1: Comparision Between WCO, Biodiesel & Thermo Fuel

Properties	WCO	Biodiesel	Thermo-fuel
Kinematic viscosity	39.7	6.58	1.1
Calorific value (kJ/Kg)	36.13	35.64	41.8
Cloud point ^{0}C	0	2	-20
Pour point ^{0}C	-40.7	-8	-20
Flash point ^{0}C	278	56	22
Density (kg/m^{2})	910	885	793

Table 2: Comparision Between Regular Gasoline & Thermofuel

Properties	Regular gasoline	Fuel extracted from waste plastic
Color & visual	Orange	Pale yellow
Specific gravity at 280^{0}C	0.7423	0.7254
Specific gravity at 150^{0}C	0.7528	0.7365
Gross calorific value (kJ/Kg)	11210	11262
Net calorific value (kJ/Kg)	10460	10498
API gravity	56.46	60.65
Sulphur content	0.1	0.002
Flash point ^{0}C	23	22
Pour point ^{0}C	<-20 ^{0}C	<-20 ^{0}C
Cloud point ^{0}C	<-20 ^{0}C	<-20 ^{0}C

Table 3: Comparision with Diesel

Sr. no.	Properties	WPP	Diesel
1	Density (kg/m^2)	793	850
2	Ash content (%)	<1.01	0.045
3	Calorific value (kJ/Kg)	41.800	42.000
4	Kinematic viscosity	2.149	3.05
5	Cetane number (stroke)	51	55
6	Flash point ^{0}C	40	40
7	Fire point ^{0}C	45	56
8	Carbon residue (%)	0.01	0.2
9	Sulphur content (%)	<0.002	<0.035

Result

KINEMATIC VISCOSITY: Thermo-fuel is having very low kinematic viscosity as compared to WCO, Biodiesel and Diesel.
CALORIFIC VALUE: Thermo-fuel is having calorific value high as compared to WCO, Biodiesel but it is less than Diesel.
FLASH POINT: Thermo-fuel is having flash point low as compared to WCO and Biodiesel but it is equal to Diesel.
FIRE POINT: Thermo-fuel is having low fire point than Diesel.
DENSITY: Thermo-fuel is having low density as compared to WCO, Biodiesel and Diesel.

Conclusion

Based on the reviewed paper, it is concluded that Thermo-fuel obtained by this method is good alternative fuel and having properties similar to other conventional fuels like Biodiesel, Gasoline. Further it is concluded that fuel obtained is pure if we use one type of plastic, 10:1 ratio of plastic wastes to catalyst and 1:1 ratio of silica alumina and zeolite as a catalyst. The amount of fuel produced increase as temperature increase up to 550°C above which fuel produced again reduces. It is also seen that the by-products obtained like solid and gases still used further for example solid by-product obtained is similar to wax and these can be used for making candles or other related applications whereas gaseous by-product is having fire property and catches fire when come in contact with fire. The process is very economical and conversion of plastic waste into fuel reduce dependence on conventional fuels as well as the most critical problem of decomposition and disposing of plastic wastes can be solved. The process is completely eco-friendly and there will be no harm to our environment.

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