Conversion of Waste Plastics into Fuel

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Abstract – Due to the current continued use of fossil fuels such as crude oil, natural gas and coal, the current economic growth rate is unstable. Therefore, renewable energy sources are being exploited, but some resources, such as plastic waste, need to be developed into a full-fledged economic activity. Pyrolysis is a process which involves thermochemical decomposition of organic matter at high temperature (>370◦C) in the absence of oxygen. Products of this process are Pyrolysis Oil, Carbon Black, and Hydrocarbons. This review paper is focusing the most efficient and widely used method of converting plastics to fuels: ‘Pyrolysis’ and its effectiveness on resolving the both issues of waste plastic management and the requirement of a good alternative fuel for use.

Key Words: *Plastic wastes, Decomposition, pyrolysis, fuel*

1.INTRODUCTION

Plastic goods and packaging and the inevitable plastic waste resulting from them are found all over the world. Plastic is a relatively cheap, durable and versatile material. However, as waste it constitutes a sizeable percentage of the litter we see every day in public places. It is also non-biodegradable; presents risks to human health and the environment; and some types are difficult to re-use and/or recycle. Almost 150 million tons per annum are produced every day. material at elevated temperatures in the absence of oxygen. Pyrolysis of organic substances produce gas and liquid products which are termed as bio-fuels and leave a solid residue. Primarily, mechanical reprocessing is the method of plastic Recycling which is the feasible only when high purity selectively collected wastes are available . Alternatively, There is an attractive process for recycling by thermal or Catalytic method which produces hydrocarbon. The pyrolysis can be cost effective compared to other processes.

In the process of plastic pyrolysis macromolecular structure of polymer are broken into smaller molecules and sometime monomer units. Further degradation is of these subsequent molecules depends on a number of different conditions including temperature, residence time, presence of catalyst and other process conditions. The pyrolysis reaction is carried out with and without catalyst. So the process of pyrolysis of plastics is attempted to reduce the waste plastics and to find a source for alternate fuel. Thermal cracking, or Pyrolysis, involves the degradation of The polymeric materials by heating in the absence of oxygen at A temperature between 500 – 800ºC and results in the Formation of a carbonized char (solid residues) and a volatile Fraction that may be separated into condensable hydrocarbon Oil consisting of paraffins, isoparaffins, olefins, naphthene’s And aromatics, and a non-condensable high calorific value gas.

2.EXPERIMENTAL PROCEDURE

2.1 Pyrolysis

Pyrolysis is the chemical decomposition of condensed substances by heating that occurs spontaneously at high enough temperatures. [In sec 1]

Pyrolysis is a special case of thermolysis, and is most commonly used for organic materials, being then one of the processes involved in charring. The pyrolysis of wood, which starts at 200°C -300 °C, occurs for example in fires or when vegetation comes into contact with lava in volcanic eruptions. In general, pyrolysis of organic substances produces gas and liquid products and leaves a solid residue her in carbon content. Extreme pyrolysis, which leaves mostly carbon the residue, is called carbonization.

2.2 Preparation of Plastic wastes into Fuel

We need a container to store all the waste Plastic which will be burnt for the process of pyrolysis to Happen and convert the waste plastic into useful product Which is fuel. For the extraction of the fuel the pyrolysis Device is connected to the container with help of pipes or Tubes. The vapors which is released from the burning of Plastic waste will further transfers with the help of tubes Connecting the pyrolysis device to the container. The vapor generates when the container is heated at 500 Degrees. Then these vapors will further send with the help Of pipes which is then divided into two or more segments As one is used to carry impunity and the other carries fuel Vapors. The working of the instrument is shown below Through the image given below. Some plastic fuel which is Obtained after the pyrolysis process is burnt to check Whether the fuel obtained is useful or not and it is one of The most important steps after the process.

Fig. 1 Experimental setup

(Experimental setup of trial test conducted, wherein plastic was dumped into closed Container and is heated)

3. THEORETICAL CALCULATIONS

3.1 Heat Energy And Current Rating:

The plastic feed supplied is 5 Kg.

Consider Polypropylene (PP)

Specific Heat of solid PP	= 2.2 kJ/kg-K
Melting Point of PP	=165°C
Latent heat of fusion of PP	= 800 kJ/kg
Specific Heat of liquid PP	= 2.79 kJ/kg
Cleavage temperature of PP	=350°C
Activation energy for PP	= 135 MJ/kmol
Molecular weight of PP	= 220000 kg/kmol

Let the mass of polypropylene be “Z” kg.

= [mass of PP × specific heat of solid PP × (melting point of PP - Ambient temperature)] + [mass of PP × latent heat of fusion of PP] + [mass of PP × specific heat of liquid PP × (cleavage temperature of PP - melting point of PP)] + [mass of PP × activation energy/molecular weight]

= [(Z)(2.2)(165-35)] + [(Z)(800)] + [(Z)(2.79)(350-165)] + [(Z)(135)(1000/220000)]

= 286 Z+ 800 Z+ 516.15 Z+ 0.6136 Z. = 1602.7636 Z kJ

Assuming that 50%plastic feed is polypropylene i.e. mass of PP = 2.5 kg

Therefore, Heat energy required by PP = 1602.7636 × 2.5 = 4006.909 kJ

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Consider Polyethylene (PE)

Specific Heat of solid PE	= 2.2 kJ/kg-K
Melting Point of PE	=125°C
Latent heat of fusion of PE	= 500 kJ/kg
Specific Heat of liquid PE	= 2.78 kJ/kg
Cleavage temperature of PE	=350°C
Activation energy for PE	= 280 MJ/kmol
Molecular weight of PE	= 90000 kg/kmol

Let the mass of polypropylene be “Z” kg.

= [mass of PE × specific heat of solid PE × (melting point of PE -Ambient temperature)] + [mass of PE × latent heat of fusion of PE] + [mass of PE × specific heat of liquid PE × (cleavage temperature of PE - melting point of PE)] + [mass of PE × activation energy/molecular weight]

= [(Z)(2.2)(125-35)] + [(Z)(500)] + [(Z)(2.78)(350-125)] + [(Z)(280)(1000/90000)]

= 198 Z + 500 Z + 625.5 Z + 3.111 Z. = 1326.61 Z kJ

Assuming that 50%plastic feed is polyethylene i.e. mass of PE = 2.5 kg

Therefore, Heat energy required by PE = 1326.61 × 2.5 = 3316.5 kJ

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Therefore Heat energy required by plastic feed containing 50% Polypropylene and 50% polyethylene

$Q_{plastic}$ = Heat energy required by PP + Heat energy required by PE

= 4006.909 + 3316.5

$Q_{plastic}$ = 7323.409 kJ

Assuming 25% of total heat for sensible heating of vapour to 550°C

$Q_{sensible}$ = (25/100) × 7323.409 = 1830.85 kJ

Assuming another 25% for heat losses

Q_{losses} = (25/100) × 7323.409 = 1830.85 kJ

Total Heat energy required $Q_{total} = Q_{plastic} + Q_{sensible} + Q_{losses}$

Q_{total} = 7323.409 + 1830.85 + 1830.85 = 10985.109 kJ

Q_{total} = 10985.109 kJ .

This heat is supplied for a span of 1 hour,

i.e. 10985.109 / (1×3600) KJ/s = 3.0514 kW.

Power required = 3.0514 kkW

3.2 Length of Condenser:

Copper tube condenser

Inner tube: copper	Outer Diameter (d_o) = 15 mm;
	Inner Diameter (d_i) = 13 mm;

3.2.1 Flow through condensers:

Heat Load ≈ 2.0 kW

$= m.\ C_p.\ \Delta T$

where,

m = mass flow rate in kg/s.

C_p= Specific heat in kJ/kgK.

ΔT= Change in temperature.

$\Delta T = 10^\circ C;$

$C_p = 4.18$ kJ / kg K.

$$m = \frac{2.0 \qquad 2.0}{[(4.18)(10)][(4.18)(10)]}$$

= 0.0478 kg/s

Since density is 1 kg/m^3 , we have volume flow rate as

= 0.0478 l/s

= q

$q = (a)(v)(a)(v)$

$$a = \left(\frac{\pi}{4}\right)(0.025^2 - 0.015^2)\left(\frac{\pi}{4}\right)(0.025^2 - 0.015^2) = (3.142)(10^{-4})(3.142)(10^{-4})\ m^2.$$

$$v = \frac{(0.0478)(10^{-3})(0.0478)(10^{-3})}{(3.142)(10^{-4})\ (3.142)(10^{-4})}$$

= 0.152 m/s

a = area of the condenser through which the water flows in m^2.

v = velocity of flow in m/s.

3.2.2 Tube outside surface

Nusselt Number, (For fully developed flow from HMT data book page.125)

$Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$

where,

Re = Reynolds number

Pr = Prandtl number

Effective diameter,

$D = (Do^2-Di^2)/Di^2$

$$= \frac{0.025^2-0.015^2 0.025^2-0.015^2}{0.015 \qquad 0.015}$$

= 0.0267 m

$$Re = (\rho)(v)\left(\frac{d}{\mu}\right)(\rho)(v)\left(\frac{d}{\mu}\right)$$

$$=(970)(0.152)\left(\frac{0.0267}{3.5*10^{-4}}\right)(970)(0.152)\left(\frac{0.0267}{3.5*10^{-4}}\right)$$

= 11248

Pr for water at 90°C = 1.9

$$Nu = (\ 0.023)(11248^{0.8})(1.9^{0.4} 0.023)(11248^{0.8})(1.9^{0.4}) = 51.77$$

$= (h_o)(D)/(k)$

Where,

h_o = Convective heat transfer coefficient along outer surface of the inner tube.

k = Thermal conductivity of the fluid.

Convective heat transfer coefficient along the outer surface of inner tube (h_o)

$$h_o = \frac{(51.77)(0.670)(51.77)(0.670)}{(0.0267) \qquad (0.0267)}$$

= 1299 W / m^{2}k

3.2.3 Tube inner Surface

Condensation in the inner tube (HMT data book page-149)

h_i = (0.555) $$\left[\frac{\rho_1(\rho_1-\rho_v)(g)(k^3)(h_{fg})}{\mu(T_v-T_s)\,d_i}\right]^{0.25}$$

$$\left[\frac{\rho_1(\rho_1-\rho_v)(g)(k^3)(h_{fg})}{\mu(T_v-T_s)\,d_i}\right]^{0.25}$$

h_i = (0.555) $$\left[\frac{\{961(961-0.578)(9.81)(680^3)(2257)(10^3)\}}{\{(2.90)(10^{-4})(0.013)(5)\}}\right]^{0.25}$$

$$\left[\frac{\{961(961-0.578)(9.81)(680^3)(2257)(10^3)\}}{\{(2.90)(10^{-4})(0.013)(5)\}}\right]^{0.25}$$

= (0.555) $[(4.297)(10^6)$ $[(4.297)(10^6)]$

= $2.385x10^6$ $2.385x10^6$ W/m^{2}K.

TUBE WALL

Overall heat transfer coefficient for tubular sections (U_o) , from HMT data book page.156.

U_o = $$\frac{1}{\left[\left\{\left(\frac{ro}{ri}\right)\left(\frac{1}{hi}\right)\right\}+\left\{\left(\frac{ro}{kw}\right)\left(\ln\left(\frac{ro}{ri}\right)\right)\right\}+\left(\frac{1}{ho}\right)\right]}$$

$$\frac{1}{\left[\left\{\left(\frac{ro}{ri}\right)\left(\frac{1}{hi}\right)\right\}+\left\{\left(\frac{ro}{kw}\right)\left(\ln\left(\frac{ro}{ri}\right)\right)\right\}+\left(\frac{1}{ho}\right)\right]}$$

= $$\frac{1}{\left[\left\{\left(\frac{7.5}{6.5}\right)\left(\frac{1}{2.385*10^6}\right)\right\}+\left\{\left(\frac{0.0075}{100}\right)\ln\left(\frac{7.5}{6.5}\right)\right\}+\left(\frac{1}{1299}\right)\right]}$$

$$\frac{1}{\left[\left\{\left(\frac{7.5}{6.5}\right)\left(\frac{1}{2.385*10^6}\right)\right\}+\left\{\left(\frac{0.0075}{100}\right)\ln\left(\frac{7.5}{6.5}\right)\right\}+\left(\frac{1}{1299}\right)\right]}$$

= $$\frac{1}{[(4.93+10^{-7})+\{(1.073)(10^{-5})\}+\{(7.70)(10^{-4})\}]}$$

$$\frac{1}{[(4.93+10^{-7})+\{(1.073)(10^{-5})\}+\{(7.70)(10^{-4})\}]}$$

= 1280 W/m^{2}K

L = $\frac{Q}{(Uo)(A)(LMTD)}$ $\frac{Q}{(Uo)(A)(LMTD)}$ (HMT data book page.151)

LMTD = $\frac{410-20}{\ln\left(\frac{410}{20}\right)}$ $\frac{410-20}{\ln\left(\frac{410}{20}\right)}$

= 130° C.

L = $$\frac{(2.07)(10^3)}{(1280)(\pi)(0.015)(130)}$$

$$\frac{(2.07)(10^3)}{(1280)(\pi)(0.015)(130)}$$

= 0.260 m.

LENGTH OF CONDENSER = 0.260 m

NOTE: To compensate for the end effects (entrance effect and exit effect) a 10% allowance is necessary. Hence the actual length of the condenser used in the setup is around 0.3 m.

3.3 Pump Power calculations:

Assuming Load ≈ 3.0 kW. = m. C_p. ΔT

where,

m = mass flow rate in kg/s.

C_p= Specific heat in kJ/kgK.

ΔT= Change in temperature.

ΔT = 10° C; C_p = 4.18 kJ / kg K;

m = $\frac{3.0}{[(4.18)(10)]}$ $\frac{3.0}{[(4.18)(10)]}$ = 0.0718 kg/s.

Since density is 1000 kg/m^3 , we have volume flow rate as

= 0.0718 l/s

= (0.0718) (10^{-3}) $10^{-3})$ m^3/s

For safer side assuming the flow rate as 6.0 l/min

Pump Power P = $[(q)(\rho)(g)(h)]$ $[(q)(\rho)(g)(h)]$

= $(0.0718)(10^{-3})(961)(9.81)(5)$

$(0.0718)(10^{-3})(961)(9.81)(5)$

=3.384 W

P = Pump Power in W.

q = flow capacity in m^3/s.

ρ = density of fluid in kg/m^3.

g = acceleration due to gravity in m/s^2.

h = differential head in m.

NOTE: The pump with minimum power available in the market is 0.12 HP. Hence a 0.12 HP centrifugal pump is used in the experimental setup.

Sr no	Characteristics	Diesel Fuel grade
1	Flash point (deg. C)	81
2	Fire point (deg. C)	90
3	Viscosity @ (40 deg. C)	3.812
4	Density kg/m3	823
5	Calorific Value kJ/kg	46888

Table 1. Diesel grade of waste Plastics

4. CONCLUSIONS

This project explores the use of waste plastics in the Growing and developing world. Other alternatives to plastic Are difficult to find because plastic has many uses and Different properties. The implementation of this project in the. Real world develops many possibilities. This is a good Solution for controlling waste plastics and finding a new Diesel source for the country.

As raw materials, wastes plastics have attractive potentials for large-scale industries and community-level enterprises. The waste plastics Used in the process must be polyethylene, polypropylene, or Low-density polyethylene to avoid chlorine contamination in The fuel.For efficient and effective conversion of waste plastics into a resource, appropriate selection of technologies is one of the vital pre-conditions. In addition, this method produces an alternative to Fossil fuels such as crude oil and petroleum, and may be an Alternative source of energy. Improvements in this Technology are in demand at this level due to the rapid Depletion of renewable energy sources such as fossil fuels. Therefore, further studies are needed and important to use This oil as fuel or feedstock. It represents the future trends of Plastic waste recycling and is fueling an industry.

“ENERGY CAN NEITHER BE CREATED NOR DESTROYED, BUT CAN BE TRANSFORMED FROM ONE FORM TO ANOTHER.”

Fig 2 (Efficient burning of the obtained fuel)

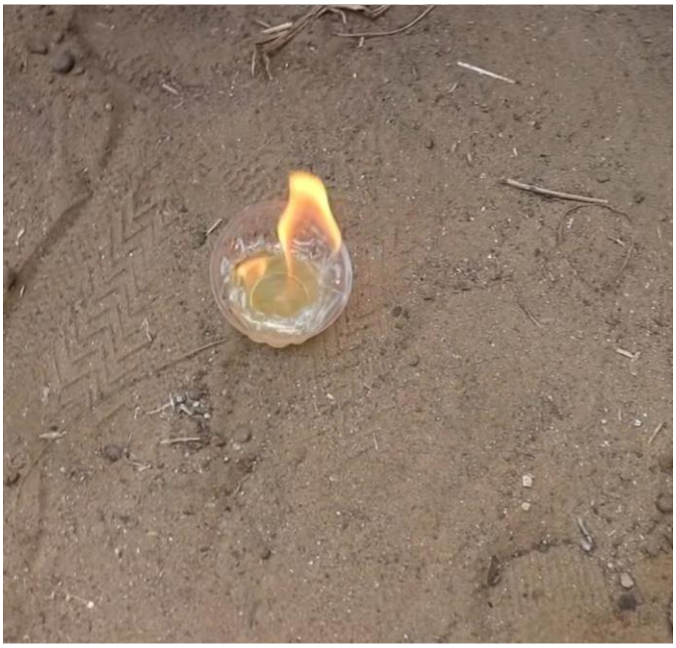
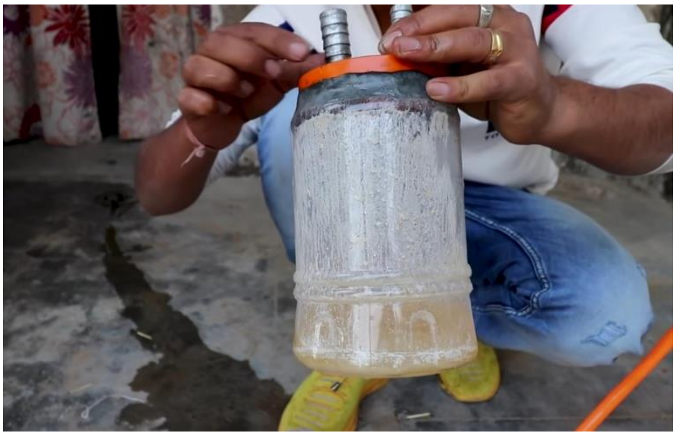


Fig 3. (Distilled fuel obtained from waste plastic)



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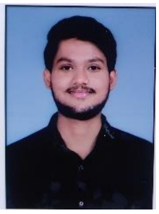

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