ISSN:2348-2079

Volume-7 Issue-2

International Journal of Intellectual Advancements and Research in Engineering Computations

Development of pyrolysis process reactor for extracting fuel from plastic waste

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ABSTRACT

Plastic is extensively used as an alternative material for wood, metal and glass due to its versatile properties like resistance to corrosion, resistant to water, low electrical and thermal conductivity, high strength-to-weight ratio, transparent, good durability, low cost, easy to manufacture and low toxicity. On the other hand, the non-biodegradable nature of plastic creates pollution to the environment after the end of life. In India around 80% of used plastics are discarded as waste and resulted in accumulation of wastes about 25,940 tons per day. Only a small portion of it is recycled and remaining non-recyclable plastic wastes were disposed by incineration, landfill, etc. In this work, an attempt is made to develop an experimental set up of capacity 14.4 liters per day to convert waste plastics into usable fuel using pyrolysis concept. The performance of the pyrolysis reactor was investigated and presented in this paper. Conversion efficiency (wt %), waste reduction efficiency (wt %), and Oil recovery (ml/kg) were found to be 60%, 99% and 600 ml/kg respectively.

Keywords: Waste, Pyrolysis, Depolymerisation, Distillation, Reactors.

INTRODUCTION

Plastic materials are non-biodegradable. The disposal of plastic waste found to be a major challenge, limiting the plastic production, usage and attract more research for solution. The different types of plastics used now days include polystyrene, poly vinyl chloride, polypropylene, PE terephthalate, acrylonitrile-butadiene-styrene, and PE. Recycling of waste plastics is found to be the most effective way. But, only a small portion of plastic waste is recycled and remaining non-recyclable plastic wastes were disposed by incineration, landfill, etc. The increase of petroleum products prices and its non-availability in future have opened the ways for industries to invest in converting plastic waste in to petrochemicals. Decomposition or cracking is a process of converting plastics waste which involves break down the long polymeric chains into useful smaller molecular weight compounds. The products obtained from this process can be utilized as fuels or chemicals in various applications. The process of degradation or cracking of the polymeric materials by heating to a very high temperature is called pyrolysis.

Models for optimal pyrolysis conditions of plastic waste mixtures have been proposed by researchers. Extensive literature is available related to conversion of plastic wastes in to fuel. In this context, an objective is set to develop a reactor for pyrolysis process, production and testing of fuel from polypropylene (PP) waste plastics [1-5].

Experimental set up and materials

A laboratory scale externally heated fixed bed pyrolysis reactor shown in Fig. 1 was fabricated.

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Fig 1.Experimental set up

Experimental set up consists of a pyrolysis chamber, temperature controller, condenser, temperature sensor, a heating set up, insulator, storage tank, valve, and gas exit line (Shown in Fig. 2 & 3).

Fig. 2 Pyrolysis Chamber

The specification of the cylindrical container is as follows.

- Material: Mild steel
- Dimension: Length 1500 mm, internal diameter of 300 mm and outer diameter of 320 mm.
- Mode of heating: LPG and stove
- Heating rate: 12°c/min.

The reactor is heated to a temperature of approximately 450°C.

Condenser

The condenser is a unit used to cool the vapor coming out of the reactor. It consists of an inlet and outlet for feeding cold water. It is made up of aluminum tubes and covered by mild steel like a tubular section [6-10].

Fig. 3 Condenser

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Materials

The plastic used in this experiment was plastic waste of PP type obtained from the collection of plastic chairs. Waste plastics were cleaned to remove foreign materials such as mud and oil. It is crushed in to small pieces as shown in Fig.4.

Fig. 4 Waste Plastic (PP)

Plastic powder was dried and used as raw material for the pyrolysis process. The powder produced from the waste plastic contains only hydrocarbons with the slight waxy odor and translucent to white of solid granules. The physical properties of the polypropylene material used in this experiment are presented in Table 1.

Table 1 Physical Properties of PP

Melting point	130-167°c
Flash point	>329°c
Ignition temperature	>400°c
Decomposition temperature	>300°c
Danger of explosion	Not explosive
Density	0.89-0.94g/cm^3
Solubility in water	insoluble
Additional information	Soluble in boiling, aromatic chlorinated solvents
Flash ignition temperature	335°c
Auto ignition temperature	350°c

RESULT AND DISCUSSION

The process was carried out by filling 1 kg of waste plastic powder in to the chamber and heated between the temperature ranges of 400^0 C and 500^0 C in the reactor for about sixty minutes. There was no output at the initial heating. The vapor produce from the reactor is fed in to the condenser. Water is used as a cooling medium to condensate the vapor. The condensed bio-oil was collected in a bottle shown in Fig. 5.

Fig 5.Vapor Condensation & Collection of Fuel

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A small part of non-condensed gas was exhausted to the atmosphere and the char was collected from the reactor after completion of pyrolysis cycle.

Fraction Distillation

The plastic fuel is distilled using glass reactor, glass condenser and glass L –bend as shown in Fig. 6.

Fig. 6 Fractional Distillation

The cooling system attachment provides support for the distillation process. More number of fractions gives better quality fuel. Fuel obtained from the above process is displayed in Fig. 7.

Fig. 7 Fuel after Fractional distillation

Pyrolysis liquid (plastic oil) and hydrocarbon gas are the major products obtained from the pyrolysis of plastic waste. The product yield of pyrolysis process widely varies due to different factors such as operating temperature, feed particle size, and running time. However, the analysis shows that the maximum 600 ml liquid oil is found at an operating temperature of 450°c-500°c for a feed size volume of 0.15 cm^3. The reactor has the volume of feed about 1000 gm. The retention time of machine is about 60 min, [11].For LPG as a source of energy

CALCULATIONS OF PERFORMANCE OF MACHINE

In this work, the performance of the fabricated waste plastic oil machine was evaluated in terms of conversion efficiency (wt %), waste reduction efficiency (wt %), oil recovery (ml of oil/kg of plastic) and presented in Table 2.

Conversion Efficiency (wt %) CE = W_O/W_{Sm} x 100 %

Where

CE = Conversion Efficiency
Wo = Weight of oil converted (g)
Wsm = weight of the sample material (g)
W_{SM} in this experiment = 1kg = 1000 g
W_O in this experiment = 0.6kg = 600g
CE = [600/1000] x 100 = 0.6 x 100 % = 60%

Waste Reduction Efficiency (wt %)

WRE = [(W_{SM} - W_C) / W_{SM}] x 100%

Where

WRE = Waste Reduction Efficiency
Wc = Weight of char inside the reactor (g)

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Wsm = weight of sample material (g)
Wc in this experiment = 0.001
Wsm in this experiments = 1kg = 1000g
WRE = [(1000 - 0.001) / 1000] x100 %
[999.99/1000] x 100% = 99%
Oil Recovery [OR} in ml/kg
OR=V/Wsm

Where
OR = Oil Recovery (ml/kg)
V = Volume of oil recovered (ml)
Wsm = Weight of sample material (kg)
V in this experiments=600ml
Wsm in this experiments=1kg
OR=600ml/1kg = 600ml/kg

Table 2. Performance of Machine

Parameters	Performance
1. Conversion Efficiency (wt %)	60%
2. Waste Reduction Efficiency (wt %)	99%
3.Oil Recovery (ml/kg)	600 ml/kg

The above calculations show that the conversion efficiency (wt %) of fabricated machine is 60 %. 99% of waste reduction efficiency (wt %) is most advantage of this fabricated machine.

CONCLUSION

The presented study proved that pyrolysis technology used for plastic waste decomposition is an efficient and effective method for extracting fuel. The optimum liquid yields conditions for the reactor system is found to be 450°c- 500∘C and size volume of 0.15 cm^3 (PP) at a gas flow rate of 0.01liters/min with a running time of 60 minutes. The liquid production is found to be the maximum (50 wt %) of the PP feedstock. The results of the present study revealed that the thermal pyrolysis of waste plastic would be better method for extracting fuel from plastic waste than the use of catalyst. It is costly and regeneration of catalyst is a difficult task.

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