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Plastic Waste to Fuel Conversion

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ABSTRACT: Disposal of plastic waste is a serious concern in India. New technologies have been developed to minimize the adverse effect on the environment. Currently widely accepted technology used for the plastic disposal is incineration; however, incinerators designed poorly, releases extremely toxic compounds (chlorinated dioxins and furans). However, a new generation of conversion technology specifically designed to manage non-recycled plastics has been developed, and commercial scale facilities that use pyrolysis technology to convert plastics into oil and fuel are being established. The electronic controls used in the plastic waste to fuel converter plays an important role in the generation and control of the process and the fuel output. On off controls are generally used for such controls. Impact of using PID control in the output has been studied. This paper provides an overview of the technology that can be adopted and can be used to compliment and support the conversion process.

KEYWORDS:PID control, pyrolysis, plastic waste, fuel generation.

I.INTRODUCTION

There are tons of plastic that get sent to landfills each year, because they are considered contaminated and therefore can't be easily or readily recycled. This is a waste of material and money since much of that plastic can be converted back into fuel, or other useful product. Plastic to fuel conversion is important not only because it reduces the amount that goes to landfills but it can also be an energy source, making plants more energy efficient. Currently there are 6 methods of converting plastics to energy: Incineration, Gasification, Hydrolysis, Anaerobic digestion, Pyrolysis, Chemical feedstock recovery (depolymerization)..

II.DEFINITION OF CONVERSION TECHNOLOGY

Definition

The term "conversion technology" encompasses a broad range of technologies that are used to treat a wide variety of materials in the waste stream. Those technologies include incineration, gasification, hydrolysis, anaerobic digestion, pyrolysis and chemical feedstock recovery. This study only focuses on pyrolysis to treat scarp plastics. It should be noted that under ISO15270, conversion technologies, such as cracking, gasification and depolymerisation are recognized as forms of recycling; Pyrolysis is a synonym for cracking.

Pyrolytic Conversion Technologies

A primary focus of this study is to identify technologies that use pyrolysis to convert scrap plastic to fuel sources. Different techniques are available. Each of these technologies is unique in terms of the type of scrap plastic the system can handle, and the output, or fuel product.

Common features of these systems include:

- Some level of pre-treatment- this could be as minor as size reduction or as involved as cleaning and moisture removal.
- Conversion- pyrolytic processes are used to convert the plastic to a gas.
- Condensation- the gas is converted to liquid form
- Acid removal process- removals of acids that form in the breakdown of some scrap plastics. These acid require removal because they can be corrosive to the PTF systems as well as engines that will consume the fuel.

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Pyrolysis is the decomposition or transformation of a compound caused by heat. There are 5 common steps in the process of pyrolysis. The first is treatment where size is reduced, then plastic is cleaned, and moisture is removed. Following the treatment, plastic is converted into gas (pyrolysis). The gas is converted to a liquid in the third step using a condenser. The newly converted fuel goes through an acid removal step so that the fuel doesn't cause corrosion to the engines its being put into. The final step includes separation/refining by distillation to meet ASTM standards. The three products of pyrolysis are natural gas, fuel, and char. Our study focused on the Conversion and Condensation process. Pretreatment and acid removal processes are done manually. Separation/refining/final blending process is omitted as it depends upon the final system design.

III.FACTORS AFFECTING PLASTIC PYROLYSIS

The major factors influencing the plastic pyrolysis include chemical composition of the feedstock, cracking temperature and heating rate, operation pressure, reactor type, residence time and application of catalyst.

The study focused on the effect of cracking temperature and heating rate only.

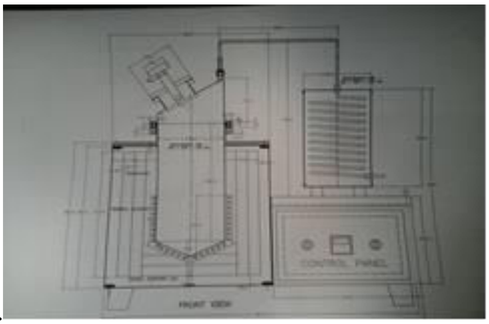
Temperature dominates the cracking reaction of the polymer materials. Not all of the polymer materials can be cracked by increasing the temperature. Van der Waals force is the force between the molecules, which attracts molecules together and prevents the collapse of molecules. When the vibration of molecules is great enough, the molecules will evaporate from the surface of the object. However, the carbon chain will be broken if energy induced by van der Waals force along the polymer chains is greater than the enthalpy of the C-C bond in the chain. This is the reason why high molecular weight polymer is decomposed rather than is boiled when it is heated. In theory, the temperature of thermal breaking the C-C bonds should be constant for a given type of plastic (polymer).

The other operating thermal dynamic parameter is heating rate. The term "heating rate" in this field means the increase of temperature per unit time. Normally, in a fast or flash pyrolysis, heating rate refers to the temperature change of the plastic from it dropped on the hot surface till decomposed and vaporized. Once the plastic feedstock is heated to the cracking temperature, the temperature remains relatively constant untilall feedstock has been pyrolyzed.

Another important factor is operatingpressure. The boiling points of the pyrolysis products are increased under higher-pressure, therefore, under pressurized environment heavy hydrocarbons are further pyrolyzed instead of vaporized at given operation temperature. In effect, under pressurized pyrolysis, more energy is required for further hydrocarbon cracking. It was also found that high pressure increases the yield of non-condensable gases and decreases the yield of liquid products

IV. EXPERIMENTATION

The machine has two major parts: Conversion and Condensation chambers. Conversion chamber consists of a chamber in which plastic waste are fed. A outlet is connected from the conversion chamber to the condensation chamber. When plastic waste undergoes high temperature and pyrolysis, gases are formed which is collected and passed into the condensation chamber. In the condensation chamber, the gas is condensate and fuel is obtained as the output.



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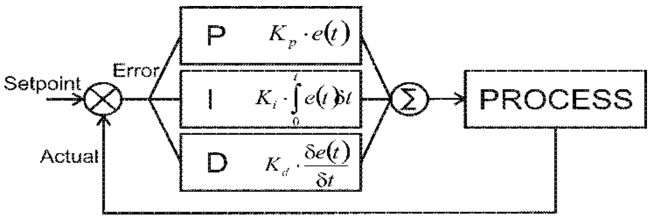
The response of the system and the quantity of the fuel generated is controlled by the manner in which the pyrolysis temperature is controlled inside the conversion chamber. An electronic controller is designed for serving this purpose which acts as the key element of this machine.

PID controller for the process

A PID controller is used as the basic temperature controller.

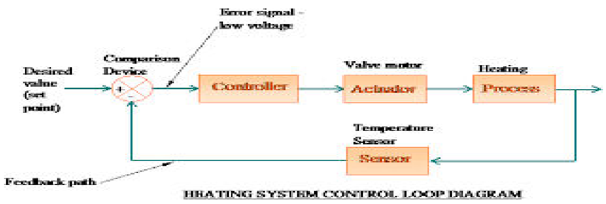


The PID controller is the summation of P, I and D control whose equations are given in the Figure 2.

$$u_{\mathrm{PID}}(t) = u_p(t) + u_i(t) + u_d(t)$$
$$= k_p e(t) + k_i \int_0^t e(\tau)\,\mathrm{d}\tau + k_d \frac{\mathrm{d}\,e(t)}{\mathrm{d}\,t}$$

On- Off Controller for the process

The same controller was employed in On Off mode to compare the results with the PID Controller.



Modes of Controller

The digital temperature controller used accepts inputs from commonly available thermocouples and Resistance Temperature Detectors (RTDs). The control mode can be set to ON-OFF control or PID control.

Tuning a temperature controller involves setting the proportional, integral, and derivative values to get the best possible control for a particular process. Auto tuning was employed for setting the PID controller.

Procedure of experimentation

Polyethylene plastic waste was used as input to the Conversion chamber. A continuous water supply is maintained for cooling the rubber beading of the input door and the condensation chamber.

The experimental result summary of two trials is given in Table 1. The summary of results shows that with PID controller the temperature and heating was controlled effectively so that the conversion of plastic to fuel was maximized. This is because of the fact that the heating rate has an important role on the degradation reaction. When the heating rate increases, the activation energy and degradation temperature of the Polyethylene plastic also increases

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Parameters	Experiment 1	Experiment 2
Weight of input	250 gm	250 gm
Set point temperature	450 degree C	450 degree C
Volume of fuel obtained	50 ml	78 ml
Controller mode	On Off	PID
Time to reach the set point	72 minutes	42 minutes

The graphical representation of the temperature vs time in minutes when the system is used as On OFF controller is in Figure 1

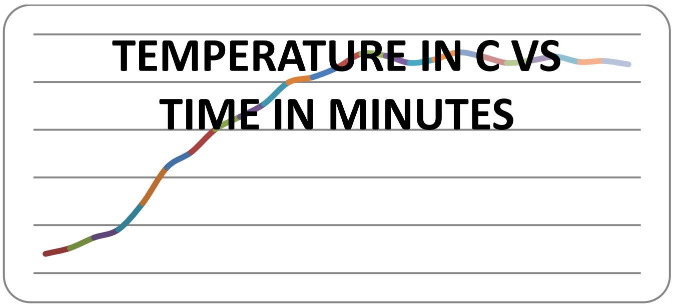

Figure 1

The system settles around 440 degree centigrade and the fuel starts flowing from 75 minutes.The graphical representation of the temperature vs time in minutes when the system is used as PID controller is in Figure.

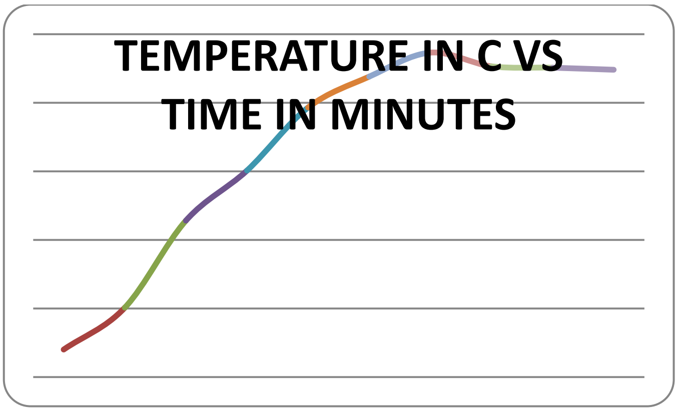

Figure 2

The system settles much faster at 450 degree centigrade and the fuel starts flowing from 25 minutes
The comparative analysis is shown in Figure 2.

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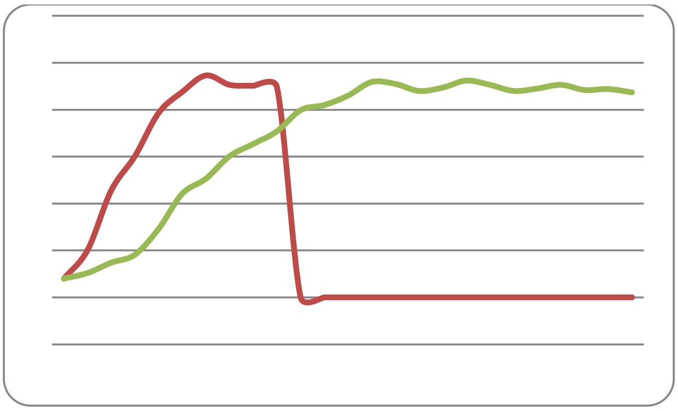

Figure 3 Temperature in degree C Vs time in minutes for On off and PID mode of Control

V. CONCLUSION

In pyrolysis system of plastic waste, it has been observed that the cracking temperature and heating rate has an important role in determining the response of the conversion machine. The chemical composition of the feedstock, reactor type, and residencetime and operation pressure cannot be changed once the system is implemented. Application of catalyst is not economical and affects the quality of the output fuel. However it has been proved that controlling the Cracking temperature and Heating rate has a great impact on the system.

PID control when compared to On Off control has almost half the settling time.

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