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Design and Fabrication of Pyrolysis Unit

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Abstract:- The amount plastic waste is increasing which results in a chronic problem to the environment. There is many efforts to reduce as well as reuse the plastic waste. In this project, we investigate about the use of pyrolysis of plastic waste to produce fuel oil. For example, Plastic carrier bags, considered a low-density polyethylene (LDPE), can be used as raw material for the production. A commercial natural zeolite namely magnesium carbonate is to be used as a catalyst to enhance the oil conversion. We use approximately two kilogram of plastic waste is crushed will be loaded into the reactor chamber for pyrolysis process. For obtaining liquid fuel from pyrolysis process a fixed bed pyrolysis system has been designed and fabricated. The major components of the system are: fixed bed reactor, fractionating cylinder and liquid condenser. A 6 inch diameter and 2 feet high fixed bed reactor is used to pyrolized externally heating the small sized LDPE. The reactor is heated by means of a LPG source.

The production of pyrolysis fuel from waste polyethylene leads to production of large amount of gaseous product, some of them are non- condensable at room temperature. The gaseous products can serve as feedstock and as fuel gas.

Keywords:- *pyrolysis, waste plastics, reaction chamber, fabrication cylinder, condenser, pyrolysis fuel and fuel properties.*

I. INTRODUCTION

Low density polyethylene, High Density Polyethylene, Polypropylene, Polyvinyl Chloride, Polystyrene and polypropylene are the mainly used plastics in the world. Polyethylene Terephthalate (PET) is used in the drinking water packaging. Plastics are derived from petroleum derivatives and it is considered to be difficult to decompose and so the plastics are a pollutant (air, land and water). The plastics are the potential problem in the future. Most of the places in the world are filled with unmanageable solid waste.Lowdensity polyethylene (LDPE) is used as the cheapest mode of packaging the materials. Immediately plastics become most popular in almost all the communities but unfortunately this has led to new source of solid waste because of the LDPE has extremely low rate of degradation. Similarly, amount of fuel decreasing day by day and a prevention method is needed to overcome this fuel deficiency. Plastics are the widely used ingredient to produce fuel by a pyrolysis process.

Pyrolysis is the chemical decomposition process of the organic substances by heating externally which involves the simultaneous change of chemical composition and physical phase, and is irreversible. Pyrolysis is used in the starting of 19th century which is mainly consists of chemical reaction. That is, take place by the burning of all solid organic wastes like wood, cloth, and paper, and also some kind plastic. Anhydrous pyrolysis process is another pyrolysis process which can be used to produce liquid fuels similar to diesel from plastic waste. The pyrolysis process is the breaking or cracking of long chain polymer molecule of the plastics into shorter chains through heat and pressure. That is, pyrolysis process is almost equal to the natural process break down carbon into oil in the earth which takes millions of years in nature. The pyrolysis process does this with the help of intense heat in a closed system in a short amount of time.

II. LITERATUREREVIEW

In future, one of the important sources of the energy can be produced all over the world by the energy from the pyrolysis because of different organic waste material available in the societies. The scrap tires are most important among the commonly used organic waste and their amount is increasing every year at an alarming rate. From I.de Marco Rotriguez, we studied about the behaviour & chemical analysis of the pyrolysis oil. From this work we understand that Pyrolysis Oil contains higher proportion of aromatics and also it is a complex mixture of organic compounds of 5-20 carbons. The operating temperature of the pyrolysis process shows the percentages of aromatics, aliphatic, nitrogenated compounds, benzothiazol. From Roy et al., he conducted experiments on the vacuum pyrolysis. In this work,he used to experiment by develop vacuum pyrolysis of waste wood uses a step-by-step approach, starting from bench-scale batch systems, to a process development unit & lastly a pilot plant. He concluded that the yield is 55% oil, 25% carbon black, 9% steel, 5% fibre and 6% gas. Adrian M. Cunliffe and Paul T. Williams (1998), studied that 3 kg of shredded waste is treated at temperature between 450°C and 600°C to obtain the composition of oils derived from the batch pyrolysis of wastes in a nitrogen purged static-bed batch reactor. He reported that the pyrolysis of wastes produced oil similar in properties to a light fuel oil such as calorific value, sulphur & nitrogen contents. The pyrolysis oil had been found to contain 1.4 % sulphur and 0.45 % nitrogen on mass basis & have similar fuel properties to other fuel. These pyrolysis oils contain a small concentration of polycyclic aromatic hydrocarbons. Polycyclic aromatic hydrocarbons are meant to be either mutagenic or carcinogenic. The oil was analysed in detail for its content of polycyclic aromatic hydrocarbon (PAH) and a single oil droplet combustion study had been carried out. The separated pyrolysis oil had been combusted in an 18.3 kW ceramic-lined, oil-fired, spray burner furnace, 1.6 m in length and 0.5 m internal diameter. Isabel de Marco Rodriguez et al., (2001) had studied the chemical analysis and behaviour of wastes pyrolysis oil. And also, an automatic distillation test was carried out at 500 deg. C to analyse the potential use of waste wood pyrolysis oil as petroleum fuels.

III. EXPERIMENTAL SETUP

A. *Selection of Material*

Galvanised iron is used due to corrosive nature of pyrolysis liquid oil derived from the LDPE plastic and high operating temperature of the process (350°C to 400°C). For joining the nipple for getting air tight chamber using brass as filler metal in the fabrication reactor is done by Oxy-acetylene gas welding has been used. For cutting the GI pipes lathe machines has been used. Drilling operation has been done by the drilling machine for drilling various sizes of holes in the GI pipes and clamps. For various joints in the stand setupArc welding has been used. Copper coil is selected as condenser coil due to high thermal conductivity (398 W/m K) and flexibility of copper.

B. *Design*

Maximum time has been spent to designing, constructing and assembling the experimental setup and the design and fabrication of the fixed bed pyrolyser is the major part of this project work. Fixed bed reactor and condenser are the main parts of the system. The pyrolysis system has been designed based on the following considerations:

- Vapour residence time in the reactor is short.
- Condensation of the vapour product to promote high yield of pyrolysis liquid product is rapid.
- Heat supply for heating the system has been reliable.
- Rapid heat rate into the reactor so it requires less heating material.
- The required amount of pyrolysis liquid can be produced by the help size of the system.

- *Design of Reactor*

The amount of plastic feed primarily depends on the selection of the size of the fixed bed reactor. The vapour residence time in the reactor is determined by the gas flow rate and the volume of the reactor and in fast pyrolysis process for maximizing liquid product, this vapour residence time is an important parameter. The residence time should not exceed 5 sec for the fast pyrolysis. A cylindrical reactor has been considered for the system using GI pipe for the ease of fabrication.

Due to pressure development inside the reactor during the heating of pyrolysis, the reactor act as pressure vessel. Only circumferential or hoop stress will be developed becausepressure vessel is an open end type.

Pressure in the reactor is the sum of atmospheric pressure and pressure due to water in fractionating column.

- *Design of Fractionating Column*

Pyro-gas consist of light hydrocarbons and tarry substances. It deposits and blocks the connecting pipe and condensing shell and produce low grade oil. A separator (a fractionating column) is used to promote high grade liquid oil a separator.

The fractionating column is a hollow cylinder. And fractionate cylinder contains water up to 1feet height. For storing the tarry substances during running time and it can be collect after completing the run, the inlet port of the fractionating column is at 304 mm height from the bottom flange.

- *Condenser*

A condenser is a device or unit used to condense a substance from its gaseous to its liquid state, typically by cooling it. By this process, the latent heat is given up by the substance, and will transfer to the condenser coolant. After separation of the heavy compounds in the fractionating column the pyro-gas is flows to the condenser for condensing the formed liquid oil.

We have to maintain constant surface temperature at the outer surface of copper coil. Heat transfer from the condensing vapour = heat transfer to the water in tank

The heat transfer takes place in three steps

- De superheating
- Two-phase forced convection with condensation
- Super cooling

IV. WORKING PRINCIPLE

The conversion of waste plastic into combustible fuel is primarily based on the pyrolysis process. Pyrolysis is a thermal decomposition of organic material at elevated temperature in the absence of oxygen. It includes the simultaneous change of physical phase as well as chemical composition, and it is irreversible. Plastic pyrolysis process is a chemical reaction. This reaction includes breakdown of larger molecules into smaller molecules in presence of heat. The other name of Pyrolysis is thermal cracking, thermolysis, de polymerisation. At any given temperature, the molecules of the pyrolysis oil are in vibrating stage. This is called molecular vibration. The temperature of the molecule is directly proportional to the frequency at which molecules vibrate. At the pyrolysisprocess the object's molecules are subjected to high molecular vibration leading to very high temperature. At these high molecular vibrations, every molecule in the object is shaken and stretched to such an extent that molecules start breaking down into smaller molecules. This is pyrolysis.

V. METHODOLOGY

There are 3 main components in a pyrolysis unit. The reactor or heating chamber, fractionating cylinder and a condenser coil. LPG is the source of heating the reactor. The input heat is around 3kW and which is provided for almost 40 minutes. The heat transfer is taken place to the plastic through the walls of the heating chamber by conduction. The pyrolysis process is promoted by a catalyst $MgCO_3$. The temperature range of 350-400^{0}C and a pressure about 15 Psi is required for the heating of the waste plastic. The thermometer and pressure gauge are placed on the setup to indicate the temperature and pressure respectively. Initially the valve provided on the pipe

lines will be closed for the increasing the pressure. After developing enough pressure inside the reactor the valve will open. The pyrolysis gas from the reactor is then passed to the fractionating cylinder through the pipe lines and non-return valve after opening of the valve. 1 feet of water is filled in the fractionating cylinder. The non-return valve prevents back flow of water. Due to high pressure gas, the non-return valve opens and gas will emerge into the water. When pressurised gas come direct contact with the water filled in the fractionated cylinder some part of the pyrolysis gas condenses and forms a layer over the water which can be separated. The more volatile part of the gas directly goes to the condensing coil which is surrounded by cold water. The heat of the pyrolysis gas is absorbed by the water and gas in the copper coil condenses into liquid fuel. Which is the final product.

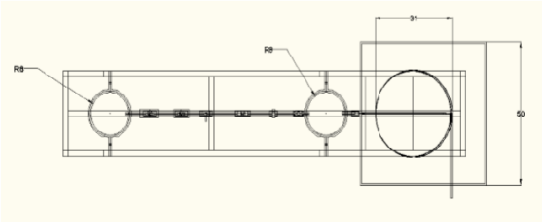

Fig 1:- top view of pyrolysis plant

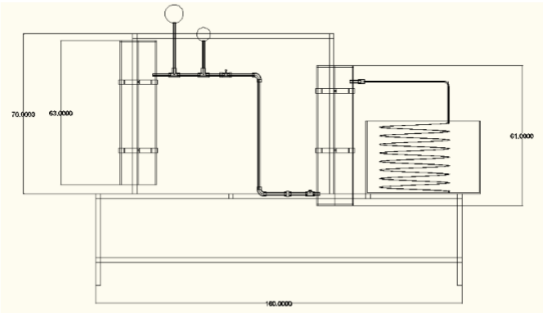

Fig 2:- front view of pyrolysis plant

VI. CONCLUSION

The Pyrolysis system made here is compatible to produce fuel without any operational deficiencies. Since pyrolysis of plastic can generate liquid as well as gaseous fuel it can be used as fuel generating method. So pyrolysis is a favourable method to treat waste plastic. From a 2kg of waste plastic about 200 ml of liquid and rest is gaseous fuel these gaseous fuel can be condensed at low temperature(-15^{0}C) and pressure. The volume of the plastic is reduced about 90%. The fuel started to obtain within 20 minutes of starting. We obtained the calorific value of this fuel by using bombcalorimeter and also flash point of the fuel.

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