# Pyrolysis: An Evolution of Waste Management

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***Abstract*—This Biomass is the natural waste which can be used as a replace of another source of energy. Biomass is also used as renewable source of energy. And there are many wastes which we get from the things we use in our daily life, which cannot be recycled. One of the most used things is plastic. From many years plastics are being used by us in our daily life, now-a-days that percentage of using plastics is rapidly getting increased by time across the world. But we know that plastics are very harmful to our nature, it create water pollution as well as air pollution and have many more disadvantages. Even it takes up-to 1000 years to get decomposed. Even biomass wastes are also there which cannot be reused or recycled.**

**So, in our review paper we are mainly focusing in the technologies of Pyrolysis which can convert those harmful plastics and many wastes like tyres and biomass wastes into the useful energy. The process of converting these wastes into useful energy or fuels is known as Pyrolysis. This process mainly converts the complex compounds of waste plastics into methane, ethylene as well as hydrogen. In these compounds, both hydrogen and methane compound can be used as clean fuels. So by this process we can get clean fuels and use them. Even from this Pyrolysis reactor we can make our city and ecosystem clean and green, which directly will have impacts in our environment. In the process of Pyrolysis, inside the reactor high temperature is generated, and in the absence of oxygen, it destroys the waste plastics or the waste products in an environmental friendly process.**

***Keywords—Pyrolysis, Reactor, Products, Biomass, Environmental friendly.***

## I. INTRODUCTION

There are many wastes in our environment which cannot be reused and recycled and are left to get decomposed by the microorganisms, like animal wastes, plants wastes and plastic. From all of these wastes, plastic is one of the most harmful wastes which are non-biodegradable. According to our studies, plastic bottle takes 450 years to decompose and plastic bag takes 10-20 years to decompose.

Plastics are mainly made up of crude oil. So we can again covert this plastic into crude oil or eco-friendly fuels from the process of Pyrolysis. In this word "Pyrolysis", Pyro means heat and lysis means breakdown. Which means Pyrolysis is the process which breakdowns the particles of the waste materials at high temperature or in high heat.

Pyrolysis is the method which converts every possible waste into energy or in fuel forms. There are many types Pyrolysis process which are used for different wastes. This review paper is mainly based on the different kinds of Pyrolysis uses for biomass wastes like animal excreta, cow dung, etc and waste plastics.

## II. PYROLYSIS SYSTEM: DEFINATION AND DETAILS

First Pyrolysis is such a technology which enables us to convert the organic compounds or high calorific wastes and plastics into the valuable syn gas (synthesis gas). It's mainly a chemical decomposition of wastes material through heat. Pyrolysis operates at around 500ºC without oxygen to produce solid (char), liquid (tar), and gas [1].In the process of Pyrolysis, in between the two electrodes the arc is produced by using the DC power supply, where the high voltage and high frequency generator is used to strike that plasma. The arc root is rotated by the magnetic field at the anode, which reduces the electrode wear. $N_2$ gas is used for producing the plasma [2].

There are three stages required in the process of Pyrolysis: first one is the dosing and feeding of raw material, second one is organic mass have to be transformed and the last one is obtaining the product and separating it. The products we get through is process are coke, gas and bio-oil. Heating rate, composition of the raw material, final temperature and pressure are the factors which affects the product distribution [3].

## III. LITERATURE SURVEY

Pyrolysis is being used since the ancient times, at that time it was mainly used to convert the wood into charcoal. Pyrolysis was done in ancient Egypt. It was done back then for the production of tar which seals the wooden boats against water and rot and in ancient Egypt there were many chemicals which was harvested as the products they got from the process of Pyrolysis, e.g., acetic acid and methanol [4]. Tar was mainly produced by the Pyrolysis of coal and woods. In the ancient times, Egyptians also done the decontamination of wood through assembling tars and also pyrolignous acid for the mummification process [5,6].

According to studies, when charcoal and wood of exact same amount is burned then the amount of heat produced from burning charcoal is twice from that of which is produced from burning wood. Charcoal creates less smoke while burning from woods, as charcoal is the pure carbon. Whereas when the pure carbon is burnt, it does not produces and other polluted products. But it produces $CO_2$ and $H_2O$. Charcoal does not easily get rotten as like wood. And that's why charcoal is more convenient to handle compared to wood. Bio char is another name of charcoal.

Plasma Pyrolysis came out as the technology which is the solution for destroying the hazardous wastes of medical, industries in an eco-friendly way in early 1990s [7].

## IV. TYPES OF PYROLYSIS

PyrolysisThere are three different types of Pyrolysis, those are:

(a) Biomass Pyrolysis,
(b) Plasma Pyrolysis
(c) Cold Plasma Pyrolysis.

Biomass Pyrolysis is also classified into three parts:[8] Slow, Fast and Flash Pyrolysis.

## V. BIOMASS PYROLYSIS: PYROLYSIS OF PLANTS AND ANIMAL WASTES

Pyrolysis Biomass is one of the most preferable wastes which can be used as renewable source of energy in all over the world. In the developing countries, rural people represent about 50% of the global population who depends on the biomass energy [9]. Biomass is biodegradable an organic matter we get from microorganisms, plants and animals that's why it can be used as an alternative source of energy also it can be a promising source of energy. Biomass is from one of those most important sources which are used for thermal applications and to generate electricity [10,11]. The commonly known and used biomass feed stocks are the waste of animals, banana peel, sugarcane bagasse, palm oil processing residues and rice and coffee husks [12,13].

There are different kinds of energy that can be produced from the thermal conversion of the biomass; those are Pyrolysis, combustion, gasification, anaerobic decomposition as well as fermentation. Pyrolysis is the process which includes thermal decomposition and it takes place in the absence of oxygen, whereas combustion is a thermo-chemical process which is used for producing heat and consists of chemical reactions where the fuel is oxidised. In the process of combustion, huge amount of energy is produce in the form heat through the exothermic reaction. [14]

In between every techniques of bio mass conversion, Pyrolysis is the only process which has many benefits like less emission is done and every by-product can be used again. Also, in between the process, Pyrolysis produce carbonised products, liquid products and gaseous mixture of CO2, CO, H2, and CH4 [14]. Here Fig.1 shows us the proportion of the products released from the biomass Pyrolysis.

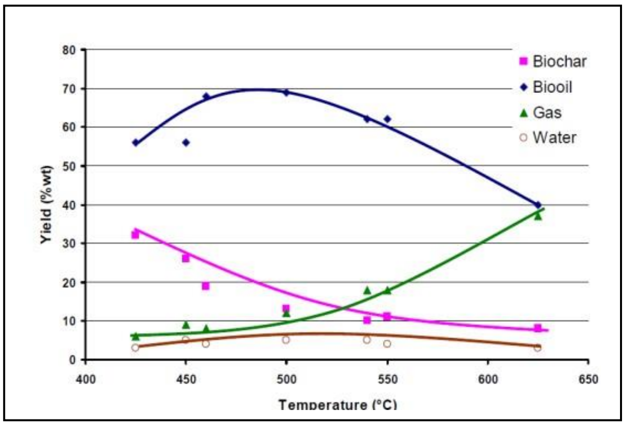


Fig.1 Proportions of end products in pyrolysis of biomass [14]

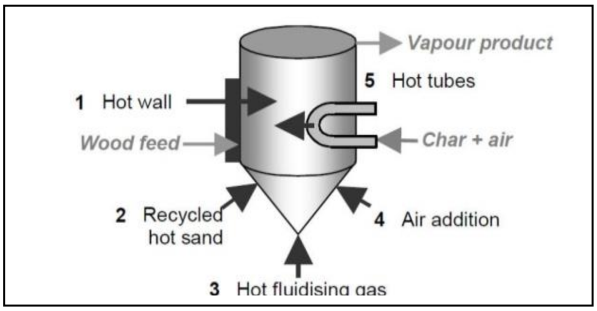


Fig.2 Types of heat transfer to Pyrolysis reactor [15]

Biomass can lead our world to achieve the goal of reducing greenhouse [16].Biomass Pyrolysis involves the breaking of carbon – carbon bonds and forming of carbon – oxygen bonds. Biomass Pyrolysis requires heat temperature approximately to 400º-500ºC or if needed then it can be done in higher temperature also [17,18]. Through the biomass Pyrolysis, liquid product is produced which is known as bio-oil. This bio-oil is an acidic liquid consists of 300 compounds or more than that [19].

In the biomass, the single part of it is reduced to carbon and left over parts are oxidised as well as hydrolysed to carbohydrates, ketones, aldehydes, phenols, carboxylic acids and alcohols. These all are combined to form much complex molecules like ester, polymers and etc [14].

There are two important requirements for the Pyrolysis reactor for heat transfer: first is to transfer heat to the reactor and second is the heat transfer from reactor to Pyrolysis biomass. The transfer of heat can be solid to solid (conductive heat transfer) or it can be gas to solid, where the heat is transferred from hot gas to the biomass particle (convection heat transfer). In the fluid bed reaction 90% of heat transfer takes place through conduction and the rest 10% of heat transfer is through convection for utilising good solid mixing. In every type of reactor, some radiation heat transfer also takes place along with conduction and convection heat transfer. To ensure the efficient conversions of the biomass into fuel, there are several heating methods which are used by various Pyrolysis reactors [20]. Different types of heat transfer to the Pyrolysis reactor are shown in Fig-2.

TABLE I. TYPES OF HEATING METHOD FOR DIFFERENT REACTORS [20]

| SL NO | Heating Method | Reactor Type |
|---|---|---|
| 1 | Heated recycle gas | Bubbling fluidized bed |
| 2 | Wall and sand heating | Circulating fluidized bed |
| 3 | Gasification of char to heat sand | Rotating cone |
| 4 | Direct contract with hot surface | Vacuum |
| 5 | Wall heating | Ablative |
| 6 | Fire tube | Auger |
| 7 | Radio frequency | Plasma |
| 8 | Electromagnetic | Microwave reactor |
| 9 | Solar | Fluidized bed/Quartz |

## VI. PLASMA PYROLYSIS

Plasma Pyrolysis is the technology which can be used as the treatment for waste plastics. It one of the most important treatment which is mainly focused on destroying the most harmful and hazardous waste i.e., plastics and this plasma Pyrolysis technology is now well established in material synthesis as well as in metallurgical processing etc. It is also in under development from long time [21] .Pyrolysis reactor is represented with the help of schematic diagram [22] as shown in Fig.4.

Plasma is the most active state of matter which is of fourth state. This fourth state of matter is mainly after solid, liquid and gas. With the help of the plasma torch and power supply, hot plasma is produced for the disposal of wastes. For the disposal, graphite torch is used. There are three graphite electrodes which are used in plasma torch. Those electrodes are directly connected to the power supply. In between those electrodes, plasma arc is produced. The electrical energy is converted to heat energy with the help of plasma torch. Then the heat energy is used to heat the primary chamber. In the Pyrolysis process, there are some compounds which are likely to produce; those are methane, hydrogen, carbonaceous matter, carbon monoxide, carbon dioxide and water molecule.

According to our studies, the chemical reactions which will take place in the Pyrolysis of polyethylene are:-

1) $CH_4 + H_2O = CO + 3H_2$

2) $C + H_2OCO = H_2$

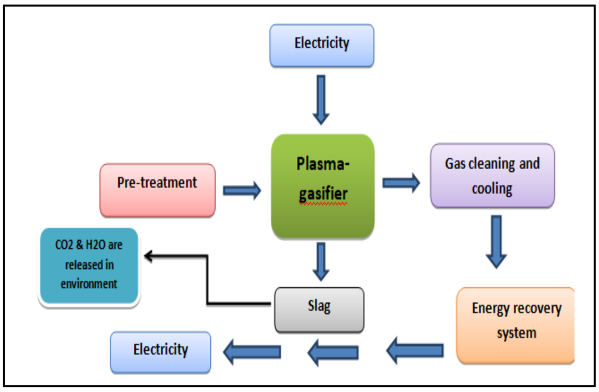


Fig.3 Block diagram of plasma pyrolysis process

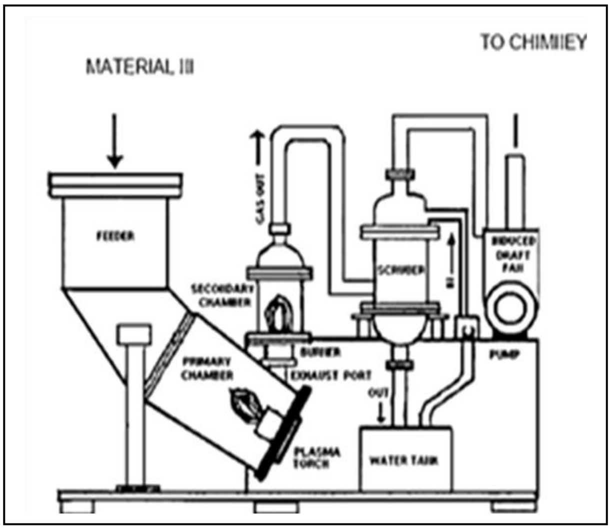


Fig.4 Schematic diagram of pyrolysis reactor[22]

## VII. COLD PLASMA PYROLYSIS

The cold plasma Pyrolysis is under the development for achieving the goal of reducing the carbon emission compared to the process of plasma Pyrolysis. The researches in the development and advancement of cold plasma Pyrolysis is still going on [23-25].

There are five types of Cold Pyrolysis Reactors. Those are as follows:-

i. Corona Discharge Reactors

In this reactor, with the help of the AC and DC corona discharge the methanol decomposition was being operated. It has been resulted that the AC corona discharge does the better conversion as compared to DC [23].

ii. Glow Discharge Reactor

In the glow discharge reactor, the methane decomposition was mainly focused on the metal effect inside the electrodes [24]. In this research the noble metals have shown, lowest deactivation rate, highest rate of decomposition as well as highest evolution of hydrogen.

iii. DBD Plasma Reactor

In the DBD plasma reactor, the researchers have showed that the energy efficiency is low than the arc plasma reactors. It have been also stated that the catalytic of different types pf dielectric materials also can be tested [26].

iv. Microwave Plasma Reactor

The microwave plasma reactor was mainly focused on the other types of hydrocarbons like isooctane and hexane with conversion and energy efficient of 50-60%.

v. Microwave Plasma Reactor

In this reactor, non-equilibrium cold plasma is generated. According to the studies, non-equilibrium plasma have more advantages than compared to the equilibrium plasma.

As per our study, the experiment of converting carbon dioxide to carbon monoxide and oxygen is performed under high temperature. Thermal plasma, corona discharge and gliding arc were used for this experiment. In this experiment, more than 60% of $CO_2$ was converted into CO.

## CONCLUSION

In this paper we have reviewed about the reuse of the waste materials with the help of Pyrolysis process. We have included biomass Pyrolysis for the biomass wastes for generating energy. As we have seen through the studies, rural people use this biomass Pyrolysis in large numbers. Biomass is a renewable source, so increase in the use of this Pyrolysis will be good as it will save other non-renewable energies. Then from the studies of plasma Pyrolysis it is concluded that it releases carbon in nature, for which the cold plasma Pyrolysis is under development for fulfilling the disadvantages of plasma Pyrolysis. Like cold plasma Pyrolysis is being developed for reducing the carbon emission. We have also included graphs, schematic diagrams and block diagrams so that the process can easily being understood. As per our future plan, we want to develop the cold plasma Pyrolysis process so that it can be used for converting the waste plastics to useful energy or fuel without any side effects of releasing toxic gases in environment.

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