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GN and Development of Fin Type Pyrolyser to Enhance Productivity of Biochar

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ABSTRACT: In this paper, we investigate Lignocellulose (refer to plant dry matter) so called Lignocellulosic Biomass can be converted to a solid product named as "Char". In recent years much effort has been made on the investigation of conversion of biomass through Pyrolysis. The finned Pyrolyser is designed for clean and pollution-free combustion of coarse type biomass material. Pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen. It is the fundamental chemical reaction that is the precursor of the combustion Process. Experiment are performed with pyrolyser of size four radial fins respectively. The temperature of the wall, fin and bed are measured for different conditions. Model Equations are formulated for the heat transfer and pyrolysis processes, considering wall heat resistance at the pyrolyser and fin walls are solved for predicting the temperature and conversion in the pyrolyser. It is found that the agreement between the experiment values and theoretical values is very good. Model Equation are also employed for obtaining temperature and conversion profiles in the pyrolyser for assessing the performance of the pyrolyser with respect to number of fins and heating rates.

KEYWORDS: Pyrolyser, Biomass, Biochar

I. INTRODUCTION

Pyrolysis is the thermal decomposition of materials at elevated temperatures in an inert atmosphere. It involves a change of chemical composition. The word is coined from the Greek-derived elements pyro "fire" and lysis "separating". Pyrolysis is most commonly used in the treatment of organic materials. It is one of the processes involved in charring wood. In general, pyrolysis of organic substances produces volatile products and leaves a solid residue enriched in carbon, char. Extreme pyrolysis, which leaves mostly carbon as the residue, is called carbonization. Pyrolysis is considered as the first step in the processes of gasification or combustion. The process is used heavily in the chemical industry, for example, to produce ethylene, many forms of carbon, and other chemicals from petroleum, coal, and even wood, to produce coke from coal. Aspirational applications of pyrolysis would convert biomass into syngas and biochar, waste plastics back into usable oil, or waste into safely disposable substances.

Pyrolysis is one of various types of chemical degradation processes that occur at higher temperatures (above the boiling point of water or other solvents). An annular Finned pyrolyser was designed for producing smokeless and clean thermal energy from biomass materials. In the previous paper, the model heat transfer equations, together with the pyrolysis reaction rate equation were solved for predicting the temperature and conversion values in the pyrolyser. It differs from other processes like combustion and hydrolysis in that it usually does not involve the addition of other reagents such as oxygen (O₂, in combustion) or water (in hydrolysis). Pyrolysis produces solids (char), condensable liquids (tar), and uncondensing/permanent gasses.

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The fundamentals of pyrolysis, its latest developments, the different conditions of the process and its residues are of great importance in evaluating the applicability of the pyrolysis process within the waste management sector and in waste treatment. In particular the types of residue and their further use or treatment is of extreme interest as they could become the source of secondary raw materials or be used for energy generation in waste treatments. The main area of focus of this paper is the investigation of the link between the pyrolysis conditions, the chemical and mineralogical composition of their products and the benefits of pyrolysis in the waste management sector. More specifically the paper covers the fast, intermediate and slow pyrolysis of organic waste and mixtures of inorganic and organic waste from households. The influence of catalysts during fast pyrolysis on the product yield and composition is not being considered in this review.

II. PYROLYSER

Pyrolysis is used to turn organic materials into carbon for the purpose of carbon-14 dating. Pyrolysis of tobacco, paper, and additives, in cigarettes and other products, generates many volatile products (including nicotine, carbon monoxide, and tar) that are responsible for the aroma and health effects of smoking. Similar considerations apply to the smoking of marijuana and the burning of incense products and mosquito coils. Pyrolysis occurs during the incineration of trash, potentially generating volatiles that are toxic or contribute to air pollution if not completely burned. Laboratory or industrial equipment sometimes gets fouled by carbonaceous residues that result from coking, the pyrolysis of organic products that come into contact with hot surfaces.

Pyrolysis has many applications in food preparation. Caramelization is the pyrolysis of sugars in food (often after the sugars have been produced by the breakdown of polysaccharides). The food goes brown and changes flavour. The distinctive flavours are used in many dishes; for instance, caramelized onion is used in French onion soup. The temperatures needed for caramelization lie above the boiling point of water. Frying oil can easily rise above boiling point. Putting a lid on the frying pan keeps the water in, and some of it re-condenses, keeping the temperature too cool to brown for longer.

Pyrolysis has been used for turning wood into charcoal since ancient times. In their embalming process, the ancient Egyptians used methanol, which they obtained from the pyrolysis of wood. The dry distillation of wood remained the major source of methanol into the early 20th century. The 8th century Caliphate philosopher Jabir ibn Hayyan (known as Geber in the West) may be considered the father of experimental chemistry because of his development of the retort, which he used to discover sulfuric, hydrochloric, and nitric acids, as well as aqua regia, by dry distillation of vitriol mixed with other salts. These discoveries became known in Europe in the 14th century, through the books of Pseudo-Geber. Pyrolysis was also instrumental in the discovery of many important chemical substances, such as phosphorus (from ammonium sodium hydrogen phosphate $\text{NH}_4\text{NaHPO}_4$ in concentrated urine) and oxygen from mercuric oxide and various nitrates.

III. EXPERIMENTAL SETUP

1. FIN TYPE PYROLYSER

The biomass was initially used to produce charcoal. The charcoal based on wood during heating produces negligible amount of smoke. Earlier it was extensively used for melting of ore to extract iron. However, the process had drawbacks of less yield percentages, less energy and excessive air pollution. After that, modern technology was developed to extract maximum possible energy from biomass using combustion (exothermic), gasification (exothermic) and pyrolysis (endothermic). Combustion deals with the burning of biomass in presence of oxygen to produce heat. The competence of this practice is not satisfactory. Gasification also takes place under oxygenated atmosphere which will yield gaseous fuels. Nevertheless, pyrolysis is the leading phase for both gasification and combustion processes. Consequently pyrolysis can be considered as part of gasification and combustion. Charcoal is a less smoky fuel than unpyrolyzed wood. Some cities ban, or used to ban, wood fires; when residents only use charcoal (and similarly-treated

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rock coal, called *coke*) air pollution is significantly reduced. In cities where people do not generally cook or heat with fires, this is not needed. In the mid-20th century, "smokeless" legislation in Europe required cleaner-burning techniques, such as coke fuel and smoke-burning incinerators^[16] as an effective measure to reduce air pollution. Gasification also takes place under oxygenated atmosphere which will yield gaseous fuels. Nevertheless, pyrolysis is the leading phase for both gasification and combustion processes. Consequently pyrolysis can be considered as part of gasification and combustion.

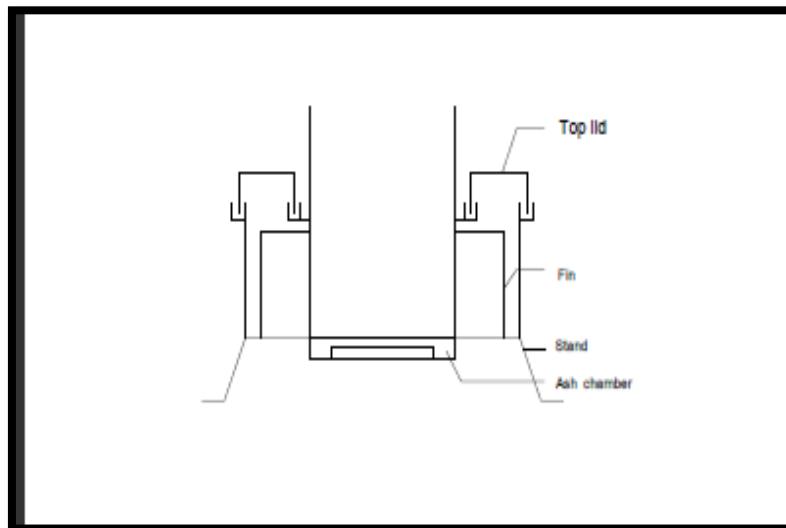


Fig 1. fin type pyrolyser front view

2. BIOCHAR DEPOSITION MODELING

Materials like pine needles, leaves, coconut coir, etc. can also be used by proper packing. The fuel in the central chamber is ignited like any other solid fuel. The resulting heat energy heats the walls of the central chamber and the fins for dissipation of heat into the biomass bed. As the temperature of the biomass bed rises beyond the minimum pyrolysis temperature, the pyrolysis process begins releasing the volatile matter, which is normally a mixture of combustible gases and high molecularweight oxygenated hydrocarbons.

These volatiles pass through the holes provided at the bottom of the central chamber into the combustion zone. As the volatiles rise through the bed, they come in close contact with the hot bed of fuel and refractory brick pieces and get thermally cracked into low molecular weight hydrocarbons which combine with the atmospheric secondary air at the top and give clean, smoke-less combustion.

The rate of pyrolysis of volatiles depends on the rate of heat transfer from the combustion chamber to the biomass bed, the kinetics of the pyrolysis of biomass material and the physical properties of the biomass material. The heat transfer rate mainly depends on the effective thermal conductivity of the bed. When most of the volatiles are released and combustion ceases, the pyrolyser is allowed to cool, and the char residue is removed.

3. MATHEMATICAL CALCULATION

1. ENERGY EQUATION:

The energy balance in a differential volume element is given by

$$\left[\frac{1}{r^2} \right] \left[\delta^2 T / \delta \theta^2 \right] + \left[\frac{1}{r} \right] \left[\delta T / \delta r^2 \right] + (\Delta H) / K_e \cdot (-r_A) = \rho_b C_p / K_e \left[\delta T / \delta t \right] \text{-----(1)}$$

$$-r_A = \rho_v \frac{dX}{dt} = K_d (1-X)^n \text{-----(2)}$$

Initial Condition :

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$$T(r, \theta) = T_s \quad \text{all } r, \theta \quad t=0$$

Boundary Condition :

$$T(R, \theta) = T_w \quad : t > 0 \quad \text{-----(3)}$$

$$T(\delta T / \delta \theta) (r, \phi/2) = 0 \quad : t > 0 \quad \text{-----(4)}$$

$$T(r, 0) = T_w \quad : t > 0 \quad \text{-----(5)}$$

Dimensionless parameter

$$T^* = (T - T_s) / T_s \quad \text{-----(6)}$$

$$r^* = r / R_0 \quad \text{-----(7)}$$

$$T_0 = T_w - T_s \quad \text{-----(8)}$$

$$t^* = at / R_0^2 \quad \text{-----(9)}$$

where $a = K_e / \rho_b C_p$

$$1/r^* \frac{\partial T^*}{\partial r^*} + \delta^2 T^* / \delta \theta^2 + (1/r^*) (\delta^2 T^* / r^{*2}) + Q_1 (-r_A) = \delta T^* / \delta t^* \quad \text{-----(10)}$$

$$Q_1 = [\Delta H / K_e] [R_0 / T_0] \quad \text{----- (11)}$$

2. DESIGN OF THE CYLINDER :

The design of pyrolyser consists of cylinder of diameter 400 mm with height of 500mm . We used mild steel sheet for making the cylindrical and its thickness is 2mm.

The volume of the cylinder was calculated by using the formula $(V) = \pi r^2 h \text{ mm}^3$

Radius of the cylinder =200mm

Height of the cylinder =500mm

$V = 3.14 \times 200 \times 200 \times 500$

$= 6.28 \times 10^7 \text{ mm}^3$

IV. ANALYSIS OF FIN TYPE PYROLYSER

1. FIN TYPE PYROLYSER PROPERTIES:

One of the most important factors in fin type pyrolyser is their barrier or permeability performance if higher heating rate up to 105–500°C/s is used for less retention time and finer particle size, finer biochar is produced during fast pyrolysis process, whereas larger particle-sized feedstock during slow pyrolysis results in a coarser biochar. Usually woody biomass results in coarser biochar whereas crop residues and manures yield more fragile-structured biochar . Earlier investigation demonstrated that biochar yield varies for different temperature regions in a fluidized bed pyrolysis reactor . The results showed that at a low temperature of around 450–500°C, the yield of biochar was high as the rate of devolatilization was low. At a temperature around 550–650°C, the yield of biochar was decreased. At that temperature maximum yield achieved was about 8–10% . However at higher temperature, around 650°C, biochar yield was very low. Biochar predominantly contains larger portion of fixed carbon along with moisture, volatile materials, hydrogen and various other constituents in two structures: stacked crystalline graphene sheets and randomly ordered amorphous aromatic structures . The aromatic portion of biochar contains H, O, N, P and S. These inorganic species have a pronounced impact on the physical and chemical properties of a biochar . The percentages of these constituents depend on the type of biomass and the process of the pyrolysis process . Biochar can be utilized as solid fuel in boilers. After catalytic pre-treatment, it can be used to produce activated carbon, carbon nanotubes and gaseous fractions, etc.

2. TEMPERATURE VARIATION ANALYSIS

1. Temperature Test:

The temperature profiles along the direction from the fin wall to the centre between the fins at fixed radial positions, $r = 0.169\text{m}$ for the different times. It observed that, during the initial period there is a temperature drop from the fin wall towards the centre between the two fins. The difference gradually decreases as time increases.

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Table 1 : Temperature test result

TEMPERATURE TEST $T_{0I=0.169} (^{\circ}C)$	Time (sec)	value
700	1	259
700	2	518
700	3	778
700	4	1037
700	5	1297
700	6	1556

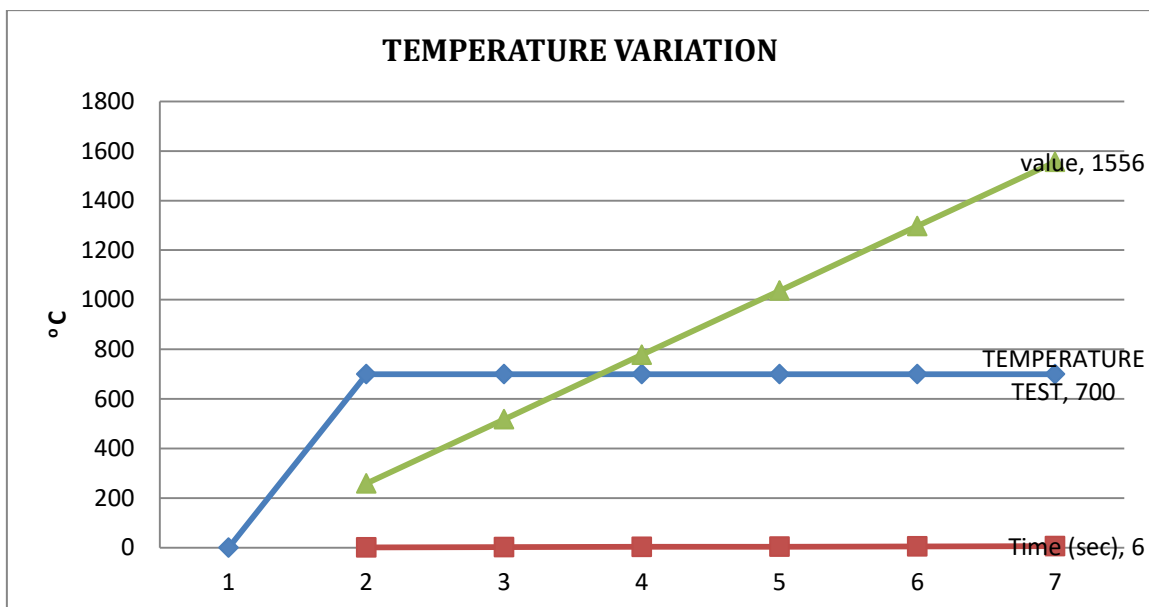


Fig 1. Temperature variation test

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2. Comparison of experimental and predicted temperature test:

Table 2 : Comparion test result

TEMPERATURE RATE	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C
THERORITICAL	112.12	222.2	315	425.25	505.2	903.5	912.2	956.23	996
PREDICTED	150	245.6	358	456.25	526.8	654.2	752.21	895.36	956.25

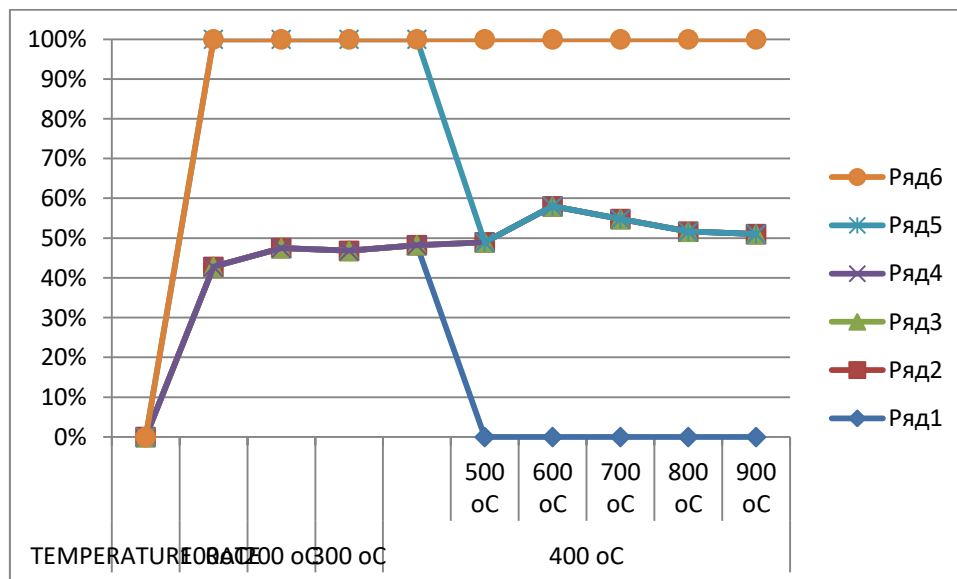


Fig 2 : Analysis of comarision test

V. ADVANTAGES

- 1) By using pyrolyser generates 50% fewer green house gases.
- 2) The pyrolyser kit uses 50% less energy than other Bio Char equipments
- 3) The Bio char produce from the pyrolyser is used as the fertilizer fot Agriculture purpose .

VI. APPLICATIONS

- 1) Mainly used for the purpose of disposal of rice or paddy wastes (strays) with less pollution rate.
- 2) Bio char is used as the fertilizer in the feild of production of crops .

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VII. CONCLUSION

In this study, the perusal showed that the transformation of biomass to value-added products still needs to resolve some trials such as determining the relation between the starting precursors or feedstock and the overall operation of the pyrolysis plant, upgrading the consistency of the pyrolysis reactions in terms of complete energy and material balances to become sustainable for profitable applications. This chapter elaborately described about the principle of pyrolysis technology including the choice of effective parameters for pyrolysis, types of reactor, etc., depending on the preferred output (bio-oil, biochar or syngas) from the process.

However, a comprehensive understanding of the typical process will permit to get maximum output. The chapter highlighted the resulting conclusions and recommendations for additional studies: The major challenge of pyrolysis process is to improve the process by enhancing the product quality and quantity as well as lessening the costs and reduce hazardous environmental impact. Appropriate selection of biomass is a crucial factor to obtain high bio-oil yields. Biomass containing high cellulose content can be selected, as bio-oils are mostly derived from it whereas lignin-based biomass can be used for biochar production. Furthermore, biomass with low moisture content is appropriate to decrease the drying costs and enhance the quality of the extracted oil

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