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Flash Pyrolysis of Biomass due to Concentrated Solar Radiation

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Abstract

The author describes the results of experiments where small samples of cellulose are submitted to short flashes of concentrated solar radiation. Also it shows the optical properties of cellulose with respect to the efficiency of sunlight absorption. The aim of the first part of paper is to briefly describe the different solar chemical reactions being studied in the world presently. The second part tells that concentrated radiation can also be used to study the basic biomass thermal degradation.

Concentrated solar energy can be used to drive the thermochemical processes. Many types of chemical systems can be considered for the production of chemical energy carriers. The solar thermochemical conversion of carbonaceous feedstock is the one of the most suggested option.

Concentrated radiations can be used to drive endothermic reactions under controllable and clean conditions of high heat flux densities. Biomass is a carbonaceous material. So special emphasis is given on biomass conversion using solar energy.

Keywords: *carbonaceous feedstock, thermal degradation, thermochemical process, residence time, cellulose*

1. Introduction

Pyrolysis is the process in which the biomass is subjected to a high temperature around 600^0C to 800^0C in the absence of air (*i.e.*, oxygen). Thus the end products obtained in a pyrolysis process are generally tar and oils. There are different types of pyrolysis processes such as slow pyrolysis, fast pyrolysis and flash pyrolysis.

Concentrated radiation can be an important part of many chemical reactions and it can be utilized in a clean and efficient way. Simple examples of utilization include solar towers, dish concentrators, solar furnaces. The power output varies form few kW to several MW.

Flash pyrolysis is the process in which the process occurs for a very short period of time and the products flash off from the pyrolysis reactor. The residence time i.e. time for which the reactants remain in the reactor is very small in flash pyrolysis.

Solar energy is the thermal form of energy and can act as the main source for obtaining a better efficiency of the pyrolysis process. So the energy from the sun is concentrated using a solar concentrator and is utilized in the pyrolysis process.

The study has been done in search of new sources of renewable energies for the future protection of environment.

2. Solar Thermochemistry

Solar energy is converted into chemical fuels which can be stored for long time and can be transported over distances. Solar energy can also drive the processing of high temperature chemical commodities. There are many chemical systems which are being extensively studied which are as follows:

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a. The solar thermochemical conversion of biomass
b. Solar reforming of natural gas
c. Thermochemical storage of solar energy for dissociation of ammonia
d. Solar thermal production of hydrogen.

The solar thermochemical conversion of biomass is the one which is currently being reviewed a lot. There are many ways in which the biomass can be thermally upgraded such as gasification, slow and fast pyrolysis, etc. which lead to a variety of useful products such as gases, charcoal, biofuels, etc. If these processes are assisted by solar energy then it helps to upgrade the totality of biomass feedstock and design a complete renewable plant with no use of fossil fuels, O_2 or air. Thus the emissions are also reduced.

However the design of these systems does not depend on the mere knowledge of the chemical systems. It is necessary to consider factors such as maintaining the window clean through which the solar radiations enter the reactor, adaptability of the reactor to the nature of the solar facility (vertical or horizontal axis, at the ground or top of the tower, *etc.*), ability to operate in transient conditions. Also the optical properties of the constituents must be known. Some of the components of the solar biomass system are not perfectly absorbing such as cellulose. Cellulose may reflect upto 80% of the incident radiation and it behaves like a semi-transparent material. So many useful radiations may cross the sample without being absorbed.

3. Concentrated Radiation: Studying The Fundamentals Of Biomass Pyrolysis

Biomass thermochemical conversions are studied using kinetic models. But these models are often valid for the unique device where they have been determined. Hence, there are many disagreements and controversies such as it is not well known if vapours formed in cellulose fast pyrolysis are formed directly from solid phase or through intermediate liquid phase.

Concentrated radiations can be available in very clean conditions and during controlled times. This helps in the better understanding of thermal degradation of cellulose.

4. Experimental Measurements

The concentrated radiation used is provided by an image furnace at the laboratory scale which is similar to the conditions of solar furnace. It uses a high power Xenon lamp located at the first focus of a first elliptical mirror, the second focus of which is adjusted at the same location as the second elliptical mirror. The image of the arc of the lamp is formed at the first focus where chemical tests on cellulose samples are performed. A system of pendulum also allows to irradiate the samples during known times. The cellulose samples subjected to the flashes of light may be under a thin layer deposited on the glass surface or small pressed cylinders. The sample is settled inside a transparent glass vessel fed by argon at the exit of which is placed a glass wool filter to trap the aerosols and condensibles.

5. Experimental Results

With available heat flux densities close to 10^7 W m^{-2}, a film of cellulose of 450 ± 50 pm thickness completely disappears in one second. The reaction does not produce measurable quantity of char. For intermediate durations of irradiation, we can observe the surface of the sample after cooling; the structure of initial cellulose has changed with the blunting of contours as during a phase change. At the same time agglomerations also occur. This behavior precedes the formation of vapours for longer flash times. Hence gases and vapours are formed only after the cellulose has passed through the intermediate liquid phase.

If pressed pellets of cellulose are used, then same intermediate species is seen. Thus a constant superficial layer of the liquid species is seen and as flash time increases, the weight of the products increases. The mass balances give accuracies upto 80%. The remaining fraction is due to untrapped vapours and formation of light gases.

The aqueous solution of intermediate species and products trapped on the filter show relatively few peaks as compared to the bio oils derived from flash pyrolysis. The intermediate species do not depend on the time of flash. The intermediate species contain high fractions of molecules with degrees of polymerization greater than 3 while trapped products have fractions of levoglucosan and cellulosan.

6. Theoretical Results

It is also possible to build models representing thermal decomposition of cellulose. These depend on heat and mass balances of solid samples subjected to external available heat flux density and undergoing endothermal chemical reaction. The reaction gives rise to liquid species remaining on the sample and it disappears form the surface by a secondary reaction in the form of vapours.

The thin film model correspond to the first approximation i.e. chemical regime which has constant sample temperature and reaction controlled by chemistry. The pressed thick pellets experiments correspond to ablation regime in which the reaction occurs near and inside the thin superficial region while heart of the pellet is at room temperature.

The comparison between these two models depends on many factors such as thermophysical properties of cellulose and liquid species and also their optical characteristics that need to be measured accurately.

7. Conclusion

The author thus concludes that concentrated solar radiation can be used to drive thermochemical reactions for the preparation of energy carriers. The high quality of solar radiations also act as a laboratory tool to study the process of thermal degradation of biomass step-by-step. Various kinetic models help us to efficiently predict our results. However it is necessary to determine the thermophysical properties of cellulose and its products of depolymerization such as thermal conductivity, mass density, heat capacity, *etc.*, more accurately. Lignin content of the biomass gives intermediate liquid species which can be recovered and are useful.

Use of concentrated radiation enhances the process and leads to a better yield from the biomass.

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