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# Current Research and Prospect of Biomass Pyrolysis Reactor

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**ABSTRACT**

Energy shortages and environmental damage have become serious problems facing the society today. Biomass can be a renewable energy source, which large-scale development and utilization are of great significance to industry and social life. Biomass pyrolysis technology can achieve effective utilization of biomass energy. It is necessary to optimize the pyrolysis reaction technology and device for realize the industrialization and large-scale production of biomass energy.

***Keywords*:** Biomass; Pyrolysis Reaction; Pyrolysis Device

Biomass pyrolysis refers to the process in which biomass is heated to a certain temperature in an anoxic or hypoxic container, such as cellulose, hemicellulose, lignin and other components are decomposed to produce char, condensable liquid and gaseous products. The energy conversion efficiency of this process can reach up to 95.5%. Biomass pyrolysis is divided into slow pyrolysis (heating rate of 3~5 ℃/s, ≤400 ℃, material reaction retention time from hours to days), conventional pyrolysis (5~100 ℃/s, ≤ 600 ℃, 5 ~ 30 min) and fast pyrolysis (500 ~ 800℃, ≤ 1 s). At present, the basic mechanism of biomass pyrolysis has been extensively studied, and new pyrolysis technology and device become the focus. In this paper, the study first reviews the currently research on biomass pyrolysis device from three aspects: pyrolysis reactor, catalytic pyrolysis reactor and biomass pretreatment reactor. Then analyze the advantages and disadvantages of the current technology to enlighten the future development direction of biomass pyrolysis technology.

## 1. Biomass pyrolysis reactor

### 1.1 Rotating cone reactor

Biomass particles and heat carriers collide and mix based on their own displacement motion, thus realizing the exchange of momentum and heat in a rotating cone reactor. It has advantage that no additional gas is required contrary to the fluidized bed reactor. So reducing the energy consumption and dilution of combustible gas. However, this reactor contains moving components (e.g. rotating cones) that need to be cantilevered at high temperatures and heavy dust exposure, thus requiring materials and bearings of high heat resistance, wear resistance and sealing performance.

### 1.2 Ablation reactor

The ablative reactor uses superheated steam or nitrogen to rotate biomass particles, and the resulting high-speed centrifugation forces the particles to contact with the heated reactor wall. The generated gas enters the cyclone separator through the pipeline, while the incomplete pyrolyzate re-enters the reactor for re-pyrolysis via the circulation loop. Due to the working characteristics, the material particle size is continuously reducing during pyrolysis, so the ablation reactor has a wide range of material particle size. NREL built a pyrolysis device with a treatment capacity of 50 kg/h in 2003. Tests showed that the total yield of liquid products reached 55% at 625 ℃.

### 1.3 Fluidized Bed Reactor

#### 1.3.1 Bubbling fluidized bed pyrolysis reactor

The bubbling fluidized bed is simple in structure, small in size and short in gas phase retention time in the reaction process, which can effectively reduce the secondary reaction and improve the tar yield. But the


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device has higher requirements on material particle size. For large particles, the char deposit generated in pyrolysis is difficult to be carried out by fluidizing gas, while small particles will be suspended in the upper layer of the fluidized bed. Both can lead to tar cracking, resulting in compromised tar yield and quality.

### 1.3.2 Circulating fluidized bed pyrolysis reactor

The Greek CRES Research Center developed a test device with a treatment capacity of 10 kg/h and used a riser system to improve the heat and mass transfer efficiency. Tests showed that at 500~ 510 ℃, the yield of bio-oil reached 70%. The Canada's Ensyn company has more advanced research and development of circulating fluidized bed reactor, which has established a reactor with a treatment capacity of 4000 kg/h. A combustion chamber was set to the circulating transfer bed, and the heat carrier was quartz sand. The heated quartz sand was in close contact with biomass particles and greatly improved the heating rate. The mixture of sand, pyrolyzed biochar and gas were blown out of the reactor and entered a cyclone separator, where the gas escaped the mixture. The remaining mixture consisting of sand and biochar returned the combustion chamber, where the biochar combustion re-heated the sand. Heated sand once again gained close contact with biomass particles to complete the pyrolysis circulation.

## 2. Biomass catalytic pyrolysis reactor

### 2.1 Dual fluidized bed catalytic pyrolysis reactor

Fluidized bed reactor has excellent treatment capacity and can better achieve the mixing and separation of biomass and catalyst. However, its demanding operation condition requires high-strength catalyst and the operation cost is also high. These limit its research and industrial application. The U.S. Department of Agriculture (USDA) and Pretoria University jointly developed a dual fluidized bed catalytic pyrolysis reactor, with a treatment capacity of 83.3 kg/h. The system included two fluidized bed reactors, one was the pyrolysis reactor and the other was the combustion reactor. The catalyst or the quartz sand was responsible for heat exchange. In operation, liquefied gasoline was first utilized to heat the heat carrier in the combustion reactor to the expected temperature. Biomass was then fed into the pyrolysis reactor through a feeding screw, where it was pyrolyzed and released the volatiles. Volatiles were separated from biomass carbons when flowing through a cyclone separator. Next, the cooling pipeline would further separate the volatiles into biomass oil and pyrolyzed gas. The resulting gas was used in three ways, (1) to re-enter the pyrolysis reactor as fluidizing gas, (2) to heat the heat carrier inside the combustion reactor as fuel, in combination with the previously isolated biomass carbon, and (3) to be collected as the end product. At last, the re-heated carrier re-entered the pyrolysis reactor to complete the circulation.

### 2.2 Dual fixed bed catalytic pyrolysis reactor

Fixed bed reactor has simple structure, low operation cost, low requirement on catalyst strength, and is therefore the most widely used. However, problems such as low processing capacity and imbalanced temperature inside the reactor restrict its industrial application. A dual fixed bed catalytic pyrolysis reactor was designed by the Biomass Energy Research Center of Tianjin university to produce hydrogen-rich combustible gas. The primary fixed bed reactor was to pyrolyze the biomass (i.e. the pyrolysis reactor), which had a rectangular carbon-steel structure, an electric heating part and an aluminum silicate insulation layer. The secondary fixed bed reactor was to catalyze the pyrolysis (i.e. the catalytic reactor), which had a cylindrical carbon steel structure and a layer at the bottom containing catalyst particles. In addition, a cooling system, a drying system and a feeder were employed as well.

## 3. Prospect

Various biomass pyrolysis reactors have been developed at home and abroad, and been applied on a large scale. Among them, fluidized bed reactors are the most studied and applied for having characteristics of high heat-transfer efficiency, large processing capacity, short gas retention time, small size, etc. However, the high operation cost and the demanding requirement on the particle size hamper their industrialization. There are novel pyrolysis reactors being proposed but most of them are still in the experimental or pilot-scale stage.

Therefore, pyrolysis reactors with strong tolerance of raw materials, low operation cost, high heat-transfer efficiency and potential of massive industrialization is in great demand.

Catalytic pyrolysis of biomass is the future focus of biomass thermal conversion which (1) greatly improves the energy conversion rate, (2) increase the yield of biomass tar or pyrolysis gas, and (3) change the composition of pyrolyzate. The performance of the reactor and catalyst determines the pyrolysis. At present, studies on biomass catalytic pyrolysis turn to focus on the catalyst, and there is little research on the design of catalytic pyrolysis reactors. Existing reactors have problems like high catalyst loss, low recycling rate, and discontinuous production. Therefore, both the development of high activity, high efficiency, low cost catalyst and the design of new catalytic pyrolysis reactors are of vital importance.

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