A Review on Biomass Utilization Technology

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Abstract

Under the goals of carbon peak and carbon neutrality, China must vigorously develop clean energy including biomass energy while its industrial transformation is taking place. The high-efficiency and clean conversion technology of biomass should be improved in order to reduce carbon emissions. This review focused on biomass utilization technology and discussed the research status of biomass pyrolysis product upgrading under different pyrolysis conditions with varied catalyst conditions. At last, we prospect the development of biomass oil and biomass oriented catalytic technology.

Keywords

Carbon Peak; Biomass; Catalyst.

1. Introduction

China proposes to achieve the peak of carbon by 2030 and achieve the goal of carbon neutrality by 2060. This is of great significance to the country's economic and social green development and the world's low-carbon development. At present, China has made certain achievements in low-carbon development, but in the process of achieving carbon peak and carbon neutrality goals, it still faces many challenges such as insufficient low-carbon technology development, high carbon emissions from energy companies, and imperfect carbon trading systems. China is rich in agricultural residues, forestry wastes and other biomass resources. In 2020, there will be 810 million tons of carbon-based solid waste that can be used [1]. For a long time, carbon-based solid waste has the problems of low utilization rate, high clean conversion cost, and low calorific value of converted energy products [2, 3]. Especially the direct incineration of crop straws and forestry wastes has caused serious environmental pollution [4, 5]. Under the new development pattern, it is necessary to strengthen technological development deployment to promote green and low-carbon technology innovation; accelerate the progress of energy conservation and emission reduction, implement pollution reduction and carbon reduction; improve the operating mechanism of the carbon trading market to ensure the orderly development of carbon trading; build modern energy Network, to achieve the "smart" transformation of the energy system structure and other measures to ensure that the carbon peak and carbon neutral goals are achieved. Carbon emissions mainly come from energy consumption in the use stage, and carbon emissions can be reduced by developing new energy vehicles, improving energy efficiency, and promoting clean energy [6]. In order to achieve the goal of carbon peak and carbon neutrality, new energy has become the protagonist of the third energy conversion and will lead carbon neutrality in the future.

Nowadays, solar energy, wind energy, hydropower, nuclear energy and hydrogen energy are the main force of new energy, helping the power industry to achieve low carbon emissions. "Green hydrogen" is a reserve force for new energy, which helps to further reduce carbon emissions in the industry and transportation [7]. Biomass energy is the only carbon-containing renewable energy. In addition to being directly used for power generation, it can also be converted into liquid fuels and chemicals to replace corresponding petroleum-based products. Taking advantage of biomass can effectively alleviate my country’s oil shortage. The current situation, the efficient development and utilization of biomass energy will play a very active role in solving energy and ecological environmental problems [8]. However, there are still many problems in the utilization technology of biomass pyrolysis oil and pyrolysis gas in our country, and how to improve the yield of meteorological products and oil quality obtained by biomass pyrolysis is the main existing problem. Most of the currently used technologies are catalytic hydrogenation, adding catalysts for deoxygenation and upgrading. A large number of studies have shown that calcium-based catalysts can promote the generation of small molecular free radicals in biomass during the pyrolysis process, thereby increasing the calorific value of gas phase products and methane yield.

2. Resent Research on Biomass Upgrading

At present, there are two main types of methods for biomass pyrolysis, The first is to use the method of deashing and deoxygenation pretreatment to improve the quality. Deashing helps increase the yield of bio-oil, Can reduce the content of acids and phenols in bio-oil, The content of carbohydrates is significantly increased. Effectively reduce the content of cellulose and hemicellulose during deoxidation, So as to reduce the acid content formed by its decomposition. The second is to add calcium catalyst to improve the quality. During the pyrolysis of biomass pyrolysis oil, Adding calcium-based catalysts (such as calcium oxide) can effectively increase the yield of bio-oil in the pyrolysis process, So as to achieve the purpose of improving its quality. The following are the more commonly used biomass pyrolysis meteorological products and pyrolysis oil upgrading technologies. Biomass pyrolysis is a complex process, It can be regarded as a comprehensive performance of the pyrolysis behavior of the three components (hemicellulose, cellulose, and lignin). The main calcium catalyst used in the pyrolysis upgrading process is calcium oxide or calcium hydroxide. In the process of biomass pyrolysis, Some findings prove that CaO can extract oxygen from bio-electronic oil in the form of carbon dioxide. It can be concluded, In the process of biomass pyrolysis, The deacidification and fibrosis effect of CaO is remarkable. Some studies have shown the pyrolysis of cellulose and lignin by CaO. Overall, The addition of CaO will promote the decomposition of biomass components. The sugar in cellulose pyrolysis and the phenol in lignin pyrolysis will react with CaO in the temperature range of 400℃ to 600℃. When the pyrolysis temperature is increased to 600 degrees Celsius, The catalytic activity of CaO is correspondingly enhanced. For hemicellulose pyrolysis, CaO promotes the catalytic decarbonization of ketones to form CO, And it enhances the formation of hydrocarbons. For cellulose pyrolysis, CaO strengthens the ring-e opening and dehydration reaction of sugar, Thereby enhancing the production of photo-organic matter. For the pyrolysis of lignin, CaO addition is conducive to radical reactions, And increased CH4 production. Further research has shown that CaO can crack tar varieties, reduce carbon dioxide production, and increase hydrogen power generation at the same time [9]. The improvement of bio-oil can be achieved through some actions before, during and after pyrolysis, Examples include roasting or demineralization of feedstocks, the use of certain catalysts in the process, and catalytic post-treatment processes. Therefore, more and more bio-oil upgrading methods are being studied, including hydrotreating, catalytic cracking, esterification and reactive distillation. The refining and subsequent purification of the original bio-oil will increase production costs and greatly reduce the net energy efficiency of the process. A simple solution to pyrolysis is to introduce a catalyst to eliminate and replace oxygen and oxygen-containing functional groups. Thereby increasing the hydrogen to carbon ratio of the final liquid product. Generally speaking, different high-cost catalysts are mainly used for the catalytic pyrolysis of biomass, such as microporous zeolites, mesoporous M41S and mesoporous aluminosilicates. All these catalysts produce bio-oils with improved properties, which may be valuable products as feedstocks for bio-refineries. On the other hand, some other inexpensive catalysts, such as bulk metal oxides or supported sulfide/oxides and metal catalysts, mainly alumina, have also been tested for biomass catalytic pyrolysis. Although improved bio-oil has also been obtained, further bio-refining processing is required for practical applications. In short, the catalyst should have high activity, selectivity for specific products, resistance to deactivation, easy to recycle, and as cheap as possible.

There are many types of reactor designs and tests for biomass pyrolysis, such as free fall, fluidized bed, vacuum, ablation, rotating cones, and augers. In this context, the spiral reactor is considered to have a high potential in technology and market due to its relatively simple design, low carrier gas flow and suitable for large biomass particles. This type of reactor operates in continuous mode and has been proven to have excellent reproducibility and stability. Spiral reactors may also be very suitable for small portable pyrolysis systems in distributed or decentralized processing schemes. However, the catalytic pyrolysis of biomass in spiral reactors has not been extensively studied. As far as the authors are aware, only one study shows the in-situ catalytic pyrolysis of biomass by adding a mixture of commercial ZSM-5 and sand. This work shows that although ex-situ catalytic upgrading can consume less catalyst, the overall performance of in-situ catalytic upgrading is much better in terms of oil quality [10].

Through the comparison of some of the above technologies, it can be found that the bio-oil obtained from the pyrolysis reaction of CaO has the lowest water content and the highest pH. In the pyrolysis or combustion process of biomass, the removal of Ca-rich wastes at relatively low temperatures (for example, <400 degrees Celsius) has little effect on the decomposition rate. However, lignin decomposition and coke combustion are greatly affected by calcium-based catalysis. The combustion of biomass can release a large amount of carbon dioxide, which is absorbed by CaO at a lower temperature [11]. In the upgrading process, the oxygen in the bio-oil is removed in the form of CO, CO2 and H2O. Among them, the CO2 is used to remove the oxygen to retain the hydrogen in the bio-oil and increase the hydrogen-to-carbon ratio of the bio-oil is the best way to deoxidize.

3. Conclusion and Prospect

Through some analysis and comparison of existing technologies, we found that most of the existing technologies require catalysts to catalytically upgrade biomass, thereby increasing the yield of gas phase products and oil phase products of biomass pyrolysis. However, these technologies have a problem, that is, the requirements for the equipment used in the experiment are relatively strict, and the cost of a large number of catalysts used in the experiment is also relatively high, which makes it difficult for these technologies to be popularized and applied. Therefore, the future pyrolysis conversion and utilization of biomass should be transformed into the direction of carbon sinks. Pyrolysis of biomass resources under mild conditions, targeted preparation of valuable chemicals, and generation of environmentally friendly porous biochar at the same time, this is the leading direction of future research one.

Acknowledgements

The work was supported by the Natural science foundation of Liaoning province (No. 20180550636) and the Scientific research projects of institutions of higher learning in Liaoning province (No. 2019LNJC14).

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