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Review of the Research Progress of Biomass Conversion and Utilization Technology

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Abstract: The energy problem has always been a common problem faced by all mankind. In recent years, with the shortage of fossil energy, the search for alternative new energy has been put on the agenda; with the environmental problems caused by burning fossil energy, such as smog, the greenhouse effect, and so on, people urgently need a new alternative energy. Biomass, as a new clean energy representative, ushered in an important development opportunity. Although China has made great achievements in the development and utilization of biomass energy, there is still a big gap compared with the world's first-class countries such as Europe and America. The development and utilization of biomass energy still stay in the first generation of biomass resources, especially some key technologies in biomass conversion and utilization technology still need to be further studied.

Keywords: Energy; Biomass; Conversion and utilization technologies; Resource recovery processing

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1. Introduction

Since the Industrial Revolution began in the developed world, the problem of resources and energy has never really been solved, and it has become more and more serious. On the other hand, the innovation of the way energy is used, that is, the so-called mode of production, will bring about great changes in productivity. For example, from the first Industrial Revolution relying on burning fossil fuels to the use of electricity in the second Industrial Revolution, there will be great productivity increases. Compared with developed countries that have completed industrialization, developing countries that are still in the process of industrialization cannot copy the old ways of developed countries due to a shortage of natural resources and serious environmental pollution. They need to find new ways. According to incomplete statistics, as of 2025, the world population has reached 8.232 billion; energy consumption is increasing; traditional fossil energy will not be produced again in a short time; looking for alternative energy will be the only way out; otherwise, it will only be empty [1]. At the same time, the traditional fossil energy situation in today's world is becoming increasingly severe. The disputes over oil issues in the Middle East are uninterrupted. In recent years, due to the sanctions imposed by the United States on Iran, a traditional oil exporter, and the existence of various problems such as economic crisis, the world oil situation is extremely unstable. At the same time, China is also a big oil consumer. On the basis of dealing with international problems, we should actively promote energy transformation and enter a new era. The emergence of a series of clean energy sources such as wind energy, tidal energy, geothermal energy, solar energy, and hydropower has greatly relieved the pressure of traditional fossil energy sources. The application of such clean energy sources has also greatly improved environmental problems.

Traditional fossil energy, such as oil, natural gas, etc., whether in development or utilization in China, is ranked at the forefront of the world; some new energy sources, including wind power, hydropower, etc., China's development and application level is also ranked at the forefront of the world. However, biomass energy, which is also a new type of energy, still has a small gap in development level compared with some developed countries. Compared with traditional fossil energy, biomass also has available hydrocarbon bonds, and the sulfide content is very small [2].

The abuse of traditional fossil resources will increase the environmental burden, cause a lot of pollution to the environment, and lead to the occurrence of severe weather such as haze and sandstorms; It will also produce a large number of greenhouse gases, which makes the greenhouse effect continue to intensify in recent years, especially since the 20th century, leading to global climate change. It is urgent to protect the environment. Therefore, while improving the utilization rate of traditional fossil energy, vigorously developing and utilizing various new energy sources is the correct direction of energy development in all countries in the world today, and it is also the inevitable choice of all countries in the world.

2. Biomass

2.1. Definition of biomass

According to the International Energy Agency (IEA), biomass comes from a wide variety of sources, including animals, plants, and microorganisms. Plants are the broadest range of biomass, and the U.S. Department of Agriculture and Department of Energy believe that anything related to plants, including plant bodies, plant processing wastes, husks, and even residues digested by animals, should be counted as biomass [3].

The energy stored in biomass is not spontaneously generated. In the end, it comes from the solar energy fixed by plants through photosynthesis. Plants, as producers, transmit the fixed solar energy to the whole ecosystem through the food chain. This is also the essence of biomass energy. Making good use of biomass energy is to make full use of solar energy.

2.2. Composition and classification of biomass

Biomass comes from a variety of sources and can be divided into the following categories: agriculture-related biomass, including energy crops such as sugar cane, crop straw, sawdust, and other wastes generated by processing; animal-related biomass, including human and animal waste, kitchen waste fermentation residues, etc.; industrial-related biomass, including fermentation residues, organic wastewater, etc. At present, with the continuous development of agriculture, industry, and catering business, the output of organic solid waste is also increasing, and it has become the main raw material of biomass.

Biomass is a complex composed of a variety of complex polymer organic compounds. Its chemical composition mainly includes cellulose, semi-cellulose, lignin, etc. These polymer substances are distributed differently in different biomass and different parts of the same biomass, and even have great differences [4].

Cellulose is the largest and most abundant carbohydrate in nature. It is the main component of the plant cell wall. It is a linear macromolecular polysaccharide polymerized by a large number of glucose molecules. Its molecular formula is $(C_6H_6O_5)_n$. Cellulose contains two terminal hydroxyl groups, one of which is a glycoside hydroxyl group, which makes it have reducing properties. The other is an alcohol hydroxyl group, which also makes the whole molecule show polarity and orientation.

Hemicellulose is an important component of plant cells. It is a polysaccharide compound composed of many non-carbon and six-carbon sugars. It is interspersed between cellulose and lignin in the cell wall. Unlike cellulose, which is formed by the polymerization of a single glucose, hemicellulose is formed by the polymerization of different sugar units, making the molecular chain short and branched.

Lignin is a kind of network, amorphous and aromatic polymer with a very complex structure. It is often composed of the same or similar structural units. The structural units are repeatedly connected to form lignin. Most of it exists in the cell wall of plant cells, and the content is second only to cellulose. Lignin can play the role of an adhesive in plants, mainly existing in woody plants, playing a strengthening role.

3. Biomass utilization technology

3.1. Biomass utilization status

In the face of increasingly serious environmental problems, countries, from the perspective of energy conservation, emission reduction, and environmental protection, in order to achieve sustainable and healthy economic development, have put forward the strategy of accelerating energy transformation. Biomass energy, a new clean renewable energy, has important practical significance in promoting energy transformation in the world.

According to incomplete statistics, the total amount of biomass on land is significantly lower than that in the ocean. On the one hand, the ocean is larger than the land, and on the other hand, the ocean is larger and can accommodate more biomass. However, the exploitation of marine biomass is far from reaching its due level. In today's world, the highest biomass use is in Europe, especially in some Nordic countries, where 12% of biomass is used in industrial heating processes, and more than 60% of biomass is used for residential heating [5]. The development and utilization of biomass in the United States has grown rapidly from relatively low-tech combustion to heat generation for export (mainly to Europe) to the use of biomass for power generation and refining bio-oil. Relatively, in some developing countries, especially those regions with relatively backward development, the development and utilization of biomass still remain at a relatively low level. The yield of biomass raw materials is very high, but the structure is relatively simple, and most of them are the first-generation biomass raw materials without processing. For example, in Ethiopia, the total annual supply of biomass raw materials can reach 141.8 million tons, but only 70.9 million tons of biomass are developed [6]. In 2016, renewable energy, including biomass fuel, as a typical representative of low-carbon energy, once again appeared in public view. The total biomass production in China is growing rapidly at an unprecedented rate, generating about 4.53 billion t per year [7]. Biomass energy accounts for 35% of energy consumption and is a potential substitute for other clean energy sources. Overall, the first generation of biomass energy uses agriculture-related products as raw materials, with access to simple methods, low cost, and low difficulty in development, industrialization has been completed in some countries; processed first generation biomass, mainly lignocellulose, known as the second generation of biomass energy, is still in the stage of technological innovation, the world has not yet formed a mature industrial production. Today, the world pattern is undergoing major changes, energy transformation is imminent, and the development of biomass energy has ushered in an important opportunity period. It is estimated that by 2050, the proportion of modern biomass energy in the global energy structure and terminal energy consumption will increase to 22% and 16% [8].

3.2. Biomass conversion and utilization technology and its research progress

At present, there are many mature biomass conversion and utilization technologies, such as direct combustion technology, compact molding technology, biomass fermentation ethanol technology, carbonization technology, biogas power generation technology, etc.; at the same time, there are many high-tech technologies, such as gasification technology, cracking, vegetable oil esterification technology, municipal landfill gas power generation and heat supply. Biomass is utilized in a variety of ways, but only a few methods have truly achieved scale and industrialization, mainly biomass power generation, refining liquid fuel bio-oil, gas fuel, and solid fuel [9]. According to the biomass products produced, biomass technology can be divided into solid biofuel technology, gas biofuel technology, liquid biofuel technology, power production technology, etc.

3.2.1. Solid fuel technology

As early as 2010, China's Ministry of Agriculture officially promulgated and implemented the industry standard for biomass briquettes to standardize the biomass solid fuel industry [10]. In terms of technology for producing solid fuels, China has developed biomass briquettes at room temperature. The relatively mature technologies for producing solid fuels using biomass include two types: one is biomass briquettes technology, and the other is to refine biomass into biochar. The production technology of biomass briquettes is mainly to convert biomass raw materials into granules and lumps by physical methods, and the manufacturing technology of biomass briquettes is also included. Solid fuel technology originated in Europe, and because European countries attach importance to the development of biomass, Europe ranks at the forefront of the world in this respect. In terms of biomass molding technology, Japan has already taken the lead in the world due to its early development, while China still faces a large number of key technologies in this area. Only by constantly overcoming technical problems can large-scale production and utilization of biomass resources be realized.

3.2.2. Liquid fuel technology

There are two technologies for producing liquid biomass fuels: biodiesel and fuel ethanol. Biodiesel production technologies include conventional alkali (acid) catalytic technology, high-pressure alcoholysis technology, enzymatic catalytic technology, supercritical (or subcritical) technology, etc.; fuel ethanol production raw materials include cassava, sweet sorghum, and cellulose [11]. Starch biomass is the main raw material for fuel ethanol production, because starch biomass can be fermented to produce ethanol; Lignocellulose is also one of the main raw materials for the production of liquid fuels. Lignocellulose is mainly prepared by fermentation, gas-Fischer-Tropsch synthesis, liquefaction-refining, and selective synthesis of platform compound intermediates [12]. Most ethanol-producing countries are more or less invested in the development of biomass ethanol. The first-generation biomass feedstock is starch biomass; The second-generation raw material is lignocellulosic biomass, including cellulosic raw materials such as crop straw, fruit shells, and wood chips produced by crop or wood processing, woody plants, organic solid waste, etc., which have almost no acquisition cost and can also improve waste treatment. The role of the environment has great advantages in using it as a production raw material. However, due to the high technical level requirements and the large amount of funds required, its industrialization is difficult. Most of the ethanol produced on a large scale in the world comes from first-generation biomass. At present, the production technology of liquid fuel based on first-generation biomass is basically developed and mature, and it is difficult to make great progress. Although China has made certain achievements in the production technology of liquid fuel based on cellulose, there is still a certain gap between China and Europe. In terms of fuel ethanol production, the traditional use of the first generation of biomass to produce ethanol has a history of several thousand years in China, while the technology of producing ethanol from the second generation of biomass and cellulose is still facing considerable resistance: the pretreatment technology of biomass raw materials such as straw; the actual application cost of cellulose degrading enzymes is too high to be suitable for large-scale production; and there is a lack of microbial strains with high conversion rate. Biodiesel production is currently developing relatively steadily and is gradually improving. Biodiesel production from vegetable oil produced by oil crops such as peanuts and rape is relatively mature; biodiesel production from woody oil is currently being tackled.

3.2.3. Gas fuel technology

According to the principle of gas fuel generation, it can be divided into two categories: one is to use microbial fermentation, and the other is to decompose biomass into combustible gases by physical and chemical methods [13]. The second method can be classified according to the presence or absence of a gasifying agent. The application scenarios of gas fuel technology are also diverse, such as cogeneration, centralized gas supply, and hydrogen production. In biomass gasification to prepare gas fuel, the key issues restricting its development include tar content, secondary pollution, and economic benefits. For example, although the gas fuel produced from biomass is clean energy, it may cause pollution to the environment during the production process. Biomass gasification to prepare gas fuel includes raw material pretreatment, decomposition, purification of combustible gas, purification after alkylation, etc. Alkylation includes catalyst and reactor: The reactor is mainly a new form of conventional reactor; transition metals on supported and oxidized carriers are often used as catalysts for methanation, which is also the most critical technology in the process [14]. Gas fuel technology is currently the oldest and simplest technology, producing methane through biological fermentation. Although there are some innovations, the overall technology tends to be saturated and balanced.

3.2.4. Electric power production technology

Biomass as a raw material to produce electricity, the more mature methods are: direct combustion method, co-combustion method, and gasification method. Direct combustion method: biomass is used as a thermal power plant furnace fuel; the current average production efficiency is not high, only 25%, so it requires a large amount of biomass raw materials. Because of the limited raw materials, such thermal power plants usually have only a small production capacity. Co-combustion, as its name suggests, is to make coal and biomass co-combust in the furnace of a thermal power plant, with biomass replacing 5% to 30% of coal, if the ratio is appropriate. Co-fired thermal power plants (usually around 35%) have a power generation efficiency level comparable to that of all-coal-fired thermal power plants [15]. Gasification is a method of heating and burning biomass to produce combustible gases. The energy conversion rate of this method is extremely high, up to 60%. It can be found that gasification should be the optimal method if conditions permit, but it is limited by the current technical level and is not suitable for actual production. At the present stage, biomass combustion will produce a large amount of heat; biomass will also be widely used in cogeneration plants to provide electricity without wasting biomass combustion heat. In 2025, China had built more than 930 power stations using biomass as raw material, and the total power generation using biomass as raw material had exceeded 47GW [16].

4. Conclusion

By discussing the research status of biomass-related fields at home and abroad and the specific application and conversion technology of biomass as energy, it is not difficult to find that due to the continuous aggravation of resource and environmental problems, the application prospect of biomass energy is getting better. Although China has made great achievements in the development and application of biomass, and even reached the world advanced level in some aspects, it has to be admitted that in some high-end fields, such as biomass processing equipment, solid waste reduction, Compared with developed countries, there is still a big gap in the technology of harmless and resource treatment, so it is urgent to develop more advanced and clean treatment technology and realize the efficient utilization of biomass resources in the future.

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Disclosure statement

The authors declare no conflict of interest.

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