Current and Future Prospects for Hydrogen Production from Biomass

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Abstract

Biomass is now considered to have a key role in building a foundation for energy and heat production, because biomass can be produced and implemented effectively, moreover, the cost of production is competitive. In addition, a renewable energy source, biomass, can be sustainably used in the production of hydrogen which is an efficient fuel for highly effective combustion with environmental friendliness. In many countries, hydrogen is viewed as a key renewable energy and can be used as sustainable energy. Hydrogen is not only energy capable of existing independently in nature, but can be produced from a variety of sources by employing different types of manufacturing technology. The methods generally employed in producing hydrogen from biomass can be categorized into two main methods, i.e. thermochemical processes and biological processes. At present, a large number of researches have focused studies on the sustainability and environmental friendliness of various alternative energies to be used as a substitute for fossil fuels. And this type of biochemical fuel is one of the best choices with high capacity for implementing as an alternative energy to meet the increasing energy demands in the future.

Keywords : Biomass, Hydrogen, Production, Renewable Energy.

1. Introduction

From the past to the present, demands for the use of oil fuels have been continually increasing because oil fuel is a key factor in responding to the basic needs of mankind. It is also a key production factor in the business and industrial sectors. As the world has undergone continually increasing technological growth, various advancements have begun to play their roles in society with the effect gradually increasing the need to use oil fuels. However, the main problem of using oil fuel is that we can never be certain about the current remaining volume of oil reserves, so there is an impact on oil prices until high oil prices have become a global crisis [1]. In addition, increasing demands for oil fuels not only have an impact on oil prices, but also affect the environment as well. For example, the rapid economic growth of countries from the agricultural sector into the industrial sector has resulted in increasing needs for oil fuels to be used in transportation, industry and daily living. When oil is burned at increasing rates, the result is pollution in escalating proportions, especially in terms of carbon dioxide which has been found to be released into the atmosphere in higher amounts every year in line with the increasing volume of fuel used. These pollutants lead to global warming. Moreover, the impact of the fuel price crisis which has spread across the globe in combination with the awareness of global warming that has taken place which has brought about changes in the structure of energy use all over the world. Greater importance is now given to research, development and promotion of clean energy use, e.g. wind energy, solar energy, biochemical fuels, hydrogen energy for greater energy security because clean energy or renewable energy is natural energy offering unlimited use [2-5]. In addition, clean energy can reduce greenhouse gas emissions, especially carbon dioxide.

Hydrogen energy can be classified as clean energy and a fuel in the future for highly effective combusts with environmental friendliness because steam is only released when hydrogen combustion with oxygen, which makes it different from other types of oil fuels capable of emitting carbon dioxide because carbon dioxide is a greenhouse gas

with direct impact on global warming. Moreover, the production source of hydrogen energy comes from unlimited renewable energy, e.g. water, sunlight and biomass which have made hydrogen another alternative to replace former energy sources [6-8]. Hence, various countries all over the world have exerted efforts toward finding ways to reduce our dependence on use of oil by turning to the support of using hydrogen as a fuel instead [9-10]. A great deal of research and development is currently taking place in the use of hydrogen. If oil becomes more expensive, new alternative fuels will become likely candidates for use. Nevertheless, long-term solutions cannot be found for the energy issue by using any particular type of technology. Rather, a variety of technologies need to be used together such as renewable energy, alternative energy and energy use behavior.

Hydrogen can be produced from two main raw materials, i.e. fossil fuel in the form of natural gas, coal and fuel from renewable energy, such as biomass and water. Because water and biomass are available in large volumes, especially biomass from plants and animals, they are key sources of renewable energy for the world and have been classified as sources of alternative energy to be used instead of energy sources from fossil fuels which are limited and may become depleted [11]. Recently, biomass research is receiving increasing attention for waste to energy application because 150 GT of biomass can produce about 1.08×10^{10} GJ energy [7] . Biomass can be processed into energy in a variety of forms, such as thermo energy, electrical energy and hydrogen energy, etc. From these points of view, current situations and future trends of hydrogen use are reviewed. In addition, a number of hydrogen production methods from biomass are described.

2. Hydrogen Production Methods

The production of hydrogen from biomass can be classified into two main categories, i.e. thermochemical processes and biological processes. Thermochemical processes comprise the process of pyrolysis, gasification, supercritical water gasification and steam reforming of bio-oils from biomass pyrolysis. The pyrolysis process involves destructive distillation without oxygen. Products obtained from the pyrolysis process include solids, liquids and gases. The solid obtained is biochar or charcoal while the liquid is bio-oil and the gas is non condensable gas. The two main variables in the pyrolysis system are the temperature of the process operation and the heating rate in bringing the fuel to the desired temperature. The values of the temperature and heating rate are the factors that determine the characteristics of products obtained [12]. Moreover, the steam reforming process endothermically converts bio-oils from biomass pyrolysis with steam into synthesis gas in catalytic reactors. The first step involves a hydrocarbon (bio-oil) reacts with steam to produce a syngas; hydrogen and carbon monoxide. In the present of oxygen, gasification of biomass is carried out. The goal of gasification process is to produce gaseous products while pyrolysis is to produce bio-oils and charcoal. Gasification is incomplete combustion of biomass resulting in production of synthesis gas or syngas such as carbon monoxide and hydrogen. Then, water-gas shift and methanation reactions occur to increase the hydrogen production by converting carbon monoxide and methane into hydrogen [13] . Biomass can be converted to syngas by non-catalytic, catalytic and steam gasification processes. In general, the gasification temperature is higher than that of pryolysis, and hydrogen production yield is higher than that of pyrolysis [11] . For supercritical water gasification process (SCWG), wet biomass is used as raw material without drying. Supercritical water gasification is a promising technology for the efficient conversion of wet biomass (i.e., 60-95 weight-percent water) into syngas. The process takes place above the critical pressure and temperature of water. This process is highly efficient with capacity for performance at low temperatures. Nevertheless, some disadvantages of gasification process are that biomass decomposition will be in the form

of chars and tars [14], and carbon dioxide emission about 70% vol of syngas during the reaction [15].

All of the abovementioned processes involve converting energy from biomass, solid fuel, to gas fuel by providing heat through various mediums e.g. air, oxygen, or steam. The gasification processes is completely different from combustion processes because gasification processes involve conversions of chemical energy carbons in biomass into combustible gas through four processes, i.e. drying, pyrolysis, oxidation and reduction. Pyrolysis in gasification is a devolatilization process in which tar and other volatiles are driven off. The syngas has better quality and simplicity of usage than direct use of biomass. The advantages of the thermochemical process includes high overall efficiency (η= 52%) and low production costs while the disadvantages include rather low amounts of hydrogen produced at approximately 16-18% by weight, which depends on the weight of dry biomass [16]. The gasification process is applicable to biomass having moisture content less than 35% [7]. However, thermochemical process has some disadvantage that is the release of carbon dioxide. Therefore, carbon dioxide capture process is proposed for improving this process.

Biological processes produce hydrogen by using the photosynthesis processes of small organisms, such as microorganisms and cyanobacteria. The biological processes for hydrogen production or biohydrogen are by-products from the metabolisms of microorganisms, which enhance hydrogen production capacity from an infinite source. Biological processes can be divided into the following groups: biophotolysis of water using green algae and blue-green algae (or cyanobacteria), photo-fermentation, dark-fermentation, and hybrid reactor systems [11]. Biological processes have positive effects on the environment and consume less energy in comparison to thermochemical processes. However, this method has the drawback of low efficiency because production capacity is limited by the light intensity received. Popularly used types of microorganisms include cyanobacteria and anaerobic bacteria, which are fermentative bacteria [17]. The best method in the biological processes of hydrogen production is fermentation which is one of the guidelines for sustainable hydrogen economies in the future. Moreover, hydrogen can be produced from electrolysis processes using electricity to separate hydrogen and oxygen from water [8]. Electricity from all types of generators can be used for this process whether the electricity comes from renewable energy sources or nuclear sources, etc.

In conclusion, the processes for the production of hydrogen from biomass include thermochemical processes and biological processes. Thermochemocal processes are efficient hydrogen production processes. In the past, thermochemical processes used for industrial hydrogen production consisted of gasification and steam reforming, which are consumed in various types of industries, such as ammonia production, petroleum and petrochemical industries, as well as methanol production [18]. Both processes can be seen as clean processes without toxic by-products in comparison with other forms of hydrogen production technology involving the use of hydrocarbon compounds as reactants.

3. Current Hydrogen Productions and Future Trends

Current energy demands are on the rise with gradually escalating trends. Energy is necessary for economic growth. At present, the main source of energy comes from fossil fuels. Approximately 80% of all energy needs involve crude oil, natural gas and coal [11]. In 1985, the world consumed 2,807 million tons of petroleum energy. In 2008, however, petroleum energy consumption increased to 3,928 million tons with usage rates growing at approximately 1.5% per year. Today, nearly all transportation sectors across the globe consume petroleum fuels at 60% of global oil consumption and one-fifth of global carbon dioxide emissions are caused by the transportation sector [19].

Thus, causing concerns regarding the environmental impacts involved, especially in terms of greenhouse gas (GHG) emissions. Since hydrogen production from fossil fuels has a by-product, carbon dioxide, which is a significant cause of the greenhouse effect. Therefore, searches are currently underway for new alternative sources of energy. Previous studies have discovered that hydrogen can be produced from recyclable sources of energy or renewable energy, such as water, sunlight and biomass, etc. Nevertheless, these energy sources cannot replace all fossil fuels. The use of biomass and biomass fuels to produce hydrogen can reduce carbon dioxide emissions. Several researchers have reported that hydrogen will play an important role as an energy service provider in the future [20-22]. Hydrogen can be produced from various energy sources. In the past, hydrogen was produced from non-renewable energy, such as petroleum, natural gas and coal. However, a number of hydrogen production methods involve renewable energy sources, such as thermochemical processes and biological processes processes. Regardless, these methods continue to have high costs at present.

Today, the world uses approximately 400-500 million cubic meters of hydrogen per year [23]. Sources of hydrogen production come from natural gas at approximately 48% of all hydrogen, 30% of all hydrogen is produced from heavy oil and naphtha oil, 18% of all hydrogen is produced from coal, and 4% of all hydrogen is produced by electrochemical processes [16]. Hydrogen is mainly used as a chemical raw material for petrochemical industry, food industry, electronics industry and metallurgy processes. Moreover, hydrogen can be transported and stored chemically or physiochemically in various solid and liquid compounds [24]. Hydrogen can be used as a transportation fuel which makes it different from nuclear and solar energies. Hydrogen is also an environmentally friendly fuel as no toxicity or ozone-forming potential. In addition, it has been found that an internal combustion efficiency not much different from the engines used with gasoline. Furthermore, hydrogen also has better special qualifies in terms of high octane quality and a wider flammability range than methane and gasoline [16].

Nowadays, petroleum reserves are limit resources, projections show that existing petroleum reserves will be exhausted within 50 years at current consumption rates [25]. Therefore, the demand for new energy sources from renewable energy is on the rise because energy needs have grown greatly and will continue to grow in the future, especially in developing countries where energy is an important factor affecting economic growth. Estimates show that global energy consumptions will rise to approximately 600 – 1,000 EJ (EJ = 10^{18} Jules) in 2050 as compared to approximately 500 EJ in 2008 [26]. However, the primary sources of energy are currently found in crude oil, natural gas and coal (approximately 80% of global energy). Furthermore, many researchers consider that hydrogen energy will play an important role as an important energy carrier in the future energy sector.

Hydrogen is clean fuel with no carbon dioxide emission. In addition, hydrogen can be used as fuel in combustion engines and in fuel cells electric vehicles[27]. Moreover, the fertilizer and petroleum industries remain the two largest consumers of hydrogen in production processes at 49% and 37%, respectively [18]. Current use of hydrogen is equal to 3% of all energy consumption with a growth rate of approximately 5-10% per year [28]. Nevertheless, hydrogen is currently more expensive than conventional energy sources, which constitutes a significant limitation for hydrogen use. Furthermore, estimates show that renewable energies will become an important energy source for hydrogen production and hydrogen will play important role in future economic systems[16].

4. Conclusion

The world is currently faced with crisis due to fuel prices and global warming issues. Therefore, many countries are becoming increasingly dependent on alternative energy,

such as hydrogen, because hydrogen is a highly efficient, clean and environmentally friendly combustion fuel. Hydrogen can be produced from renewable energy sources, such as water, solar and biomass. Hydrogen is gaining acceptance as an extremely important source of fuel in the future. However, the main problem with some hydrogen production processes is the emission of large amounts of carbon dioxide, which is a cause of global warming or the greenhouse effect. Furthermore, there are also problems concerning deficient hydrocarbon sources used in hydrogen production processes. Therefore, other processes need to be used as new and safe options capable of efficiently producing hydrogen to support future hydrogen demands. Hydrogen production from biomass can be divided into thermochemical processes and biological processes. Thermochemical processes are capable of efficient hydrogen production. Therefore, the popularity of thermochemical processes is currently on the rise. Presently, most hydrogen is produced from natural gas by the steam methane reforming process, which is a non-renewable energy source. Therefore, searches are currently underway for methods of hydrogen production from renewable energy sources, such as water, biomass and solar energies, etc., because these energies have environmental safety while also conserving money needed for the import of energy from abroad. The use of biomass as a main raw material in hydrogen production has received more attention over the past year. Nevertheless, these technologies continue to require further development, even though hydrogen can be produced from biomass, so hydrogen can be produced efficiently and inexpensively. It is plausible that biomass will become an important source of future sustainable hydrogen energy development.

5. Acknowledgement

The author would like to acknowledge financial support from Engineering Faculty and Thammasat University Scholarships.

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