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Review Article

Liquid fuel processing for hydrogen production: A review

Joongmyeon Bae [a,*], Sangho Lee [a], Sunyoung Kim [a], Jiwoo Oh [a], Seunghyeon Choi [a], Minseok Bae [a], Inyong Kang [b], Sai P. Katikaneni [c]

[a] Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology (KAIST), 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea

[b] H&Power, 27 Yuseong-daero 1628 beon-gil, Yuseong-gu, Daejeon 34054, Republic of Korea

[c] Research and Development Center, Saudi Aramco, Dhahran 31311, Saudi Arabia

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ABSTRACT

Liquid fuel processing technologies have attracted attention because of the increasing importance of energy and environmental problems. Liquid fuels such as gasoline and diesel are promising hydrogen sources because of their high hydrogen densities, widespread applications and well-constructed infrastructure. Liquid fuels can be used in various applications, such as fuel cells, through liquid fuel processing. Pure hydrogen or natural gas has been used depending on the fuel cell type. However, pure hydrogen and natural gas are unavailable in some applications and areas. Therefore, fuel cell applications can be diversified by using liquid fuels. The liquid fuel delivery, catalytic reforming and reformate cleaning processes have been investigated for producing hydrogen-rich gases. Some kW-class reactors have also been developed for practical applications. This paper will summarize and discuss each liquid fuel processing technology and the kW-class reactors for converting liquid fuels into hydrogen-rich gases in a stable manner.

Contents

* Corresponding author. Fax: +82 42 350 8207.
E-mail address: jmbae@kaist.ac.kr (J. Bae).

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Introduction

Requirements for an energy conversion device

High efficiency is required for an energy conversion device to reduce greenhouse gases such as carbon dioxide and methane. Greenhouse gas emissions are closely related to energy consumption because fossil fuels account for the largest portion of the world's energy consumption. Economic growth is based on energy consumption. Consequently, the world's energy consumption has substantially increased since the 20th century. According to BP Energy Outlook 2035, the primary energy consumption was approximately 4 billion toe (tonnage of oil equivalent) in 1965. Because of the growth of Asian countries, such as China and India, the primary energy consumption of the world was over 12 billion toe in 2010 [1]. The Annual Energy Outlook 2015 projected the U.S. energy-related carbon dioxide emissions in 6 cases [2]. The high-economic-growth case also showed the highest energy-related carbon dioxide emissions. Considerable efforts are being devoted to reducing greenhouse gas emissions. In total, 195 countries agreed to the Paris climate change agreement in December 2015. Keeping the increase in global warming below 2 °C was set as a goal. The U.S. pledged a 26–28% reduction in greenhouse gas emissions from the 2005 level until 2030. Carbon monoxide reduction plans were not included in the annual energy outlook. Energy conversion with high efficiency devices is a method for reducing greenhouse gas emissions. High efficiency implies low fossil fuel consumption to generate other types of energies. Therefore, the efficiency of energy conversion devices must be increased to reduce greenhouse gas emissions.

An energy conversion device must also have low pollutant emissions. In particular, pollutant-emission regulations have been stringent in transportation areas. Low-emission vehicle III (LEV III) and Euro 6 are the representative emission standards for vehicles. In 2025, a 73% reduction in non-methane organic gases (NMOG) and NO_x emissions will be achieved by the average requirements of the LEV fleet. Euro 6 requires a more than 50% NO_x reduction from Euro 5. NO_x and SO_x emissions from shipping are also regulated [3,4]. The sulfur contents in shipping fuels must be less than 3.5% after 2012. In particular, the sulfur contents in the sulfur emission control areas (SECA) were limited to 0.1% in January 2015. Tier 3 on NO_x emissions also began on 1 January 2016. Compared to Tier 2, approximately one fourth of the total weighted cycle emission limit of NO_x was reduced in Tier 3 [5]. Various technologies have been applied to reduce pollutant emissions. Selective catalytic reduction (SCR) and lean NO_x trap (LNT) are applied to vehicles. Ships are forced to use expensive fuels, such as marine gas oil (MGO), ultra-low-sulfur heavy fuel oils (HFO) and liquefied natural gas (LNG). An auxiliary power unit (APU) is also considered for reducing the SO_x and NO_x emissions from trucks and ships.

A high energy density is required for an energy conversion device in various applications. The weight and volume significantly affect the efficiency and applications of energy conversion devices. In particular, a high energy density of the energy conversion device is required for submarines,