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Industrial Application of Carbon Recycling Energy System Technology Driven by Nuclear Power

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Abstract

Industrial application of carbon recycling energy system technology driven by nuclear power as low-carbon new energy systems was discussed in this study. For establishment of nuclear power contribution on low-carbon energy system in future, energy storage and energy carrier technologies for nuclear power are required. Chemical energy storage would be an effective candidate for energy carrier. From the stand point of exergy, that is thermal energy quality, carbon media is higher quality than hydrogen. Carbon dioxide (CO_2) decompositions into carbon monoxide (CO) is candidate for the carbon energy carrier. Carbon recycling energy system driven by a nuclear power has potential for new energy storage and carrier technologies. A new energy system of Active Carbon Recycle Energy System (ACRES) using CO as energy carrier driven by a high temperature gas cooled reactor (HTGR) was proposed for reduction of carbon dioxide emission and establishment of carbon supply security of a country. The feasibility of an ironmaking system based on ACRES (iACRES) driven by HTGR was discussed as an example of nuclear industrial application by process numerical analysis. It was expected that ACRES was capable to be a carbon recycling energy system technology driven by nuclear power for industrial sector as a low-carbon energy system methodology.

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Keywords: carbon dioxide; carbon monoxide; carbon recycling; HTGR; iron-making

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Nomenclature

ed	Electrolysis degree [%]
m	CO_2 separated from furnace gas (reduced to electrolysis gas of CO and CO_2 mixture) relative to total inlet reduction gas for the furnace [%]

1. Introduction

Industrial application of carbon recycling energy system technology driven by nuclear power as low-carbon new energy systems was discussed in this study. Energy system designs are required to be changed following with social structure. In energy consumption side, fossil fuel consumption and energy demand will increase globally. Because Japan primary energy converted from nuclear power to natural gas, carbon dioxide emission per unit has been increased after 2011. On the other hand, Japanese government declared to reduce 26% of domestic CO_2 emission by 2030 for global warming prevention in 2015. Renewable energy is one of expected candidate, however, instability of the energy would cause difficulty of its implementation, because Japanese energy networks are isolated from others. For fulfillment of the reduction target, nuclear energy is still important non-fossil energy resources for not only power production sector, but also industrial and other sectors. For establishment of nuclear power contribution on low-carbon energy system in future, energy storage and energy carrier technologies for nuclear power are required. Energy can be stored by electricity, kinetic potential, heat and chemical material. Electricity battery is smart energy storage system, however, it is still expensive, and flammable risk for massive storage. Chemical energy storage would be a candidate for energy carrier. From the stand point of exergy ratio, carbon media is higher quality than hydrogen. Carbon dioxide (CO_2) decompositions into carbon monoxide (CO) is candidate for the carbon energy carrier.

$$CO_2 \rightarrow CO + 1/2O_2\ ,\ \Delta H = +283.0\ \text{kJ/mol} \quad (1)$$

Carbon recycling energy system driven by a nuclear power has potential for new energy storage and carrier technologies. High-temperature CO_2 electrolysis reduction and CO production is able to be realized by solid oxide electrolysis cell (SOEC) [1]. A new energy carrier system of Active Carbon Recycle Energy System (ACRES) with SOEC driven by a high temperature gas cooled reactor (HTGR) was proposed for reduction of carbon dioxide emission and establishment of carbon supply security of a country [2]. Availability of industrial application of ACRES as low-carbon energy system was discussed in this study.

2. Principle of ACRES

A concept of the proposed ACRES is shown in Figure 1. Carbon dioxide (CO_2) with/without water is the ground state of carbon. CO_2 is converted into carbon materials by non-fossil primary energy using some chemical technologies [3]. Produced carbon material is useful for co-production process. The carbon materials provide thermal and electricity energies during oxidation into CO_2. The carbon materials are capable to be used as raw material for industrial materials. The carbon materials are ease to be stored and transferred under lower compression pressure in comparison with H_2. The carbon materials have quite high affinity with common manufacturing industries. If the carbon recycle system can be established thermally and kinetically, it is expected that the system is diffused easily into conventional industries. Natural carbon recycle energy system has already been existed by plant lives in nature, and an ideal recycle system. However, potential amount of bio-mass is not enough for a modern society. Especially it is less than 10 % of all demand of energy in Japan. The natural recycle system is not enough for energy demand in Japan. Then, an artificial active carbon recycle system was proposed as ACRES in this study.