Analyses of Exergy and Environmental Impact on Bio-H$_2$ Production System Using 2-step PSA

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In recent years, technological development of fuel cells has progressed, and hydrogen demand for the fuel is expanding. However, since fossil fuel is mainly used as the energy source for hydrogen, from the viewpoint of life cycle assessment (LCA), even if hydrogen is used as energy, it contributes to the emission of greenhouse gases. Therefore, we have been developing biomass-derived hydrogen (Bio-H$_2$) production process. It was deemed that the hydrogen purification process (PSA; pressure swing adsorption) had the most environmental impact. Therefore, we developed a 2-step PSA. However, the effective use of energy and the environmental impact in the Bio-H$_2$ production process that introduced 2-step PSA have not been conducted.

Therefore, in order to verify the effective use of energy and the environmental impact of the process, we designed Bio-H$_2$ production process using 2-step PSA based on gasification and purification experimental data, and evaluate the effectiveness of energy use of the process using the exergy analysis. In addition, we assessed the environmental impact of the process using LCA analysis. As a result, it was shown that the exergy efficiency of the 2-step PSA case could be improved by 1.7 points over that of the conventional PSA case. Furthermore, compared to the conventional PSA case, LCA analysis resolved that consumption of fossil fuel would be reduced in the case of 2-step PSA case, and the effect of global warming be greatly reduced. By using the evaluation method integrating the exergy analysis and the environmental impact assessment, which was newly proposed in this paper, we believe that it should contribute to promoting technology development of energy conversion process derived from renewable energy.

**Key Words**
2-step Pressure Swing Adsorption(PSA), Exergy, Life Cycle Impact Analysis

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Behavior of Sulfur in Liquid Phase Oxidation of Coal

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In order to develop an efficient pre-desulfurization technology for both inorganic and organic sulfurs in coals under the mild condition, oxidative desulfurization using hydrogen peroxide was carried out for five kinds of coals with different rank. The coal samples were agitated in the hydrogen peroxide aqueous solution for 2 h at the room temperature. Pyritic sulfur and sulfate as the inorganic sulfur were removed completely from the solid phase by the treatment. Organic sulfur was simultaneously removed, for example, 84% of organic sulfur was reduced for a low rank coal. The removed sulfur from the solid phase dissolved in the hydrogen peroxide aqueous solution as sulfate. XANES analysis showed that thiophenic sulfurs in the coals changed to sulfoxide and sulfone during the hydrogen peroxide treatment. The removal extent of thiophenic sulfur decreased with the increase of the coal rank and correlated well with the aromaticity of the raw coals.

Key Words
Coal, Desulfurization, Hydrogen peroxide, XANES, Sulfur form
Effects of Fast Pyrolysis on Bed Agglomeration and the Following Gasification Rate in Fluidized Bed

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During the fluidized bed fast pyrolysis/gasification of woody biomass, a few characteristic phenomena were observed. In our small scale fluidized bed fast pyrolysis, agglomerates were found in the bed, which will cause serious engineering problems, such as plugging and defluidization. In the present study, the agglomerates formed were recovered and weighed after pyrolysis of Japanese cypress with different particle diameters using two bed materials of porous alumina and silica sand. The agglomeration was found to be observed mainly between 500-900 °C. Then soluble organic compounds were extracted and the agglomerates were again weighed. The reduction in weight of agglomerates was correlated with the weight of recovered organic compounds. In all of the results, some effects of bed particle and biomass particle diameter were observed.

Then the in-situ gasification of biomass char produced was conducted at between 800-1100 °C for different bed materials. The progress of the gasification was different between two bed materials. The different behavior observed in pyrolysis and gasification was explained by the difference in volatile release behavior between large and small biomass particles and by the difference in adsorption/decomposition behavior of volatile between two bed materials.

Key Words
Woody biomass, Fast pyrolysis, Volatile matter, Gasification rate, Fluidized bed

キーワード
木質バイオマス、熱分解、ガス化、流動層、揮発分

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Original Paper
Development of Digestion Technology for Oil Extract Residue from Microalgae

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Microalgae *Botryococcus braunii* produces and stores liquid hydrocarbons. The oil extraction residue of the microalgae is a good substitution for anaerobic digestion. However, hexane used as extraction solvent inhibits anaerobic digestion. In this study, the degree of inhibition from hexane and carbohydrate were measured in the continuous experiments. It was found that the hexane concentration and the remained carbohydrate should be kept under upper limits for success of the anaerobic digestion.

Microalgaeの一種である*B. braunii*は、液状炭化水素を大量に組織内に蓄積し、次世代燃料の生産リソースとして注目されている。更にその炭化水素を抽出した後の藻類の残渣、メタン発酵の基質に適している。しかし、炭化水素を抽出する溶媒として使用しているヘキサンは、多量に含まれる場合生物毒として作用し、メタン発酵を阻害する。本研究では、長期試験でヘキサンや残渣炭化水素による阻害による影響を定量化し、メタン発酵の阻害を回避できることを確認したので報告する。

**Key Words**

Microalga, Anaerobic digestion, Biogas, Inhibition
Novel Application of Atomization Technology to a City Gas Calorific Value Adjustment System

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In Japan, the main feedstock for city gas is imported natural gas. In a city gas production process, the calorific value of natural gas is adjusted upward to regulated value of city gas by addition of LPG. In recent years, the method of adding LPG directly in the liquid phase has become the main stream in calorific value adjustment, where all of the added LPG must be securely vaporized. Otherwise, the LPG that does not contribute to increasing the calorific value flows out to the downstream side of the calorific value adjustment system, where the system is not functioning properly. Atomization of added LPG is the KEY for stable calorific value adjustment. In addition, demand for city gas varies greatly depending on the season and time of day, where a turndown, operating flow rate / rated flow rate, of natural gas reaches as small as 1/20, and that of LPG becomes even less than 1/500. The newly developed calorific value adjustment system realized complete and reliable atomization of added LPG over such a wide flow rate range without increasing pressure loss, resulting in a wide possible operating range and excellent calorific value controllability.

Key Words
Atomization, Vaporization, Natural gas, City gas, Calorific value adjustment

日本では，輸入天然ガスを原料に都市ガスを製造している。都市ガス製造工程では，天然ガスにLPGを添加することにより増熱し，規定の都市ガス熱量に調整している。近年，LPGを液のまま直接添加する方法が主流となっており，添加したLPGを全量確保に蒸発させることが求められる。全量蒸発しない場合，増熱に寄与しないLPGが下流側に流出し，燃焼調整が機能しない状態となる。LPGの微粒化が熱量調整の鍵となる。さらに，都市ガス需要は季節や時間帯で大きく変化し，ターンダウン（運転流量/定格流量）は天然ガスでは1/20，LPGに至っては1/500に達する。今回，そのような広い流量範囲において圧力損失を増大することなく完全かつ確実なLPG微粒化技術を開発し，広い運転可能範囲と良好な制御性を有する熱量調整装置を実現した。

キーワード
微粒化，気化，天然ガス，都市ガス，熱量調整
New BOG Recondensing System
Utilizing Gas-Liquid Direct Mixing Technology

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LNG stored in a tank is always subject to heat input because the temperature of LNG, at approximately -160 °C, is far below the ambient temperature. The LNG is partly evaporated by the heat, and this evaporated gas is the BOG (boil off gas). Processing BOG is a challenge for the industries importing LNG such as city gas industry or electric power industry. The industries have been addressing the issue by installing BOG recondensing systems, which reduce power consumption by the BOG compressor. To further minimize the lifecycle cost of BOG processing, the authors developed a new BOG recondensing system utilizing gas-liquid direct mixing technology, which enables to substantially reduce the size of the BOG recondenser. In a course of developing the gas-liquid mixer, as a key device of the recondensing system, several technical features have to be taken into account and confirmed, such as, high recondensing performance, low pressure loss, prevention of internal cavitation-erosion, and, reduction of thermal stress due to large temperature difference of BOG and LNG. The paper describes the confirmed recondensing performance and features of the system. This paper also introduces the first commercial system utilizing developed mixer with a volume of only 2% of conventional system.

Key Words
LNG, Boil off gas, Direct Mixing, Recondensing system

LNGは-160℃という低温のため、タンク貯蔵している間に常に外部からの入熱がある。そのためLNGの一部が蒸発することになり、この蒸発ガスをボイルオフガス（BOG）と呼ぶ。BOG処理動力の増大は都市ガス業界や電力業界のようなLNGを輸入する産業にとって大きな課題であり、BOGを再液化する設備を導入してBOG圧縮機動力の削減を図ってきた。著者らはBOG処理に関するコストの更なる低減に向け、新型BOG再液化設備を開発した。気液直接混合技術の適用により、従来に比べてBOG再液化設備の大幅なコンパクト化が可能となる。再液化設備の中核機器である混合器には、高い再液化性能、低い圧力損失、内部におけるキャビテーションエロージョンの防止、BOGとLNGの大温度差への耐久性、といったことが要求され、これらの要求性能を満たしていることを検証する必要がある。本論文では、確認された再液化性能や要求性能について述べると共に、従来型設備の1/50という大幅な小型化を実現した商用初号機についても紹介する。

キーワード
LNG、ボイルオフガス、直接混合、再液化設備