

Low-Grade Waste Heat Upgrade and Utilization through Advanced Adsorption Technologies: Open Carbon Dioxide Adsorption and Adsorption Heat Transformer

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論 文 名	Low-Grade Waste Heat Upgrade and Utilization through Advanced Adsorption Technologies: Open Carbon Dioxide Adsorption and Adsorption Heat Transformer (低品位廃熱のアップグレードと利用に向けた先進吸着技術：オープン二酸化炭素吸着と吸着熱変換器)			
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論 文 審 査 の 結 果 の 要 旨

The escalating industrial energy consumption and the associated environmental impacts necessitate innovative solutions for energy recovery and environmental sustainability. In global energy consumption, the industrial sector accounts for a significant share. A substantial amount of low-to-medium temperature waste heat is directly released during production processes, resulting in massive energy waste. A report shows that 20-50% of the energy consumed in the industrial sector is lost in the form of waste heat, with 60% of it being below 230 °C. Recovering and utilizing the low-to-medium temperature waste heat is crucial for improving energy efficiency, reducing greenhouse gas emissions and achieving sustainable development.

In this context, the study focused on the critical area of low-grade waste heat recovery using advanced adsorption technologies, which were the scaling analysis of an open CO₂ adsorption cycle and the development of a dynamic model for a large pressure jump (LPJ)-driven adsorption heat transformer (AHT) system. These methodologies were applied to capture CO₂ and enhance the utility of low-grade waste heat, which was often overlooked due to technological constraints. The main findings of the study are summarized below.

- The scaling analysis was meticulously validated through comparison with computational fluid dynamics (CFD) simulations, demonstrating its robustness in predicting the operational behavior of the open CO₂ adsorption process. This validation underscored the utility of scaling analysis as a potent tool for preliminary assessments in the design and optimization of CO₂ adsorption system.
- The dynamic models developed for the AHT system provided deeper insights into the transient behaviors under varying operational conditions. These models successfully captured the complex interplay between mass transfer dynamics and thermal response, thereby facilitating a more nuanced understanding of system performance.
- Through sensitivity analysis, critical parameters influencing the performance of the AHT

system were identified, enabling targeted improvements. The optimization of these parameters had led to enhanced efficiency and stability of the system, thus promoting the effective utilization of low-grade waste heat.

In conclusion, the study improved mathematical modeling for carbon dioxide adsorption systems as well as advanced adsorption cycles, and revealed potentials of adsorption technologies as sustainable solutions. The findings of the study will lead to a carbon neutrality by low-grade thermal energy utilization and contribute greatly to the progress of thermal engineering. Therefore, the author of the thesis deserves to receive Doctor of Engineering.