# 論 文 の 内 容 の 要 旨

論文題目　A Novel Energy-Saving Biomass Drying Process Based on Self-Heat Recuperation Technology
（自己熱再生技術を用いた省エネルギーバイオマス乾燥プロセスの開発）

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Biomass is a promising sustainable energy; however, its current application for energy supply was limited and its high moisture content was one of the main reasons. Drying could reduce its moisture content but consumes a large amount of energy, and current biomass dryers (rotary dryer and conveyor dryer) are large. To solve the above problems, in this research we developed biomass drying processes based on SHR technology to reduce the energy consumption for biomass drying. We also succeed to apply the fluidized bed dryer for biomass drying which is more compact and efficient.

In Chapter 2, exergy loss was investigated in the drying process and heat pairing concept was developed to apply SHR technology for the drying process. Energy analysis was performed in the existing energy-saving drying processes and the unmatched heat pairing was found as the main reason for the large amount of energy consumption in the existing energy-saving processes. Initial design was proposed for biomass drying in a fluidized bed dryer which saved energy consumption to 1/4 of the conventional heat recovery drying process. Exergy analysis showed that the exergy loss was greater in the fluidized bed dryer than in other units due to the sensible heat of air was paired with the latent heat of water evaporation.

In Chapter 3, SHR technology was succeeded to be applied to the fluidized bed dryer. The

energy consumption could be saved to 1/6 of the conventional heat recovery dryer due to the good heat pairing. In the experiment, we investigated the hydrodynamic behavior inside the fluidized bed dryer with silica sand as the fluidizing particles and immersed heating elements as a heat source. The results showed that good solid mixing, as well as a uniform temperature across the bed, could be achieved under the condition that the fluidization velocity was at least three times the minimum fluidization velocity of sand and a good drying performance could be also achieved in this situation. Furthermore, a stability investigation of the fluidized bed dryer was conducted.

In Chapter 4, the other biomass drying systems (rotary dryer and screw conveyor dryer) were investigated based on SHR technology. Energy consumption can be reduced to 1/7 of that of a conventional heat recovery dryer. Effects of the heat exchange type, ratio of air to product, minimum temperature difference between the hot and cold streams in the heat exchanger, and drying medium on the system energy consumption were evaluated when applying self-heat recuperation technology to a biomass drying system. Energy saving by applying SHR technology to the biomass drying systems mainly depended on the minimum temperature difference between the hot and cold streams in the heat exchanger.

In Chapter 5, an exergy recuperative module for energy-saving drying with superheated steam has been proposed and applied to design an exergy recuperative drying system. Simulation results show that energy consumption in the exergy recuperative drying process could be reduced to 1/7–1/12 that of the CHR, less than 1/4 that of the MSD and near 1/2 that of the MVR. Energy consumption of the exergy recuperative drying process would increase slightly with the decrease in the final water content and the adiabatic efficiency of the compressor affects the total energy consumption reduction slightly. The exergy recuperative module was applied for the biomass drying system. Furthermore, a steam fluidized bed dryer was built in our lab. Hydrodynamic study, drying kinetics of sawdust and heat transfer stability in the fluidized bed dryer with steam were investigated. Biomass could be dried at near to the boiling point in the fluidized bed dryer with a high drying rate. More energy supply through increasing the heat exchange surfaces could shorten the drying time especially for the constant drying period. In Section 5.4, a new fluidized bed dryer was proposed for biomass drying. Biomass particles could form a good solid circulation in the fluidized bed without adding inert particles and mechanical aids. Results showed that initial moisture content of input sawdust affected on the sawdust fluidization performance. For sawdust of high moisture content drying, the fluidization behavior could be divided into three stages: partial fluidization, full fluidization with an increasing drying rate and full fluidization with a decreasing drying rate. A high drying rate could be achieved due to the fast mass and heat transfer rate in the fluidized bed. The fluidized bed dryer has a similar drying performance as a binary mixture fluidized bed dryer, however, more compact and require no separation from inert particles.

In Chapter 6, summary of this research and future work was given.