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STUDY ON CO2/O2-BLOWN COAL GASIFICATION IN TWO STAGE ENTRAINED FLOW GASIFIER

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論 文 要 旨

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論文題名 STUDY ON CO_2/O_2-BLOWN COAL GASIFICATION IN TWO STAGE ENTRAINED FLOW GASIFIER
（２段噴流層式ガス化炉におけるCO_2/O_2吹き石炭ガス化に関する研究）

論 文 内 容 の 要 旨

Global energy consumption in 2030 is predicted to increase 1.4 times that in 2007, where about half of the increase will be contributed by Asia. It is also predicted that remaining years of exploitable global energy resources in sequences are: coal (122 years), uranium (100 years), natural gas (60 years) and oil (42 years). Presently, approximately 40% of electric power generation worldwide depends on coals. Because of limited exploitable oil resources and the risk for nuclear power plant, Japan now depends heavily on imported fossil fuels to meet its energy demand. The contribution of coal to total energy production is increasing day by day. However, the use of coal faces several challenges. The major one is the considerable emission of CO_2, which leads to climate change and air pollution.

Therefore, to reduce the CO_2 release into the atmosphere and to increase the gasification efficiency, attention is currently focused on coal gasification with CO_2/O_2 mixtures rather than with air (N_2/O_2). To implement the IGCC (Integrated gasification combined cycle) system efficiently and to mitigate the CO_2 emission problem, it is necessary to study CO_2/O_2-blown coal gasification. Moreover, the soot formation, which is of significant environmental concern, is still being neglected in the past studies.

This thesis systemically conducted the numerical simulation of coal volatiles gasification, soot formation in coal volatiles gasification and coal gasification including soot formation under various conditions. The numerical results obtained from this study are considered to be an important step towards better designs of gasifiers.

Chapter 1 gave an introduction to the contribution of coal to the global energy demand. The energy production from coal fired power plant is increasing day by day, which result in increased CO_2 emission from the existing power plant. However, CO_2 emission from coal gasification can be reduced if an efficient $CO_2/O_2/N_2$ coal gasification is implemented in IGCC system.

Chapter 2 discussed the study of reaction mechanism in coal volatiles gasification under various conditions. In this chapter, the detailed reaction mechanism (255 species and 1095 elementary reactions) is reduced by using the rate of production analysis under $CO_2/O_2/N_2$ gasification condition. The derived reduced mechanism consists of 46 chemical species and 165 elementary chemical reactions, which is validated under various gasification conditions. The effect of CO_2/O_2 mixtures is evaluated under

$CO_2/O_2/N_2$ gasification condition in an effort to increase syngas and decrease soot and CO_2 emissions. Higher temperatures result in an increase in CO and H_2 concentrations and a decrease in PAHs and soot concentrations compared with lower temperatures. CO_2 inlet mass fraction shows a large effect on PAHs/soot reduction at higher temperatures. At lower temperatures, the O_2 input becomes important in reducing PAHs/soot.

Chapter 3 discussed the effect of various types of reaction mechanism (detailed and overall) on product gas concentration. The large number of species and reactions sometimes make difficulty to run the simulation especially for the complex flow system. One step soot formation mechanism is proposed in here to implement it in coal gasification simulation for predicting soot in two stage entrained flow coal gasifier. The calculated trend of species concentration shows a reasonable agreement with those of the detailed mechanism with soot.

Chapter 4 explained various models and sub-models used for the simulation of coal gasification in this study.

Chapter 5 explained the results for the numerical simulation of coal gasification with soot formation in two stage entrained flow gasifier under various gasification conditions. It is found that the contribution of the combustor to the overall CO and H_2 production is very small relative to the reductor. However, the combustor plays a major role in increasing gas temperature. In contrast, soot formation decreases the gas temperature in the gasifier because of high heat capacity of PAH/soot produced in the gasification process. Some higher soot is formed in the reductor part near the gasifier wall which may be similar to the deposition of soot at real gasifier wall. Coal gasification under CO_2-rich environment shows that higher inlet CO_2 concentrations enhance the char-CO_2 reaction, result in an increase in CO concentration.

Chapter 6 discussed the sensitivity analysis of coal gasification in two stage coal gasifier under $CO_2/O_2/N_2$ gasification condition. The carbon conversion of reductor coal is comparatively lower than the combustor coal, because reductor is operated under lower temperatures. Remarkable outlet concentrations about 32 wt% and 0.58 wt% are obtained for CO and H_2, respectively if a high temperature is maintained in the reductor. Higher CO_2 concentrations can produce high heating value syngas. However, a high inlet concentration of CO_2 at 50wt% reduces the carbon conversion in combustor. On the other hand, with increasing the O_2 ratio, it is possible to increase the carbon conversion and syngas heating value. A maximum heating value gas with the minimum CO_2 production can be obtained if the gasification is carried out with O_2 ratio at 0.7. The change of soot concentration under various gasification conditions is found to be limited. However, at higher O_2 ratios soot concentration disappears significantly.

Chapter 7 concluded that higher CO_2 concentrations can produce high heating value syngas. However, a high inlet CO_2 concentration at 50wt% reduces the carbon conversion in the combustor. To get maximum syngas heating value from coal gasification, O_2 ratio needs to be increased to 0.7.