

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

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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 CO₂, which leads to climate change and air pollution.

Therefore, to reduce the CO₂ release into the atmosphere and to increase the gasification efficiency, attention is currently focused on coal gasification with CO₂/O₂ mixtures rather than with air (N₂/O₂). To implement the IGCC (Integrated gasification combined cycle) system efficiently and to mitigate the CO₂ emission problem, it is necessary to study CO₂/O₂-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 CO₂ emission from the existing power plant. However, CO₂ emission from coal gasification can be reduced if an efficient CO₂/O₂/N₂ 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 CO₂/O₂/N₂ 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 CO₂/O₂ mixtures is evaluated under CO₂/O₂/N₂ gasification condition in an effort to increase syngas and decrease soot and CO₂ emissions. Higher temperatures result in an increase in CO and H₂ concentrations and a decrease in PAHs and soot concentrations compared with lower temperatures. CO₂ inlet mass fraction shows a large effect on PAHs/soot reduction at higher temperatures. At lower temperatures, the O₂ 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 H₂ 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 CO₂-rich environment shows that higher inlet CO₂ concentrations enhance the char-CO₂ reaction, result in an increase in CO concentration.

Chapter 6 discussed the sensitivity analysis of coal gasification in two stage coal gasifier under CO₂/O₂/N₂ 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 H₂, respectively if a high temperature is maintained in the reductor. Higher CO₂ concentrations can produce high heating value syngas. However, a high inlet concentration of CO₂ at 50wt% reduces the carbon conversion in combustor. On the other hand, with increasing the O₂ ratio, it is possible to increase the carbon conversion and syngas heating value. A maximum heating value gas with the minimum CO₂ production can be obtained if the gasification is carried out with O₂ ratio at 0.7. The change of soot concentration under various gasification conditions is found to be limited. However, at higher O₂ ratios soot concentration disappears significantly.

Chapter 7 concluded that higher CO₂ concentrations can produce high heating value syngas. However, a high inlet CO₂ concentration at 50wt% reduces the carbon conversion in the combustor. To get maximum syngas heating value from coal gasification, O₂ ratio needs to be increased to 0.7.

論文審査の結果の要旨

本論文は、CO/CO₂/O₂雰囲気での気相反応機構を詳細に検討するとともに、その知見を活かした数値解析モデルを構築し、CO₂/O₂吹き2段噴流層式ガス化炉内における石炭の反応挙動を予測したものであり、化学システム工学上寄与するところが大きい。よって、本論文は博士(工学)の学位論文に値するものと認める。