The effect of different moisture contents and forms of low-rank coal on CO_2 adsorption capacity

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出版情報：Kyushu University, 2022, 博士（工学）, 課程博士
バージョン：
権利関係：

（様式２）

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論 文 名　: The effect of different moisture contents and forms of low-rank coal on CO_2 adsorption capacity（低品位炭の水分含有量と形態の違いが CO_2吸着量に及ぼす影響）

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論　文　内　容　の　要　旨

The growing interest in CO_2 sequestration in coal seams has prompted researchers to measure the amount of CO_2 adsorption of coal as a potential long-term solution to global warming. Although there are still vast reserves of low-rank coal in the world, it cannot be expected that a significant increase in demand for low-rank coal in the future considering the recent trend toward decarbonization. However, low-rank coal seams are expected as potential CO_2 sequestration sites because prior studies have shown the CO_2 adsorption capacity of low-rank coal. Previous studies on the CO_2 adsorption of low-rank coal have used crushed and dried coal to evaluate its ability for CO_2 adsorption. However, low-rank coal contains a lot of water in itself, which may make it difficult to adsorb CO_2, and it is important to examine the effect of moisture of low-rank coal on its CO_2 adsorption. In addition, since there are various forms of low-rank coal, it is necessary to consider the effect of different forms of low-rank coal on its CO_2 adsorption. This study aimed to evaluate the CO_2 adsorption capacities of several types of low-rank coal and the effect of moisture and their forms on the CO_2 adsorption of low-rank coal. This dissertation consists of six chapters laid out as follows:

Chapter 1 introduces the possibility of maximizing low-rank coal seams as a potential CO_2 sequestration site. Measurement of adsorption has become a critical issue for fitting different scenarios for the CO_2 sequestration in low-rank coal seams and enhancement of coal bed methane (ECBM) from low-rank coal seams. Hypotheses and objectives of this study are presented in that regard.

Chapter 2 presents the literature review of CO_2 adsorption of coal and reviews studies conducted to assess the effect of various influencing parameters on CO_2 adsorption of coal. It also provides a brief overview of the methods used for measuring gas adsorption factors on solid materials. In addition, recent studies on the CO_2 adsorption of low-rank coal are discussed to demonstrate the need for this research.

Chapter 3 investigates the CO_2 adsorption of low-rank coals which were collected from three coalfields in the South Sumatra Basin in Indonesia, namely West Banko (WB), East Banko (EB), and North Muara Tiga Besar (NMTB). All coal samples used in this study had a similar value of fixed carbon content and volatile matter content, but the coal collected from WB had a lower moisture content than other coals. Comparing CO_2 adsorption of low-rank coal samples collected from other countries, Indonesian low-rank coals with lower moisture content showed higher CO_2 adsorption capacity, suggesting that moisture was an important factor in CO_2 adsorption. Experimental results showed that CO_2 adsorption capacity was greatest in WB with the lowest moisture content, followed by EB with a lower moisture content than NMTB. CO_2 adsorption of low-rank coal also varied depending on the form of the sample such as powder form and block form. CO_2 adsorption of the raw powder coal which was not dry treated was 1.1 and 1.4 times larger than that of raw block coal under 0.5 to 2.0 MPa and 2.0 to 3.0 MPa respectively. Furthermore, dry powder coal adsorbed 1.9 to 2.2 times more CO_2 than raw powder coal whereas dry block coal adsorbed 1.7 to 1.8 times more CO_2

than raw block coal. These results indicate that CO_2 adsorption is affected not only by moisture content but also by the forms of coal samples. In actual coal seams, the coal is present in a block form and contains a lot of moisture, so the CO_2 adsorption measured using dry powder coal needs to be corrected. The results of those experiments were fitted to the adsorption isotherms such as Langmuir, Freundlich and Temkin isotherms to investigate the CO_2 adsorption mechanism of low-rank coal. Both Langmuir and Freundlich isotherms were closely fitted to the experimental data, indicating that CO_2 adsorbed on coal monolayer or multilayer. It was found that the coal samples collected from WB had the greatest potential for CO_2 storage in the three coal samples due to their lower moisture content than those collected from EB and NMTB.

Chapter 4 presents the CO_2 adsorption of low-rank coal collected from five coal seams such as A1, A2, B1, C and D in WB. The coal collected from seams B1 and C resulted in higher CO_2 adsorption than the coal samples collected from other seams due to their low moisture content and high fixed carbon content. CO_2 adsorption of dry block coal collected from seam B1 was 1.6 to 1.8 times larger than that of raw block coal. The statistical evaluations of the experimental results based on the sum square error and average relative error indicated that both Langmuir and Freundlich were the most accurate adsorption models, as they showed CO_2 adsorption in both monolayers and multilayers. The values of Henry coefficients which were calculated using experimental results were larger for dry powder coal, dry block coal, raw powder coal and block raw coal. The values of Henry coefficients of dry coal were higher than those of raw coal because the availability of micropores in the coal which was capable of adsorbing CO_2 was increased through the drying process. The surface potential and Gibbs-free energy of coal were also increased through the drying process. The drying process facilitated and enhanced the CO_2 adsorption of low-rank coal due to an increase in the micropores, surface potential, and Gibbs-free energy of coal. In the previous chapter, it was shown that the moisture content of coal had an important influence on the CO_2 adsorption of coal. The low-rank coal collected from seam B1 had higher moisture content and fixed carbon content than the low-rank coal collected from seam C. The CO_2 adsorption of the coal collected from seam B1 was similar to that from seam C although the moisture content of the former coal was higher than that of the latter one. The experimental results of this chapter indicated that the moisture content was not the only factor affecting CO_2 adsorption but the fixed carbon content. Those results indicate that both seams B1 and C are suitable layers for CO_2 sequestration in WB.

Chapter 5 discusses the relationship between the components in low-rank coal and CO_2 adsorption under different conditions. The content of huminite in coal showed a strong positive correlation with CO_2 adsorption of coal, especially in the case of dry coal. The content of liptinite in coal had a weak positive correlation with CO_2 adsorption of both dry and raw coal. There was a negative correlation between the content of inertinite and CO_2 adsorption of both dry and raw coal. Low-pressure nitrogen adsorption and scanning electron microscopy (SEM) were used to analyze the change in pore structure associated with CO_2 adsorption under different conditions. The results of the analyses indicated that the swelling of coal caused by CO_2 adsorption resulted in the reduction of micropores in coal. The dissolution of minerals on coal pores due to acidic environments derived by CO_2 adsorption was found by SEM analysis. The dissolution of minerals results in an increase in mesopores. CO_2 injection into dry coal has a lower chance of swelling than CO_2 injection into raw coal, which is advantageous for increasing CO_2 adsorption. On the other hand, CO_2 injection into raw coal also has a chance of increasing mesopores due to dissolution of minerals under acidic environment, which is also advantageous for increasing CO_2 adsorption.

Chapter 6 concludes the present research by highlighting the major findings and further research suggestions.