GHGT-12

Test Operation Results of the 10 MWe-scale Dry-sorbent CO₂ Capture Process Integrated with a Real Coal-fired Power Plant in Korea

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Abstract

The ground-breaking ceremony of the 10 MWe-scale dry-sorbent CO₂ capture process was held in August 2012 and the construction was finished in October 2013. It was integrated with a 500 MW power plant and used a slip-stream of that, located at the Hadong coal-fired power plant (Unit #8), Korea Southern Power Company. From October 2013, Korea Institute of Energy Research (KIER), Korea Southern Power Company, and KC Cottrell have executed the test operations in order to find out the optimal operational conditions and several modification parts to achieve the target project goals of the 10 MWe-scale dry-sorbent CO₂ capture technology.

The dry-sorbents have been developed by KEPCO Research Institute and massively produced and supplied by TODA-ISU, which consists of 35 wt.% of active components for the CO₂ sorption and 65 wt.% of supporters for the mechanical strength. The some portions of the dry-sorbents have been tested at the 0.5 MWe-scale dry-sorbent CO₂ capture process in order to analyze the sorbent performance through the two-week operation campaign in June 2013.

During the test operations, the 10 MWe-scale dry-sorbent CO₂ capture process has been divided into four parts such as a sorbent handling part, a flue gas pre-treatment part, a main reactor part, and a utility (steam, cooling water, and instrument air) part. In the sorbent handling part, the sorbent feeding system has been tested so that the sorbent has automatically fed to the reactor system and conversely fed to the sorbent silo. In the flue gas pre-treatment part, main blower, the secondary flue gas desulfurization, and the moisture control of the flue gas have been tested. In the main reactor part, the solid hold-up in the carbonation reactor, the solid circulation rate, control concept, and the reaction performance of the sorbent have been tested. In the utility part, steam supply, cooling tower operation, and instrument air compressor operation have been tested.

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The test operations will be done on January 2014 and the long-term continuous operations will be performed from early March 2014. We plan to continuously operate the 10 MWe-scale dry-sorbent CO₂ capture process from the second quarter of this year, to analyze the economics of the dry-sorbent CO₂ capture technology based on the operational results, and to finish FEED of the 300 MWe-scale dry-sorbent CO₂ capture technology until the end of the third quarter of this year.

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Peer-review under responsibility of the Organizing Committee of GHGT-12

Keywords: CO₂ Capture; Dry-sorbent; Fluidized-bed Reactor; Test-bed; Pilot Unit

1. Introduction

Korea Institute of Energy Research (KIER) and Korea Electric Power Research Institute (KEPRI) have been developed the dry-sorbent CO₂ capture technology using sodium carbonate or potassium carbonate as a sorption material in the fluidized-bed reactors from 2002. There have been several research works for CO₂ sorption in a batch or continuous system using Na- or K-based regenerable sorbents which was manufactured by KEPRI [1-15]. KIER has developed the dry-sorbent CO₂ capture process which consists of a carbonation reactor and a regeneration reactor. Yi et al. reported the continuous experimental results using K-based solid sorbents in the lab-scale continuous CO₂ capture process [15]. Park et al. reported the bench-scale and test-bed experimental results at the international conference of greenhouse gas control [7-9]. Choi et al. reported the simulation results of the lab-scale unit which consists of two bubbling beds for the carbonation and regeneration and compared with the experimental results [1,2].

Based on the experimental results of the bench-scale unit and the test-bed which consists of a fast fluidized-bed type carbonator and a bubbling fluidized-bed type regenerator, 10 MWe-scale pilot unit has been developed. The ground-breaking ceremony of the pilot unit has been held in 24th August, 2012 and the completion ceremony of that in 8th April, 2014. In this study, we reported the results of the continuous operation campaign of the test-bed and those of the pilot unit.

2. The test-bed

The test-bed mainly consists of a carbonation reactor for CO₂ sorption, a regeneration reactor for sorbent regeneration, a sorbent cooler for cooling sorbent from the regeneration temperature to the carbonation temperature, and several cyclones for separating gas and solid. Fig. 1 shows the schematic diagram of the dry-sorbent CO₂ capture process [9]. KIER has performed about 200-day operation campaigns of the test-bed using K-based solid sorbents which were supplied by KEPRI. Fig. 2 shows that the long-term continuous experimental results of the test-bed. The flue gas flow rate has been maintained from 1,900 to 2,100 Nm³/h. Fig. 2 (a) shows that the CO₂ removal has been maintained above 80%. The carbonator consists of a mixing zone and a fast zone so that the CO₂ removal has reached above 80% level. The differential pressure of the lower part of the mixing zone has been maintained from 400 to 600 mmH₂O and that of other parts of the carbonator are shown in Fig. 2 (b). In this experiment, we used K-based solid sorbents in which the optimal carbonation reaction temperature is 70°C based on the equilibrium data. In the carbonator, the heat transfer tubes have been installed and cooling water has been used as a cooling medium. Fig. 2 (c) shows that the temperature in the every part of the carbonator has been well maintained around 70°C.
3. The 10 MWe-scale pilot unit

The 10 MWe-scale pilot unit has exactly the same reactor configuration as the pilot-scale unit like Fig. 1. Park et al. introduced the process development history and the construction procedure of the pilot unit [10]. It can handle 35,000 Nm³/h of flue gas. Fig. 3 shows that the long-term continuous experimental results of the pilot unit. Fig. 3 (a) shows that the CO₂ removal has been maintained around 80% level and the inlet CO₂ concentration maintained from 14 to 15 vol.% (dry basis). The differential pressure of the mixing zone has been maintained from 300 to 500 mmH₂O and that of other parts of the carbonator are shown in Fig. 3 (b). Fig. 3 (c) shows that the temperature in the every part of the carbonator has been maintained between 70 and 80°C.
Currently, above 1,000-hour continuous operation of the pilot unit has been performed. The results show that the 80% level of CO$_2$ removal is capable, above 95 vol.% of CO$_2$ purity in the regenerator is capable and the operation stability of the developed pilot unit is guaranteed. We plan to analyze the economics of the dry-sorbent CO$_2$ capture technology based on the operational results of the pilot unit and to finish FEED of the 300 MWe-scale dry-sorbent CO$_2$ capture technology until the end of the third quarter of this year.

4. Conclusions

The test operation of the pilot unit has been successfully performed so that the 80% level of CO$_2$ removal with a real coal-fired flue gas during 240 hours has been maintained. Compared with operation results of the test-bed, the differential pressure profiles in the carbonator of the pilot unit was similar to those of the test-bed. The performance
of the pilot unit was also similar to that of the test-bed. Through the scale-up, not only the performance but also the operation stability of the pilot unit has been guaranteed. To secure the definite operation stability of the pilot unit, the 1,000-hour continuous operation has been started on July in this year. We plan to analyze the economics of the dry-sorbent CO\textsubscript{2} capture technology based on the 1,000-hour continuous operational results of the pilot unit.

Acknowledgements

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Trade, Industry and Energy (No. 20102010200007B).

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