Research concerning Fluidized Bed Combustion (FBC) in Shimizu's Lab.

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Calcium Looping Process for CO_2 capture

- ✓ Char transportation from regenerator to carbonator
- ✓ NOx emissions from regenerator

Emission control of NOx, N_2O, and SO_2 during coal combustion in FBCs

- ✓ Simultaneous reduction of NOx, N_2O, and SO_2 using alternative bed materials
- ✓ Reactions catalyzed by limestone (kinetic study and bubbling/circulating FBC tests)
- ✓ Simultaneous reduction of pollutants by using two stage BFBC
- ✓ Alternate fuel (petroleum coke) combustion: Different behavior from coal
- ✓ NOx formation during char combustion

Combustion of high-volatile fuels such as wastes and biomass

- ✓ Reduction of unburnt carbon/hydrocarbon emissions from fluidized bed waste incinerator (suppression of precursors of dioxins)
- ✓ Hydrocarbon capture by porous bed materials
- ✓ Suppression of heat transfer between bed and fed fuel
- ✓ Stable operation without sintering/agglomeration problems
- ✓ Abatement of pollutants (NOx, N_2O, SO_2)

Test facilities

No.	Reactor type	Objective
1.	Bubbling FBC, 1.3 m height, 5.3 cm i.d. (SUS: Stainless steel)	General purpose: Combustion, gasification, pyrolysis of coal, biomass and wastes.
2.	Bubbling FBC, 1 m height, 4 cm x 16 cm square cross section (SUS)	Evaluation of horizontal dispersion of carbonaceous material with high-volatile fuel combustion (evaluation of capacitance effect)
3.	Bubbling FBC, 1 m height, 5.3 cm i.d. (Quartz, transparent)	Visual observation of sintering/agglomeration during biomass combustion
4.	Circulating FBC, 1.9 m height, 2.2 cm i.d. (SUS)	Combustion of coal and other solid fuels.
5.	Circulating FBC, 4.3 m height, 5.3 cm i.d. (SUS)	Not working now.
6.	Fixed bed experimental apparatus	Evaluation of catalytic effect/capacitance effect
7.	Dual fluidized bed solid circulating system, 1.9 m height, 2.2 cm i.d. and 0.6m height, 9.3 cm i.d. (SUS)	Combustion of coal under Calcium Looping Process conditions

Recent research topics

1. Calcium Looping Process for CO2 capture

Global warming caused by increase in GHG gases (CO_2, N_2O, …) in atmosphere.

Proposed solution: CO_2 capture and geological storage (CCS)

Approach: Development of low energy-penalty CO_2 separation process. Calcium Looping Process (CaL process), which was firstly proposed by the present researchers in 1994, is expected to be an energy-efficient and low-cost CO_2 separation process. The basic concept is illustrated in Fig.1-1. CaO particles capture CO_2 at high temperatures (873 – 923 K) in one fluidized bed reactor. The produced $CaCO_3$ particles are transported to another fluidized bed reactor in which oxyfuel combustion is conducted to supply heat of $CaCO_3$ decomposition. The produced CO_2 is then compressed for storage.

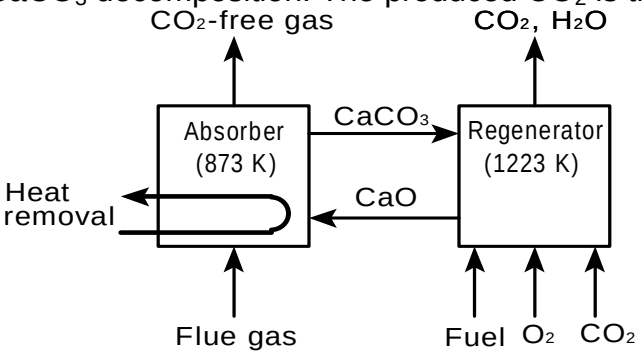

Fig.1-1 Concept of Calcium Looping Process (CaL process)

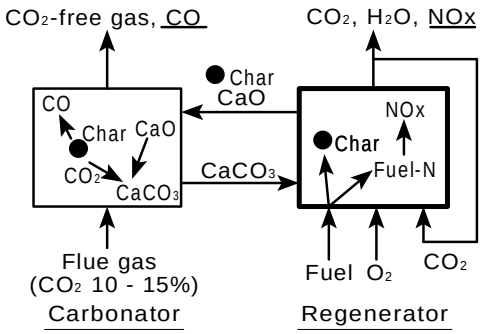

Fig.1-2 Anticipated problems with CaL process

Problems: With coal combustion in regenerator (calciner), char (solid carbon) particles are formed. A part of unreacted char is then transported to carbonator and oxidized by oxygen in flue gas. If CO is formed, it may be released to the atmosphere. Also NOx may be formed in regenerator. The anticipated problems are illustrated in Fig.1-2.

Research work: A laboratory-scale dual fluidized bed system (Fig.1-3) is operated to evaluate the transportation of char particles to carbonator followed by oxidation there. Also NOx emissions from the regenerator are measured. The fate of NOx and char in dual fluidized bed system is discussed..

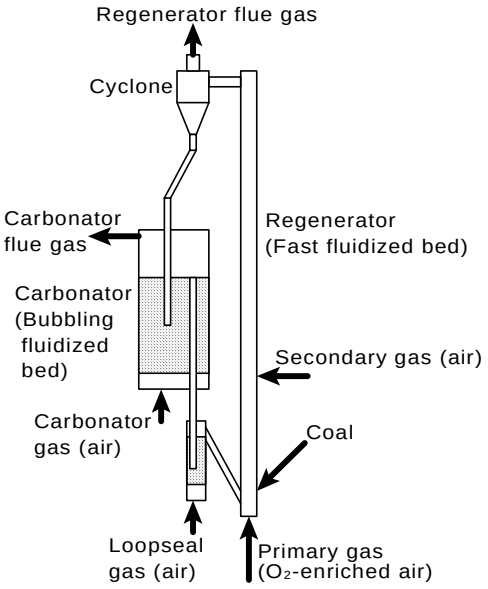

Fig.1-3 Experimental apparatus of dual fluidized bed system

2. Alternative bed material to solve the problems of high-volatile fuels

Problem: Rapid volatile matter release from fuels in the vicinity of fuel feed point
→ Local evolution of volatile matter (VM) with poor mixing in the freeboard.
→ Emission of unreacted VM (precursors of dioxins, tar troubles, flame combustion)

Proposed solution: Use of porous bed material that has capacitance effect

Effect (1): Hydrocarbon capture and solid carbon formation within pores (Fig.2-1):
→Reduced hydrocarbon emission, increased in-bed combustion
→Enhanced horizontal dispersion of carbonaceous material with solid mixing (uniform combustion in bed) (Fig.2-2)
→Reduced emissions of unburnt gases (CO, HC) and dioxins (Fig.2-3)

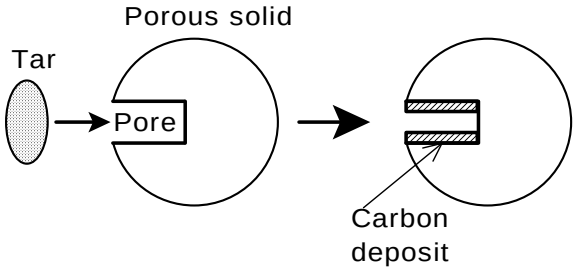

Fig.2-1: Capacitance effect of porous solids (hydrocarbon capture and formation of carbon deposit within the pores at high temperatures)

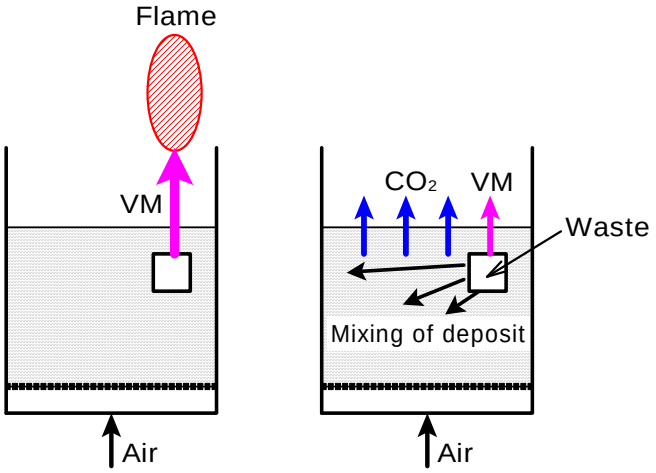

Fig.2-2 Conventional bed (left) and porous solids bed (right)

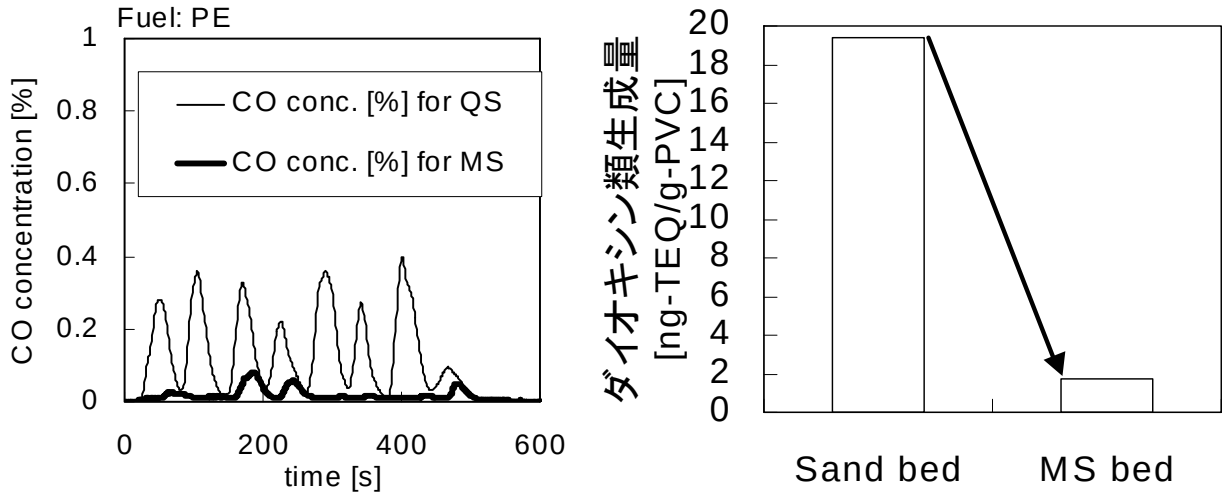

Fig.2-3 Reduced emissions of CO (left) and dioxins (right)

Effect (2): Reduction of heat transfer coefficient between bed and fuel
→Reduced heat-up rate of fuels
→Delayed volatile matter evolution
Relative importance of reduced heat transfer and capacitance effect is evaluated.

3. **Alternative bed material for stable operation during biomass combustion**

Problem: High-volatile fuel, agglomeration problems caused by alkaline material in the fuel (with silica-based solids)

Proposed solution: Use of porous alumina bed material

Effect (1): Hydrocarbon capture (same as previous section)

Effect (2): Stable operation (less agglomeration problem) (Table .3-1)

Effect (3): Low NOx emissions, though the mechanism is not yet clear (Fig.3-1).

Table 3-1 Total amount of fuel burned during experiments and effect of bed material (BM) type on agglomeration

BM	Fuel amount	Agglomeration
QS	0.337 kg	Occurred
QS	0.317 kg	Occurred
QS	0.318 kg	Occurred
QS	0.285 kg	Occurred
MS	0.388 kg	Not
MS	0.398 kg	Not
MS	0.392 kg	Not
MS	1.064 kg	Not

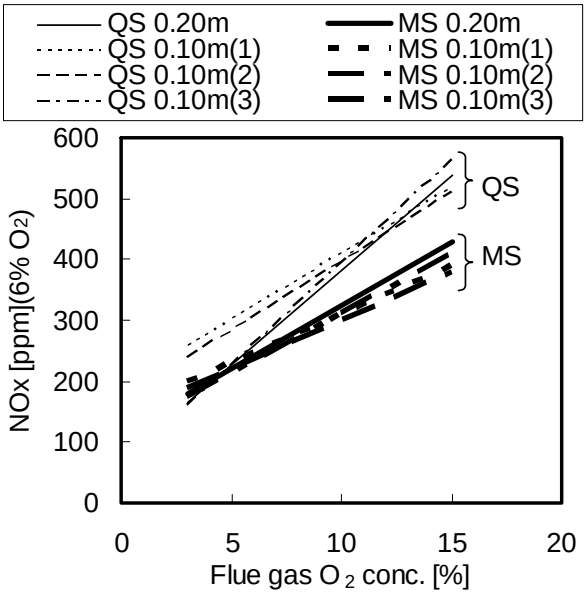

Fig.3-1 Emissions of NOx during rice husk combustion in quartz sand and porous alumina

4. NOx emission from municipal sewage sludge (dried sludge) combustion

Problem: High-nitrogen fuel and high-iron in ash → NOx emissions

Present work: Measurement of NOx emissions during mono-combustion of dried sludge and co-combustion with coal

Results: NOx emissions increased with sludge ash accumulation. (Fig.4-1)
→ Removal of ash by attrition is a measure to avoid increase in NOx emissions. A model of ash accumulation is developed.

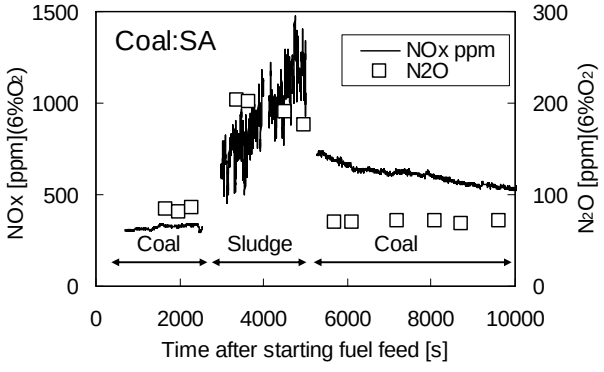

Fig.4-1 Effect of ash accumulation on emissions of NOx during dried sludge combustion

Curriculum Vitae

Name: Tadaaki Shimizu
Male, born on Oct. 11, 1960, Japanese

Present position: Professor
Degree: Ph.D (Eng.)

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Educational background

1983 Graduated Department of Chemical Engineering, Tokyo University
1985 Master degree, Graduate School of Engineering, Course of Chemical Energy Engineering, Tokyo University
1994 Ph.D. (Engineering), Graduate School of Engineering, Course of Chemical Energy Engineering, Tokyo University

Job history

1988 - 2003 Research associate, Department of Chemical Engineering, Niigata University
2003 - 2008 Associate Professor, Department of Chemical Engineering, Niigata University
2008 - Professor, Department of Chemical Engineering, Niigata University

Academic activities (International, selected)

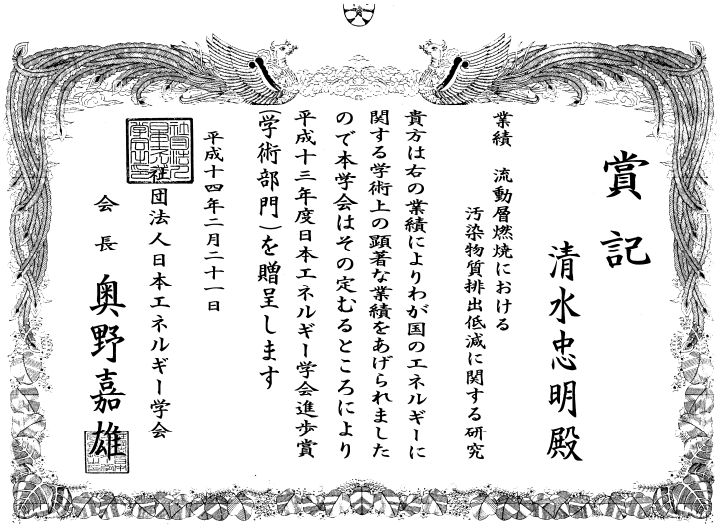
1997 International Congress on Acid Snow and Rain, Niigata, 1997, Secretary
2000 7th Asian Conference on Fluidized-Bed and Three-Phase Reactors, Local organizing committee member
2002 20th Annual International Pittsburgh Coal Conference, Session Organizer
2003 21st Annual International Pittsburgh Coal Conference, Local organizing committee member
2004 International Conference on Coal Science and Technology 2005, Local organizing committee member
2007 20th International Symposium on Chemical Reaction Engineering, Local organizing committee member
2008 1st Asian Conference on Innovative Energy & Environmental Chemical Engineering, Program committee member
2008 International Advisory Board Member of the Circulating Fluidized Bed Conferences
2011 Steering Committee member of 21st Int. Conf. on Fluidized Bed Combustion
2012 The 9th Asian Pacific Conference on Sustainable Energy & Environmental Technologies, Local Organizing Committee

Academic activities (Domestic, selected)

2007 JSPS the 148th committee member
1995, 1996, 2004, 2010 Chairman of SCEJ Symposium on Fluidized Beds
2007 – 2008 Representative of Fluidization Research Group of Soc. Chem. Eng. Jpn.

Awards

1. Tadaaki Shimizu, “A new approach to suppress rapid devolatilization during fluidized bed waste incineration”, ***SCEJ Fluidization Symposium Award***, 2000, Fluidization Research Committee, The Society of Chemical Engineering, Japan, 2000
2. Tadaaki Shimizu, “Research on emission control of fluidized bed combustion”, ***The Japan Institute of Energy Award for Progress*** (FY2001), Japan Institute of Energy, 2002
3. Tadaaki Shimizu, Hans-Jürgen Franke, Satoko Hori, Yasuo Takano, Masaru Tonsho, Makoto Inagaki, Masato Tanaka, “Porous bed material - An approach to reduce both unburnt gas emission and NOx emission from a bubbling fluidized bed waste incinerator”, ***The Japan Institute of Energy Award for Distinguished Paper***, Japan Institute of Energy, 2003
4. T. Shimizu, C.-Y. Gao, H. Narisawa, A. Yoshizawa, Y. Shimazaki, K. Suzaki, H.-J. Kim, L.-Y. Li, “Coal combustion under calcium looping process conditions”, ***The 11th International Conference on Fluidized Bed Technology Best Poster Award***, 2014



賞記

清水忠明殿

業績　流動層燃焼における
汚染物質排出低減に関する研究

貴方は右の業績によりわが国のエネルギーに関する学術上の顕著な業績をあげられましたので本学会はその定むるところにより平成十三年度日本エネルギー学会進歩賞（学術部門）を贈呈します

平成十四年二月二十一日

社団法人日本エネルギー学会
会長　奥野嘉雄

賞記

清水忠明殿
Hans-Jürgen FRANKE殿
堀彩統子殿
高野康夫殿
頓所勝殿
稲垣眞殿
田中真人殿

論文　多孔質粒子流動媒体による気泡流動層焼却炉からの未燃分とNOxの同時排出低減

上記は本学会誌に発表された論文中特に優れた業績と認め本学会はその定むるところにより平成14年度日本エネルギー学会論文賞を贈呈します

平成15年2月21日

社団法人 日本エネルギー学会
会長　藤元薫

賞記

新潟大学
清水忠明殿

業績　流動層燃焼炉における揮発分の安定的排出低減する方法の提案

貴方の創造的な努力と精励から生み出された右の業績は流動層技術の発展に対する著しい貢献でした化学工学会流動層特別研究会は茲にその功績をたたえ平成十二年度流動層シンポジウム賞（研究部門）を贈呈いたします

平成十二年十二月七日

化学工学会流動層特別研究会
代表　守富寛

CFB-11

The 11th International Conference on Fluidized Bed Technology

Present

Best Poster Award

To

T. Shimizu, C. Gao, H. Narisawa, A. Yoshizawa, Y. Shimazaki, K. Suzaki, H. Kim, L. Li

For Their Poster

Coal Combustion under Calcium Looping Process Conditions

Conference Chairman

Prof. Jinghai Li　Prof. Fei Wei　Prof. Xiaoqin Bao

May 15~17, 2014, Beijing, China