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Outline of Course 50

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Abstract

COURSE 50 aims at developing technologies to reduce CO2 emissions by approximately 30% through suppression of CO2 emissions from blast furnaces as well as capture - separation and recovery - of CO2 from blast furnace gas (BFG), and establishing the technologies by ca. 2030 with the final goal of industrializing and transferring the developed technologies by 2050.
(CO2 Ultimate Reduction in Steelmaking process by Innovative technology for cool Earth 50)

keywords:Hydrogen reduction;By-productt gas;Coke oven gas;CO2 reduction of Steelmaking:Course50;Chemival absorption in steelmaking;Physical adsorption in steelmaking

1. Introduction

COURSE 50 aims at developing technologies to reduce CO2 emissions by approximately 30% through suppression of CO2 emissions from blast furnaces as well as capture - separation and recovery - of CO2 from blast furnace gas (BFG), and establishing the technologies by ca. 2030 with the final goal of industrializing and transferring the developed technologies by 2050.
CO2 Emissions Reduction methods have been discussed which are divided into two categories, the 1st category is to use procured alternative reducing agents. The second category is to reduce the carbon dioxides which are inevitably emitted during the production of steel.COURSE50 aim the total CO2 Emissions reduction system in the whole steelmaking process which is shown in Fig1.

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2. Target setting

Table 1 shows the outline of CO2 Emissions Reduction methods which are divided into two categories

Table 1 Case Study for CO2 Emissions Reduction in Steel Industry

Alternative reducing agents	Reduction by carbon
(1)Utilization of hydrogen	(4)CO2 capyure
1-1 Natural gas	4-1 CO2 capture from BFG
1-2 By-product gas	4-1-1 Chemical Absorption
(2) Direct use of electricity	4-1-2 Physical Adsorption
(Hydrometallugy)	(5)CO2 capture from other reduction processes
(3) Use of C-neutral agents	5-1 Coal-based smelting reduction
3-1 Biomass	5-2 Coal-based direct reduction
Charcoal reductiob,waste use	

The first step project of this initiative, STEP 1 within Phase I, was launched in 2008, scheduled to be completed in March 2013. This project is funded by NEDO, or New Energy and Industrial Technology Development Organization, with the budget of approximately 10 billion yen, joined by five of the integrated steel companies and one engineering company: Kobe Steel; JFE Steel; Nippon Steel; Sumitomo Metal Industries; Nisshin Steel; and Nippon Steel Engineering.

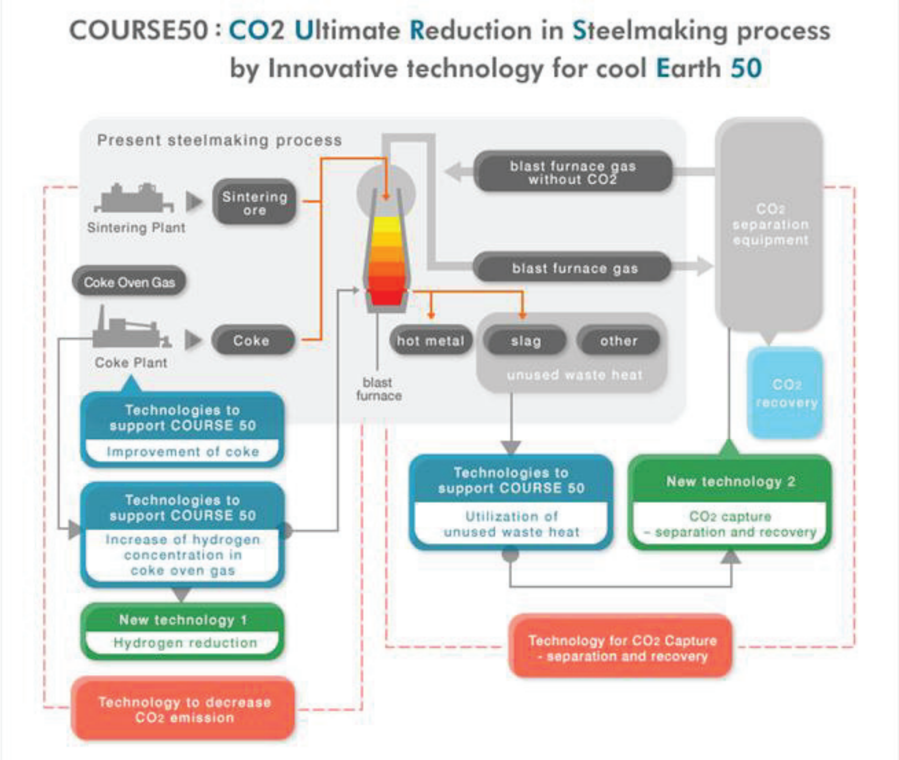


Fig 1Total CO2 Emission Reduction system of COURSE50

Several universities and research institutes have joined forces through the relevant joint R&D programs.The Outline, Project Targets and Sub Projects Organization are shown in Fig2,Fig3 ,Fig4 ,respectively.

Outline of COURSE 50

1. Total budget: approximately 10 billion yen (planned)
2. Term for R&D: Step 1 of Phase 1 for 5 years (Fy 2008 – Fy 2012)
3. R&D targets:
   (1) Development of technologies to reduce CO_2 emissions from blast furnace
   (2) Development of technologies to capture - separate and recover - CO_2 from blast furnace gas (BFG)

Fig 2 Outline of Course 50

Project Targets

(1) Development of technologies to reduce CO2 emissions from blast furnace

- Develop technologies to control reactions for reducing iron ore with reducing agents such as hydrogen to decrease coke consumption in BF.
- Develop technologies to reform coke oven gas (COG) aiming at amplifying its hydrogen content by utilizing unused waste heat (800℃ generated at coke ovens).
- Develop technologies to produce high strength and high reactivity coke for reduction with hydrogen.

(2) Development of technologies to capture - separate and recover - CO2 from blast furnace gas (BFG)

- Develop techniques for chemical absorption and physical adsorption to capture CO2 from blast furnace gas (BFG).
- Develop technologies to reduce energy to capture CO2 through enhanced utilization of unused waste heat from steel plants.

Fig 3 Project target

SG1. Development of technologies to utilize hydrogen for iron ore reduction.

SG2. Development of technologies to reform COG through the amplification of hydrogen.

SG3. Development of technologies to produce optimum coke for hydrogen reduction of iron ore.

SG4. Development of technologies to capture – separate and recover – CO2 from BFG.

SG5. Development of technologies to recover unused sensible heat.

SG6. Holistic evaluation of the total process.

Fig4 Sub project organization

3. Technology development programs

COURSE50 bases its CO2 reduction technology development on the blast furnace process rather than trying to develop a totally different process to accomplish such a high level of CO2 reduction within a short period by as early as 2030 in consideration of blast furnaces' capability of providing large throughput. The project targets are two-pronged:

3.1 Development of technologies to reduce CO2 emissions from blast furnace

3.1.1 Basic concept

Aimed at is the reduction of CO2 generation from the blast furnace with the introduction of hydrogen into the blast furnace. Hydrogen, a carbon-free reducing agent, replaces as much carbon as possible to the extent that normal blast furnace operations and a sound energy balance within a steelworks can be maintained. The Concept of Hydrogen reduction is shown in Fig5.

Hydrogen-enriched coke oven gas (COG) will be blown into the blast furnace to accomplish this aim, avoiding additional CO2 generation if hydrogen is externally procured. Here the technology to reform tar contained in COG is key to implement this hydrogen reduction technology, and is being developed with the use of catalysts to enhance the reformation reactions to obtain hydrogen.(Fig6)

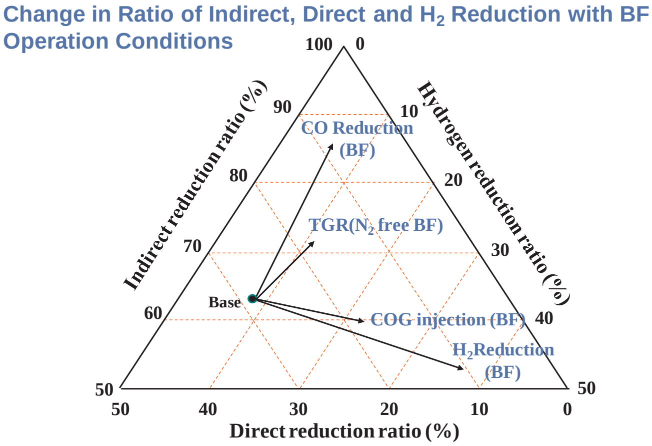


Fig 5 Concept of Hydrogen reduction

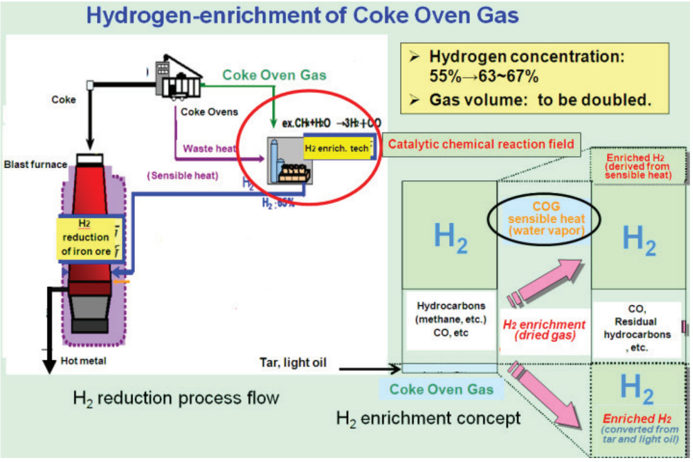


Fig 6 Hydrogen enrichment of Coke Oven Gas

3.1.2 Items of Research and Development

Fig7 shows Itemps of reseach and development concering the iron ore reduction by hydrogen. reduction promotion, temperature decrease and Sinter degradation(accelation of sinter pulverization)are main items.

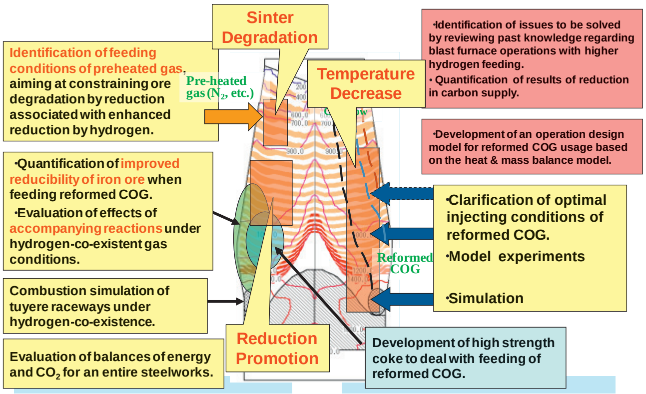


Fig 7 Items of Research and Development concerning the iron ore reduction by hydrogen

2.1.3 Experimental method Fig8 shows an experimental apparatus for blast furnace inner reaction gas compositions are controllable, and temperature is under regulation using thermocouple and heater.

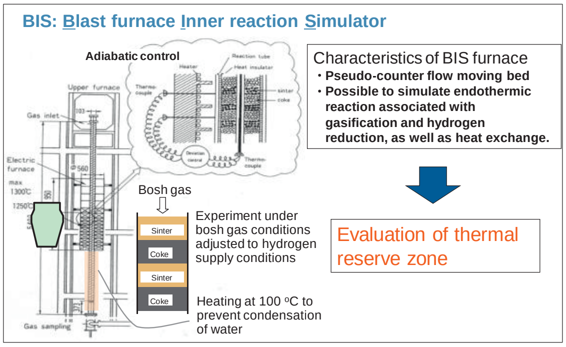
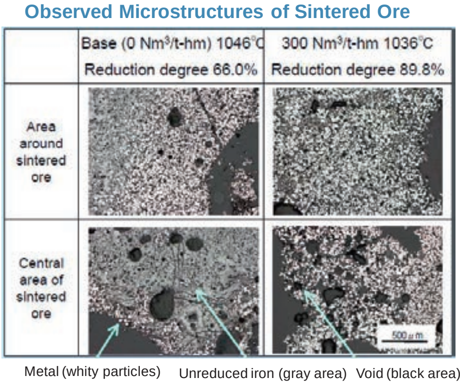


Fig 8 Experimental apparatus for Blast Fuenace Inner reaction

2.1.4 Experimental result

Application of hydrogen reduction improves the reduction rate. Fig 9 shows the example of the result of hydrogen reduction which shows the well-reduced microstructure.



Reduction degree of the high temperature part of the *sintered ore after reduction with the BIS furnace improved by blowing in reformed COG.

* Reduction was interrupted before completion.

Fig 9. Observed Microstructure of Sinter Ore

3.2 Development of technologies to capture CO2 from blast furnace gas (BFG)

3.2.1 Chemical absorption

3.2.1.1 Fundamental researches of chemical absorption

Chemical absorption and physical adsorption technologies are being developed to efficiently capture CO2 from BFG.

In this research, we have investigated ca. 20 single amine-based CO2 absorbents with particular chemical structures (e.g. aliphatic monoalkanolamines, aliphatic dialkanolamines and cyclic alkanolamines, etc.) and alkyl substituents (e.g. methyl, ethyl, propyl, etc.) around the amino group. We identified certain secondary and tertiary alkanolamines with higher CO2 absorption rate and lower heat of reaction compared with AMP and MDEA, as shown inFig10. As shown inFig10, absorbents with low heat of reaction usually had the feature of low CO2 absorption rate. However, several alkanolamines showed opposite trend. Although some absorbents do not show improvement when compared with AMP and MEA, some useful information has been obtained to understand structure–performance relationships.

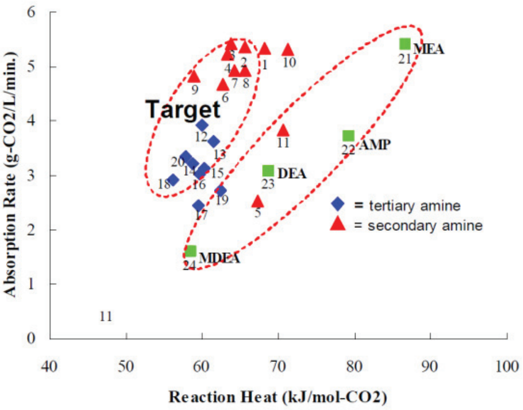


Fig 10 Performances comparison between conventional amines and synthesized new amines

Based on the results of screening experiments and careful analysis of them, we worked on the development of advanced chemical solvent applicable to CO2 removal in steel making industry. Thus, the RN solvents were formulated from the viewpoint of the concentration and ratio of amines with a choice of some activators to maximize the potential of the amines. Some RN solvents were already demonstrated with real blast furnace gas at pilot test plants 1t/d and 30t/d and showed promising results in terms of reducing absorbent regeneration energy.

3.2.1.2 Bench scale approach

Chemical absorption is a technology to capture CO2 from BFG: an alkaline aqueous solution, or absorbent, such as amine, selectively absorbs CO2 when contacting BFG containing CO2 in an absorption tower, and then the CO2-laden absorbent releases CO2 after heating in a regeneration tower. This process is suitable for capturing large amount of CO2 from gases at ordinary pressure. However, in order to incorporate it in the COURSE50's CO2 capturing process, new chemical absorbents, requiring much less CO2 capture energy compared with currently available absorbents, as well as an optimal absorption process must be developed to secure minimum operating cost. New chemical absorbents are being developed by means of combined experimental and computational methods such as quantum chemistry and statistical data processing. Pilot plants with the capacities of 1 ton-CO2/day and 30 tons-CO2/day have been in operation to evaluate newly developed absorbents which is shown in Fig11.

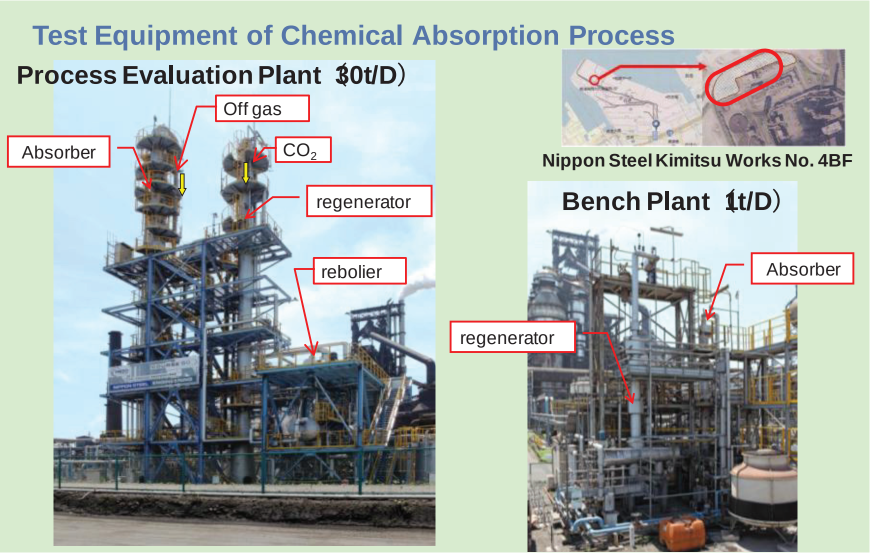


Fig 11 Test Equipment of Chemical Absorption Process

3.2.1.3 Development Procedure of CO2 Capture Technology

Though chemical absorption process is suitable for capture of large amount of CO2 from gases at just above ambient pressure, several technical issues shall be developed and solved in order that the process will applied to steelmaking process for the first time in the world.

(1) Reduction of heat consumption

In order to reduce large amount of heat consumption necessary for chemical absorption process, development of new absorbents and development of chemical absorption process bringing out of features of developed new absorbents are needed.

The skeletons of the development are most appropriate temperature control throughout absorption/regeneration process to get maximum absorption of carbon dioxide and reduction of heat losses of the process. This subject stimulates development of more effective utilization of lots of low temperature energy hardly utilized in steel works, which temperatures are so below as 200 deg-C and are high enough to be utilized as heat input to chemical absorption process.

(2) Quantification of effects of CO2 capture process onto steelmaking processes coming after the CO2 capture process -

3.2.1.4 Results of chemical absorption

(1) Reduction of heat consumption was realized down to 2.5 GJ/CO2-ton at CAT30 during continuous running over 2000 hours in the former half year of 2011. This means that the heat consumption will be realized less than 2.4 GJ/ton-CO2 in such a commercialized plant as of one hundred times of CAT30 (3,000 ton CO2/day; 1Mil.ton/year) in Fig 12.

① Recovery rate of CO2 was set at around 90%.

② Most appropriate temperature control was taken in chemical absorption process.③ Absorbent’s feature of low regeneration energy of CO2 appeared in ever-lower temperature of a regenerator. A regenerator in such low temperature of a regenerator top as far below 100 deg-C produced off-CO2 with lean steam which resulted in smaller heat loss from a reflux heat exchanger.

(2) High durability of developed absorbent was verified through long running hours over 2,000 hours.

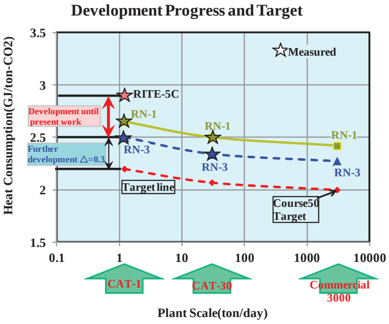


Fig 12 Chemical absorption:Development Progress

Fig13 Physical Adsorption equipment ASCOA3

3.2.2 Physical Adsorption

Physical adsorption method is a technology that can capture carbon dioxide with low energy consumption, requiring a simple system configuration. With the physical adsorption method, adsorbents, first of all, selectively adsorb CO2 with the help of the van der Waals force working between the molecules of fluid and the surface of the adsorbents, and then release the adsorbed CO2 under a reduced pressure, consequently allowing CO2 capture with high purity at high recovery rates. This is a first attempt in Japan to apply this technology to a processing on a very large scale, i.e., capture of CO2 from BFG. In this project, an evaluation plant with a capacity of 3t-CO2/day has been built within a steel plant, and various experiments are being run(Fig 13).

3.2.4 Utilization of waste heat

Furthermore technologies for recovering unused waste heat within a steel plant are being developed to compensate for the required heat for CO2 capture from BFG to achieve no additional external heat supply. Energy in the form of steam and electricity is required for CO2 capture from BFG. If the energy is procured from external sources, CO2 will be emitted at the production sites of the energy. Therefore in this project, technologies will be developed to make use of conventionally unused waste heat that has not been utilized due to technological and/or economic difficulties.

The technologies to be developed to accomplish the aim are as follows:

・Development of sensible heat recovery from steelmaking slag
・Development of Kalina cycle power generation technology ・Utilization of heat pumps etc

4. Conclusions

This five-year project will shortly be completed with the R&D programs progressing almost as planned. Among other things, more-than-expected improvements in the reduction rate of iron ore were observed when hydrogen was injected into experimental apparatus. In addition, pilot plants or CO2 capture from BFG have been successfully operated with promising results.

Acknowledgement

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