Advanced Oxy-Fuel Combustion Technology

Toshihiko Mine\textsuperscript{a,∗}, Kenji Kiyama\textsuperscript{a}, Yuji Fukuda\textsuperscript{a}, Noriyuki Imada\textsuperscript{a}, Pauli Dernjatin\textsuperscript{b}

\textsuperscript{a} Babcock- Hitachi K.K., Kure Research Laboratory, Takara-machi 6-9, Kure, Hiroshima, 737-8508, Japan
\textsuperscript{b} Fortum Power and Heat, Power Division, POB 100, FI-00048 FORTUM, Finland

Keywords: Gas cooler; SO\textsubscript{3}; Hg; Corrosion; Burner

1. Introduction

Babcock-Hitachi K.K. (BHK) has been developed an oxy-fuel combustion technology, and proposed an advanced oxy-fuel combustion system for a feasibility study of 500MW class boiler retrofit with Fortum OYJ.

BHK’s original oxy-fuel combustion system has the following features;

(1) Corrosive gases of mercury and SO\textsubscript{3} removal by decreasing flue gas temperature at ESP inlets with a unique gas cooler system. The risk of corrosion at CPU and gas recirculation line can be minimized in BHK’s system. In the case of oxy-fuel combustion system, corrosion potential at pressure parts in the furnace and other area would be similar to that in the case of air combustion.

(2) A large increases power of LP turbine output (18MW for a 500MW class unit) as the gas cooler preheats boiler feed water and reduces steam extraction from LP turbine. Improvement of plant net efficiency (2.0 percents)

(3) Stable combustion under low O\textsubscript{2} concentration of primary gas with a new burner.

2. An advanced oxy-fuel combustion system (Gas cooler system)

BHK has developed a unique flue gas treatment system with a gas cooler before the ESP, which has been applied to actual boilers of air-combustion. The system with the gas cooler will be applied also to the boilers of oxy-fuel combustion.

The oxy-fuel combustion system has some corrosion potentials. One is mercury in flue gas which may cause corrosion in CO\textsubscript{2} purification and compression units. The other one is SO\textsubscript{3} which may cause acid corrosion at gas ducts and equipment in the gas recirculation lines. By reducing flue gas temperatures below 90 °C, the Hg removal across the ESP could be improved by which corrosion is negligible. At the flue gas temperature below acid dew point, SO\textsubscript{3} gas contained in flue gas changes to mists (liquid) and sticks to coal ash particles, which are caught by

∗ Corresponding author. Tel.: +81-823-21-1160; fax: +81-823-22-9504.
E-mail address: toshihiko.mine.ex@hitachi.com.
the ESP. SO3 mists are neutralized by alkali contained in ash, so that corrosion of ESP material is prevented. The gas cooler system reduces SO3 concentration below 1 ppm at the ESP Inlet. The value of 1 ppm is low enough to avoid acid corrosion of carbon steel material of ducts and equipment in the flue gas and recirculation gas lines. BHK carried out corrosion tests in total system test facility consisting of combustion system and environmental equipment such as gas cooler, ESP, SCR and FGD. As the result, in case of the system without gas cooler, SO3 concentration was over 1 ppm at the recirculation gas line, and acid corrosion appeared in the re-circulation gas duct. However in case of the system with gas cooler, SO3 concentration was below 1 ppm at the recirculation gas line, and acid corrosion did not appear at the recirculation gas duct.

From the fundamental study by laboratory tests, potential of corrosion in oxy-fuel combustion at pressure parts in the furnace and other area would be similar to that in air combustion.

In the case of oxy-fuel combustion, the potentials of erosion and fouling at heating sections may be increased because of ash contents increasing in the re-circulations gas line. In BHK's system, the recycling point is downstream of ESP. Therefore, erosion and fouling potential must be same to air combustion because ash concentration of oxy-fuel combustion is same to that of air combustion. Other risk for fouling is change of ash characteristic in oxy-fuel combustion. But, it is confirmed through the combustion test in the total system test facility that ash deposition rate at heating sections in oxy-fuel combustion is same as that in air combustion.

A large increase power of LP turbine output was obtained (18MW for a 500MW class unit) because the gas cooler preheats boiler feed water and reduces steam extraction from the LP turbine.

Total value is 2.0% improved of plant efficiency by BHK oxy-fuel combustion system.

3. Development of new burner for oxy-fuel combustion

The difference of flue gas composition between air combustion and oxy-fuel combustion will be making a difference of flame stability of burner. BHK has several types of burner for coal combustion, and NR-LE Burner was originally developed for lignite coal combustion. To achieve stable combustion under oxy-fuel conditions, NR-LE Burner was designed with the following concept.

(1) O2 concentration of primary gas is maintained at 21vol% - wet or less.

(2) To promote the ignition of the pulverized coal, secondary gas of higher O2 concentration is supplied to the area in the primary gas nozzle where pulverized coal is concentrated.

BHK has conducted the combustion tests at 4.0MWe test facility to check the flame stability of NR-LE burner. For NR-LE burner, the primary O2 concentration can be reduced to 10%-wet without any combustion problems such as flame instability or high levels of unburned carbon.

4. Summery

BHK has developed a new system for oxy-fuel combustion which is highly reliable, safety and efficient. Features of this system include:

(1) Corrosive gases of mercury and SO3 removal by decreasing flue gas temperature at ESP inlet with a gas cooler system. The risk of corrosion at CPU and re-circulation line is minimized in Hitachi’s system. In the case of oxy-fuel combustion system, corrosion potential at pressure parts in the furnace and other area would be similar to that in the case of air combustion.

(2) Same erosion and fouling potential as air combustion because of the same ash concentration in oxy-fuel combustion as that in air combustion by optimization of gas recirculation point.

(3) A large increases power of LP turbine output (18MW for a 500MW class unit) as the gas cooler preheats boiler feed water and reduces steam extraction from LP turbine.

(4) Improvement of plant net efficiency (2.0 percents).

(5) Stable combustion under low O2 concentration of primary gas with a new burner.
Fig. 1 Mechanism of SO3 removal with cooler system

Fig. 2 Configuration of NR-LE Burner