Circulating Fluidized Bed Boiler Oxygen-enriched Combustion Technology Application Research

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Abstract. Energy is the foundation of human survival and development, the conventional energy in our country, the coal reserves accounted for more than 90%, this determines the coal in the dominant position in China energy structure, coal combustion produces a lot of dust and pollutants such as SO₂, NOₓ and CO₂, oxygen-enriched combustion as a new technology is more and more attention.

1. Introduction
Popular circulating fluidized bed boiler technology is a rapid development in the recent 20 years of an efficient low pollution clean combustion technology. International on the technique in power station boiler, industry boiler and waste treatment and utilization, and other fields has been widely commercial application, and to the scale of hundreds of thousands of kilowatt large circulating fluidized bed boiler development, domestic research, development and application in this respect also gradually rise, more than 1000 Taiwan circulating fluidized bed boiler in operation or is in manufacturing. The next few years will be circulating fluidized bed is an important period of rapid development. How to further improve thermal efficiency of circulating fluidized bed boiler, achieve the energy conservation and emissions reduction of the enterprise, is an important task in front of us. High oxygen-enriched combustion technology as a kind of new energy-saving combustion technology, the popular in circulating fluidized bed boiler burning innovative applications, good for further energy conservation and emissions reduction of CFB boiler, has a huge market potential.

2. An Overview of the Oxygen-enriched Combustion Circulating Fluidized Bed Boiler
Oxygen-enriched combustion is sometimes referred to as O₂ / CO₂ combustion, it is the use of air separation of pure oxygen and part of the boiler exhaust gas mixture instead of fossil fuel combustion air do antioxidants, this way of combustion can make the concentration of CO₂ in flue gas is as high as 90% above, can not separate direct liquefaction and most of the flue gas recycling, is advantageous to the CO₂ recycling, can effectively reduce greenhouse gas emissions, oxygen-enriched combustion also can effectively reduce the emissions of pollutants such as SO₂ and NOₓ, is a high efficiency and energy saving way of combustion. According to the characteristics of the circulating fluidized bed boiler material cycle for many times, oxygen-enriched combustion technology and the integration of circulating fluidized bed into a more competitive combustion technology will be the new trend of clean coal power generation technology in the future [1].

Oxygen-enriched combustion technology is put forward in the 1980 s, mainly used in metallurgy, glass, preparation and other industrial boilers, with oxygen preparation technology and the increasing
maturity of oxygen-enriched combustion technology has been rapid development. Argonne national laboratory (ANL) studies have shown that just appropriate modification of conventional boiler this technique can be used. ALSTOM company in 2004 in the United States Connecticut research center successfully conducted CFBC oxygen-enriched combustion of pilot scale test. Foster Wheeler company design of thermal power of 30 MW CFB boiler oxygen-enriched combustion successfully put into operation in 2012.

At present, some famous foreign scientific research units and companies (such as ALSTOM, Foster Wheeler, etc.) are strongly oxygen-enriched combustion technology research and development of large supercritical unit, 2015 years into the demonstration project commissioning phase, has entered the stage of commercial operation after 2022.

Circulating fluidized bed boiler oxygen-enriched combustion has the following characteristics:

1. Cost saving, recycling in favour of pollutants. In a typical unit, emissions control equipment generally includes used to except the particles of the electrostatic precipitator and wet desulphurization agent, catalytic reduction system, effective control of NOX emissions), mercury removal equipment. The biggest advantages is the oxygen-enriched combustion emissions cuts, emissions control equipment and the cost is mainly dependent on the exhaust flow, so the oxygen-enriched combustion technology can greatly save cost. And oxygen-enriched combustion technology itself has the ability to capture CO2, he make the CO2 concentration in flue gas of 90% or more, can be compressed recycled.

2. Reduce the coefficient of excess air and save energy. After adopting oxygen-enriched combustion can reduce secondary combustion air volume, reduce flue gas emissions substantially, thereby reducing the exhaust heat loss, improve the boiler thermal efficiency.

3. Improve productivity and reduce cost. Fuel in the condition of oxygen enrichment can lower ignition temperature, the oxygen into the area, due to high oxygen concentration and surface temperature of combustion rate will be increased greatly, thus improve the flame intensity, obtained the good heat conduction, and radiation ability is higher than ordinary combustion products of combustion, greatly enhancing heat transfer in furnace, so as to improve the productivity and reduces the manufacturing and running cost.

4. By flue gas recycling, increases the chances of limestone and SO2 exposure and improve the desulphurization efficiency and calcium utilization.

5. NO thermal NOX formation, and can realize low NOX emission.

6. Back through the solid particles combustion, can improve the solid particle residence time in the furnace, weakened the oxygen-enriched combustion of fuel burning time prolonged.

7. Oxygen-enriched combustion technology, suitable for both new boiler, and is suitable for reconstruction of old boiler, easy to implement, and test shows that run in good condition, the combustion stability.

3. The Application of Oxygen-enriched Combustion Technology of Circulating Fluidized Bed Boiler

3.1. Structure Size

Due to the changes of oxygen-enriched combustion heat transfer characteristics, size is much smaller than air combustion boiler equipment. According to the study of 210 MW CFB boiler ALSTOM company contrast: oxygen-enriched combustion boiler island covers an area of only 51% of the air combustion, weight is only 65% of the air combustion boiler. Furnace actively reduce heating surface arrangement to bring very great difficulty, the larger the boiler unit problem the outstanding, how to effectively the layout of furnace heating surface, and development efficiency of external heat exchanger is circulating fluidized bed boiler to solve one of the key problems of oxygen-enriched combustion boiler [2].
3.2. The Thermal Efficiency and Temperature in the Furnace
Because by flue gas recycling, flue gas flow rate decreases, and so reduce exhaust smoke loss, boiler efficiency is improved conventional air combustion boiler, a preliminary estimate is about 3-5%, the specific data should be determined based on factors such as fuel, oxygen concentration. The oxygen-enriched combustion technology is applied to CFB boiler, need to take the advantage of CFB boiler and combine the advantages of the oxygen-enriched combustion, i.e., under the conditions of oxygen-rich combustion desulfurization effect, and still keep the chamber of a stove or furnace control is less nox generation, at the same time the oxygen-enriched combustion of high heat transfer efficiency, complete combustion, combined the advantages of low flue gas emissions. To achieve such effect, you need to control the furnace temperature when the original air combustion chamber of a stove or furnace for the range of $870^\circ C \sim 950^\circ C$.

60% according to the literature oxygen-enriched combustion chamber of a stove or furnace when the highest temperature is 95°C, up from using air combustion furnace temperature 30°C to 50°C or so, under normal circumstances the CFB boiler running best temperature is $870^\circ C \sim 920^\circ C$, can infer that 30% oxygen-enriched combustion and fuel used in the same amount of furnace temperature will be slightly lower than $950^\circ C$, the temperature is in CFB boiler operating temperature range. And burning temperature changed when oxygen concentration is greater than 30%, so the use of oxygen concentration is 27~45% of membrane oxygen enrichment technology can meet the needs of the CFB boiler energy conservation. For CFB furnace type, the temperature field is still in the furnace desulfurization and denitration reaction zone, circulating fluidized bed desulfurization denitration technology advantage is still there [3].

3.3. Heat Transfer Performance
Because the oxygen-enriched combustion system of burning is a high concentration of oxygen, under the same unit of flue gas flow rate than the smaller air combustion flue gas flow, to achieve enough fluidization velocity, furnace structure is compact, so the furnace internal heat transfer becomes small. ALSTOM oxygen-enriched combustion in 210 mw CFB boiler and compared with the power of CFB boiler air research found that oxygen-enriched combustion boiler furnace and the tail of convection heating surface heat absorption capacity is only about 40% of the air combustion. This can make in the big unit to increase the external heat exchanger to absorb the quantity of heat of flue gas, and the unit, the greater the proportion of external heat exchanger heat is larger.

In boiler design, must consider the change of the coefficient of heat transfer in the thermodynamic calculation, while the proportion of the three atoms inside the furnace gas, increase the radiation heat transfer, but the inside of the circulating fluidized bed boiler furnace heat transfer mainly by circulating ash, flue gas composition change on the influence of furnace heat transfer coefficient is not very obvious; In the tail flue, flue gas ash content of the greatly reduced, the flue gas CO$_2$ gas concentration increased the gas radiation heat transfer, so the convection heat transfer coefficient of flue than conventional combustion heat transfer coefficient increased by 10%.

3.4. The Emissions of Pollutants
Oxygen-enriched combustion with CO$_2$ was captured 90%, CO$_2$ emissions decreased significantly, according to the study of 210 MW CFB boiler ALSTOM company contrast: reduce 0.83 kg CO$_2$ per kilowatt-hour oxygen-enriched combustion emissions. Oxygen-enriched combustion, flue gas in circulation and smoke volume decreased significantly, while the NO$_X$ emission concentration increased, but the absolute emissions is to reduce, oxygen-enriched combustion NO$_X$ emissions than the air in the combustion to reduce generated by a third to a half. On SO$_2$ emissions, the industry point of view is not completely unified. Some researchers think that oxygen-enriched combustion in SO$_2$ emissions less than when air combustion; Some researchers think that the SO$_2$ emissions and air combustion, no obvious decrease. Specific situation needs further validation. The oxygen-enriched combustion, may be affected by high concentration of CO$_2$ in flue gas, CO emissions more than the air combustion [4].
4. Restricting Factors

4.1. Economy
Although the oxygen-enriched combustion technology to improve the boiler thermal efficiency, but the oxygen preparation and CO₂ recycling consumes a lot of power, auxiliary power obvious rise, cause the loss of the power plant instead of total power generation efficiency for 7 ~ 9%, and makes the oxygen-enriched combustion power investment cost compared with air combustion increased by about 30% (not considering the value of CO₂ and N₂ as a by-product). CO₂ emissions regulations in the country and the carbon market formation, oxygen-enriched combustion technology of economy does not have competitive advantage obviously, how to reduce oxygen preparation cost and energy consumption and CO₂ recycling technology is main technical challenge for the oxygen-enriched combustion technology.

4.2. Psa Technology
Psa technology at present mainly include low temperature distillation and pressure swing adsorption and membrane separation of three, though oxygen generation method many, but every method has defects: low temperature distillation method while production is big, but its power consumption, maintenance, technical difficulty and high cost;Variable pressure adsorption rely too much on clean atmospheric environment, short service life.Membrane separation method restricted by size, low reliability and low oxygen concentration.Psa technology needs further development, in order to improve its market competitiveness.

4.3. The CO₂ Recovery Technology
Boiler in addition to the main CO₂ in flue gas, but also contains some impurity content (Ar, O₂, N₂, SO₂, NOₓ, H₂, O), the impurity content will affect the CO₂ mixture of enthalpy, entropy and heat capacity, enthalpy and entropy changes will affect the energy consumption and condensation of liquefied compressed system.In addition, impurity concentration changes will not affect the effective volume of CO₂ and thus affecting CO₂ transport and storage efficiency and economy.Understand the oxygen-enriched combustion boiler smoke flow of pure substance concentration distribution characteristics of CO₂ and the CO₂ recovery technology is very important.

4.4. The SOₓ Enrichment Acid Corrosion Problems
Oxygen-enriched combustion boiler flue gas recirculation makes the SO₂ concentration is much higher than the traditional air combustion.On the one hand, high SO₂ concentration directly affect the compression efficiency and safe transport of CO₂, every 1% increase in CO₂ in flue gas SO₂ mole fraction of compression work to improve the 0.18 kW, cause obvious economic and security hidden danger;On the other hand, high SO₂ concentration and high dust load, increase the effects of slagging and high-temperature corrosion on boiler.Flue gas must be removed before entering the compression with a high concentration of water, resulting in the flue gas cooling below acid dew point, SO₃ low temperature corrosion problems also cannot be ignored.

5. Conclusion
Because of rich oxygen combustion, increase the combustion temperature, burning more completely, reduced by local hypoxia caused by incomplete combustion, and at the same time can make the oxygen-enriched combustion flame shorten, improve local strength, speed up the combustion, achieve good heat conduction, circulating fluidized bed boiler using oxygen-enriched combustion technology can improve the operation of the boiler efficiency, make solid fuel burn more fully, increase the heat transfer efficiency, while reducing the CFB boiler cyclone separator of load and wear;Smoke volume decreases, and reduce exhaust smoke loss;Higher concentration of harmful gases, facilitate NOₓ and capture our fleet, so as to achieve the purpose of energy saving and emission reduction.
Application of oxygen-enriched combustion in CFB boiler is a innovation of science and technology, but its in easy to produce large amounts of nitrogen oxides in combustion process, although there have been some methods to control it, but it is not very ideal, also need scientific research workers on the basis of in-depth study.

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