Steam Temperature Of 600MW Subcritical Boiler Unit Research And Practice Of Upgrading To Ultra Supercritical Parameters

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Abstract: In order to save energy and improve the working efficiency of the unit, this paper analyzes the data improvement after the steam temperature of the subcritical boiler unit rises to the ultra supercritical parameters through the transformation of the unit and makes a summary of the change of the boiler efficiency. In order to effectively improve the economic benefits, environmental protection and energy saving effect.

1. Introduction

With the continuous development of technology, how to improve the economic efficiency of the unit, save energy and reduce pollution emissions, has become the main concern of the industry. The disadvantages of Subcritical Units are low power generation efficiency and high coal consumption, and China's Subcritical Units account for a large part of the whole thermal equipment system. On this premise, this paper studies the ultra supercritical parameters of subcritical equipment in order to improve the efficiency of the unit.

2. Equipment and related concepts

2.1 Main design parameters of boiler

The 2 × 600MW Subcritical coal-fired units of Daihai Power Generation Company phase I project were put into commercial operation in October 2005 and January 2006 respectively, and the capacity of the two units was increased to 630MW after 2013. It is a subcritical full steel frame drum boiler designed and manufactured by Beijing Babcock Wilcox Company. the designed coal type of the boiler is Zhungeer Coal, and the check coal type is Dongsheng coal in nanminiao, Inner Mongolia. The main design parameters of the boiler are shown in Table 1.

| Working condition of the name | Superheated steam flow/(t•h⁻¹) | Superheater outlet steam pressure/MPa | Superheater outlet steam temperature/°C | Reheat steam flow/(t•h⁻¹) | Steam pressure at reheater inlet/MPa | Steam pressure at reheater outlet/M | Steam temperature at reheater outlet/°C |
|-----------------------------|---------------------------------|------------------------------------|--------------------------------------|--------------------------|-----------------------------------|-------------------------------------|-------------------------------------|

Table 1: Main design parameters of boiler
2.2 Start up system of boiler
The system consists of built-in separator, liquid storage tank, water level control valve (361 valve), etc. The working fluid heated by the water wall enters the starting separator, and the separated water enters the liquid storage tank through the connecting pipe under the starting separator. In the initial stage of boiler cleaning and ignition, the steam enters the roof main tank through the connecting pipe above the separator, and the water in the liquid storage tank is discharged to the fixed discharge expansion tank or recycled to the condenser through valve 361[1].

2.3 Combustion system of boiler
The boiler adopts the two-stage ignition mode of high-energy ignition gun to ignite the oil gun of heater and the oil gun of heater ignites pulverized coal. Oil burners and pulverized coal burners are matched, and each burner is equipped with a set of high-energy automatic ignition device. The oil gun nozzle adopts mechanical atomization mode. The ignition gun and oil gun are both telescopic. The total maximum output of the oil gun accounts for about 20% of the boiler BMCR load. The B-layer burner is equipped with plasma ignition device. 72 flame detectors were respectively installed at 36 pulverized coal burners and 36 ignition oil guns.

2.4 Boiler temperature regulation mode
The regulation of superheated steam temperature is mainly realized by adjusting the ratio of primary feed water and secondary superheated protection water. The superheat protection water comes from the supply water at the outlet of the economizer. There is a main thermostat between the low temperature superheater and the screen type superheater, and an auxiliary thermostat is used to control the temperature between the screen type superheater and the high temperature superheater[2].

3. Feasibility of using ultra supercritical parameters in Subcritical Boiler Units
Since the beginning of this century, three domestic power generation groups have successively introduced foreign advanced supercritical and supercritical unit technologies, and rapidly completed the technical digestion and localization work. So far, they have progressed from 17.5 MPa / 540 °C / 540 °C to supercritical, and gradually become ultra supercritical. In recent years, with the deepening of understanding and verification of the properties of high-temperature heat-resistant materials, and parameter design has been carried out, so many technical progress has been made. At present, whether the parameters of domestic small and medium-sized equipment can be improved depends on two factors. One is technical and economic considerations, the other is equipment manufacturing capacity. In the long run, it is meaningful to improve the parameters at an appropriate stage. There are no technical problems in the design and manufacture of supercritical equipment, only the development and completion cycle of the complete set of equipment by the machine manufacturer[3].

4. Comprehensive parameter upgrading of Daihai boiler

4.1 Necessity of transformation
The necessity of comprehensive parameter upgrading transformation of Daihai boiler can be divided into the following points: (1) national energy conservation and emission reduction related policies; (2) local policies and development requirements; (3) protection of Daihai Lake. The proportion of water intake of the first phase unit on Daihai Lake water volume is 11.5%; and (4) the need to enhance the competitiveness of enterprises. The coal consumption is relatively high. According to the bottom test, the coal consumption of 1 × 10 unit under rated condition is 317.1g/kwh, which is higher than the average value of domestic similar units. The main reasons are low flow efficiency of steam turbine and
high auxiliary power rate; ② it is difficult to put denitrification into operation at low load, which affects the deep peak load regulation ability of the unit.

4.2 Boiler parameter improvement

4.2.1 Ideas of boiler parameter improvement
- The original design of the boiler is simulated by using American B & W program, and the correct boiler model is preliminarily established, which provides accurate boiler boundary conditions for the following actual operation data simulation calculation, boiler model modification and performance calculation after parameters are proposed[5].
- On the basis of the above boiler design model, through the analysis of the actual operation data of the boiler, the simulation calculation is carried out, and the original design model of the boiler is modified, so that the established boiler model is consistent with the actual operation situation.
- The detailed calculation of the boiler is carried out by substituting the design data of the parameter improvement scheme, so as to find out and analyze in detail the problems existing in the boiler after the parameter improvement and the parts to be transformed, and then form the parameter improvement scheme through detailed calculation.

4.2.2 Boiler parameter improvement principle
- Boiler shape, general layout and steel structure system remain basically unchanged;
- The water circulation system does not change, that is to maintain natural circulation, control circulation or direct current mode;
  - The general layout of the heating surface in the furnace does not change greatly, but the area and material of some heating surface are adjusted;
  - The layout of connecting pipes outside the furnace shall be the same as possible, and the material specifications shall be adjusted accordingly;
  - The existing design of combustion system, flue gas and air system and preheater system shall be maintained;
  - Simultaneous consideration of boiler wide load denitrification transformation.

4.2.3 Key points of boiler parameter improvement
- Coal quality judgment after boiler transformation;
  - The design pressure of the boiler, especially the design pressure of the steam drum, is calculated after the transformation;
  - Calculation of drum separation capacity after revamping;
  - Calculation of discharge capacity and material strength of boiler safety valve;
  - Calculation of boiler metal wall temperature, strength calculation of header, pipe and heating surface;
  - Deviation control of wall temperature peak value and steam temperature of high temperature heating surface of boiler;
  - The optimization design of boiler high temperature heating surface structure and the selection of high-grade materials can avoid the problem of oxide scale after parameter raising;
  - Boiler water cycle accounting;
  - Calculation of boiler steam water resistance and smoke air resistance;
  - Calculation of boiler thermal parameters and coordination calculation of boiler auxiliary equipment[4].

4.3 Reconstruction scheme
4.3.1 unit transformation direction
- The wet cooling unit is changed to air cooling unit;
- The temperature parameters of the unit are greatly increased;
- The main and reheat steam temperature of the boiler is increased from 541 °C / 541 °C to 601 °C / 599 °C. After the transformation, the boiler parameters are 17.5mpa/601 °C / 599 °C. The main steam flow of the boiler under VWO condition is reduced from 2028 T / h to 2005 T / h;
- The corresponding turbine side parameters increased from 16.7 MPA / 538 °C / 538 °C to 16.7 MPA / 596 °C / 596 °C;
- Steam turbine flow path modification;
- Boiler wide load denitration transformation;
- Tail gas comprehensive waste heat utilization, external steam cooler;
- Control the heat loss of the boiler and reduce the external insulation temperature of the boiler to 45 °C.

4.3.2 Boiler transformation scheme. The specific scheme of boiler transformation is shown in Table 2.

| Table 2: Boiler transformation scheme |
|-------------------------------------|
| project                             | unit             | Original design 600MW | After transformation630MW |
|                                     | BMCR | TMCR | BMCR | BRL |
| Boiler model                        | B&WB-2028/17.5-M | B&WB-2005/17.5-M |
| Combustion mode                     | Opposed combustion |
| Superheated steam temperature       | °C   | 541  | 541  | 601  | 601  |
| Re feed water temperature           | °C   | 280  | 277  | 283.8 | 281.5 |
| Reheat steam flow                   | t/h  | 1678 | 1604 | 1701.8 | 1646.6 |
| Reheat steam inlet pressure         | MPA,g | 3.835 | 3.661 | 4.112 | 3.973 |
| Reheat steam outlet pressure        | MPA,g | 3.665 | 3.502 | 3.902 | 3.77 |
| Reheat steam inlet temperature      | °C   | 324  | 319  | 382.6 | 376.9 |
| Reheat steam outlet temperature     | °C   | 541  | 541  | 599  | 599  |

After transformation, the following conditions shall be met:
- Keep the type of subcritical drum boiler unchanged;
- The heating surfaces of superheater and reheater are re matched, the materials are upgraded and the structure is optimized;
- Superheater adopts four-stage layout, three-stage desuperheating and two-stage crossover; reheater adopts two-stage layout, two-stage desuperheating and one-time crossover; accurately control steam temperature deviation and wall temperature peak value;
- The "single inlet and single outlet" of reheater inlet and outlet pipeline is changed to "double inlet and double outlet";
- At the same time, the working medium flow of economizer is optimized to ensure the safety of water circulation;
- The full load denitration technology of staged economizer and high temperature flue gas bypass
is adopted to realize wide load denitrification of the unit;
  - The tail two-stage flue gas waste heat utilization is adopted to further reduce coal consumption;
  - Boiler deep insulation optimization, reduce heat loss.

5. Test and engineering implementation

5.1 Collection and analysis of raw coal samples
- The raw coal samples are sent to the relevant inspection units for chemical analysis. The analysis items include total moisture, element analysis, industrial analysis and low calorific value.
- Flue gas temperature at inlet and outlet of air preheater. K-type thermocouple, T-type thermocouple and digital thermometer were used to measure the flue gas temperature at the inlet and outlet of air preheater respectively.
- Temperature of primary and secondary air at inlet and outlet of air preheater. During the test, the temperature of primary and secondary air at the inlet and outlet of air preheater shall be recorded regularly.
- The environmental temperature and relative humidity are measured by electronic hygrometer.
- Local atmospheric pressure is measured by absolute pressure gauge.
- During the operation parameter test of the dial, the operation parameters on the DCS screen are recorded regularly[6].

5.2 Transformation process
The retrofit project of capacity increase and parameter increase of two boilers is EPC contract of Beijing Bawei company. The construction assessment period of 2# boiler reconstruction project is 170 days, the actual construction period is 168 days. The formal start-up date is August 1, 2018, the water pressure is finished on December 30, the boiler acid washing is completed on January 21, 2019, the pipe blowing is finished on February 11, and the first impulse run is successful after comprehensive transformation on March 26. At 20:00 on April 18, the 168 hour trial operation of unit 2 is completed, and the overall maintenance progress is well controlled. Before repair, the detailed maintenance schedule network chart is formulated, and the maintenance period is controlled strictly according to the node schedule.

2# unit will be put into operation in March 2019, pass 168h on April 18, and unit 1# will pass 168h on June 26, 2019; the two units will successively complete the load performance test in August and October 2019. It is the first subcritical unit to raise the temperature to 600 ℃ in China; the wet cooling unit is successfully transformed into an air cooling unit; the unit economy is greatly improved.

5.3 Transformation effect
- The measured thermal efficiency of No.1 boiler under rated condition is 94.35%, which is 93.53% higher than the guaranteed value; under 75% working condition of 1 # boiler, the measured thermal efficiency of boiler is 94.76%, which is 93.3% higher than the guaranteed value.
  - The measured thermal efficiency of boiler 2# is 94.54%, which is 93.53% higher than the guaranteed value; the measured thermal efficiency of boiler 1# is 94.71% under 75% working condition, which is 93.3% higher than the guaranteed value.
  - The superheated steam temperature reaches the rated value 601 ℃, the reheated steam temperature reaches the rated value 599 ℃; the superheated steam temperature can reach the rated value within the load range of 30% - 100%, and the reheated steam temperature can reach the rated value within the load range of 50% - 100%.
  - The maximum output of the boiler reaches 2005t / h, and the pressure drop of steam water system is lower than the design value.
  - The water quantity of boiler desuperheating meets the design value, which is greatly reduced compared with that before transformation.
  - The coal consumption of 1#unit at rated load is 306.95 g / kWh (air cooling, excluding waste heat
utilization), which is 10.15 g / kWh lower than 317.1 g / kWh (wet cooling) before transformation, which meets the requirements of national policies.

- During the rated output test, the metal wall temperature of each section of heating surface is within the normal range, and there is no over temperature phenomenon.
- The flue gas temperature at SCR inlet meets the design requirements under 20% load.

6. Conclusion
After analyzing the experimental data, we can know that after the steam temperature rises to the ultra supercritical parameters after the unit transformation, the boiler efficiency can be effectively improved. In terms of the current equipment cost and coal price, it can effectively improve economic benefits, environmental protection and energy saving.

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