STUDY ON THE THERMAL PARAMETERS' DETERMINATION METHOD OF ULTRA SUPERCRITICAL THERMAL POWER GENERATING UNITS

Jian-xing REN, Fang-qin LI, Qiguang SHI, Jiang WU, Qun-zhi ZHU, Wei-guo PAN, Qi-fen LI

Energy and Environment Engineering Institute, Shanghai University of Electric Power,
Shanghai 200090, China

ABSTRACT Supercritical and ultra supercritical thermal power generating units are the major development power generating units. The main steam parameters of thermal power generating units directly affect on the generating efficiency and pollutant emission. In this paper, the state-of-the-art of oversea supercritical and ultra supercritical thermal power generating units was analyzed. Under the condition of the domestic technology and manufacture capacity, and based on the generating efficiency and unit performance meeting of requirement, the thermal parameters' determination method of ultra supercritical thermal power generating units was studied. Main steam pressure is generally less than 27.56 MPa, and the temperature of main steam and reheated steam is about 600°C.

Keywords: Ultra Supercritical, Coal-fired Generating Unit, Thermal Parameter

1. INTRODUCTION

In China, coal as main primary energy is used highly, especially by electric power industry. Now, in China, the installed gross capacity of electric power has been up to 6 hundred million kW. But, the ratio of the coal-fired unit, whose unit capacity is less than 100 MW, is very high. Subcritical 300 MW coal-fired units are about 50%. Average power supply coal consumption is very high. The development of integral technology and economy is severely affected [1, 2].

Now, with the development of generating unit from 300 MW, 600 MW subcritical generating unit to supercritical generating unit, in order to create the generating efficiency and energy utilization, rapidly develop high parameters and large capacity domestic supercritical and ultra supercritical thermal power generating units will be developed, and the unit capacity, design, manufacture, low energy consumption and low pollutant emission will be increased. This will be propitious to boost equipment manufacturing up to develop, to increase their international competition ability, make them economize limited energy and to advance the generating efficiency of generating unit. Based on the Chinese practical situation of power industry, in order to advance the technology of generating unit, it is necessary to develop the supercritical and ultra supercritical thermal power generating units. This is favor of improving Chinese power supply structure, the stability and economy of electric network peakload, unit efficiency, low coal consumption, low pollutant emission and good ecological condition [3, 4]. Now, with the national energy adjusting and environmental protection law promulgating, the supercritical and ultra supercritical thermal power generating units will be vigorously developed. To substitute supercritical and ultra supercritical thermal power generating unit for conventional coal-fired unit is a no time to delay task to

finish.

2. PRESSURE CONFIRMATION OF MAIN STEAM

The parameters of coal-fired units mainly include main steam's temperature and pressure, and reheat steam's temperature and pressure. The development of supercritical and ultra supercritical thermal power generating unit is to increase electric efficiency and decrease electric energy consumption. Based on thermal circuit theory of thermal power generation, increasing of parameters is available method to increase the electric efficiency. Parameters are higher, electric efficiency is higher, and unit electric coal consumption is less. The relationship of thermal parameters and electric efficiency saw table 1^[5, 6]. From table 1, main steam's temperature and pressure are higher, electric efficiency is higher. From subcritical unit to ultra supercritical unit, electric efficiency is increased to 6%.

Table 1 The relationship of thermal parameters and electric efficiency

Unit	Temperature (°C)	Pressure (MPa)	Electric efficiency (%)
High pressure unit	540	9.8	~ 30.0
Super high pressure unit	540	13.7	34.0 - 35.0
Subcritical unit	540	17.3	37.0 - 38.0
Supercritical unit	569	25.4	41.0 - 42.0
Ultra supercritical unit	605	27.5	43.0 - 44.0

Under the initial steam pressure ≤ 25.0 MPa, conventional supercritical steam turbine can be universal. it is to say that the design and manufacture of cylinder and rotor can be homemade. Of cause, the design of through-flow part, especially final titanium alloy blade part accessories such as valve and material, depends on import.

Under the initial steam pressure higher than 25.0 MPa, the design and manufacture of ultra supercritical unit must be cooperative with other nation. There is difference of deferent foreign cooperation. Based on outstanding achievement of main Multinational Corporations, it indicates that: Japan TOSHIBA, HITACHI and MITSUBISHI Co., SIEMENS Co., ABB Co., and ALSTOM Co. have ability of design and manufacture of supercritical and ultra supercritical unit. So, to choose the unit's pressure, it must consider the operation achievement of Corporation Co., as well as the capacity of design and manufacture and technology accoutrement of internal manufactory, material supply and manufacture, and nationalization. Now, the pressure of mature unit is less than 27.56 MPa. In YUHuan power plant, there are $4 \times 1000\text{MW}$ ultra supercritical coal-fired units, which were introduced into China as "863 plan". Boilers were made by Harbin Boiler Company Limited, and MITSUBISHI Co. offered technical support. The BMCR is 2 953 t/h, main steam pressure is 27.56 MPa. Steam turbine was made by Shanghai turbine Company Limited and generator made by Shanghai turbine generator Company Limited, and SIEMENS Co., offered technical support. Steam turbine is ultra supercritical, primary reheat, uniaxial, four-cylinder and quadruple-flow, double backpressure, condensing, eight stage backheating extraction, normal rated power 1000MW, steam pressure 26.25 MPa, generator name-plate power 1000MW, water-hydrogen-hydrogen cooling-down method[7].

In Shandong Zouxian power plant, there are $2 \times 1000\text{MW}$ ultra supercritical coal-fired units. Boilers were cooperatively designed and manufactured by Dongfang Boiler Company Limited, Japan Babcock- HITACHI Co. and Dongfang-HITACHI I Co. BMCR is 3022t/h, main steam pressure is 26.25MPa [8].

3. CONFIRMATION OF MAIN STEAM TEMPERATURE AND REHEAT STEAM TEMPERATURE

Besides of the main steam pressure, increasing of main steam temperature and reheat steam temperature is other method to reduce energy consumption and advance the electric efficiency. Based on thermal circuit theory of thermal power generation, under the same condition of steam temperature, the thermal efficiency of 24.1MPa, steam pressure supercritical unit is 1.7% higher than that of 16.6 MPa subcritical units. If reheat steam temperature is increased from 538°C to 566°C, thermal efficiency will be increased 0.8% again, and total unit efficiency will be increased 2.5%. if steam pressure is same 24.1MPa, main steam/reheat steam temperature is increased from 538/566°C to 600/600°C, the unit electric efficiency will be increased about 3.1%. When main steam temperature is up 10 °C, the increasing of unit electric efficiency see table 2. From Table 2, when main steam temperature is up 10 °C, the unit electric efficiency of one or double reheat units can be increased 0.55%. So, we can saw that increasing of steam temperature is benefit to electric efficiency.

Table 2 Increasing of unit electric efficiency with main steam temperature up 10 °C

	Main steam	Primary reheat steam	Double reheat steam
Primary reheat unit	0.30%	0.25%	--
Double reheat unit	0.25%	0.15%	0.15%

Based on thermal circuit theory of thermal power generation, increasing of primary temperature can effectively increase electric circulating efficiency, that is to say, higher main steam temperature and higher unit electric efficiency. But the increasing of main steam temperature is limited by some factors, especially pipe material. To the steel of high temperature superheater and reheater, and main steam duct, it must consider the smelting technology and capacity of Chinese steel industries. The development of supercritical and ultra supercritical unit must be established in 18 Cr austenitic steel, such as TP347HFG (18 Cr10Ni1Nb) and TP347H, P91 steel. Based on the Chinese practical situation, 580°C main steam temperature is appropriate. While, if higher electric efficiency is considered, higher main steam temperature must be adopted, such as 600°C. Thus the outlet sector of high temperature superheater should use Super TP304H or HR3C non-corrosive steel, and live steam piping P92 steel. P92 steel is a kind of heavy alloyed steel. The chemical performance of P92 steel and P91 steel is similar, but the tungsten of P92 is higher and molybdenum is less. Chemical constitutions of P92 steel and P91 steel saw Table 3.

Table 3 Chemical constitution of P91 and P92 steel (%)

	C	Mn	P	S	Si
P91					
Min content	0.08	0.3	-	-	0.2
Max content	0.12	0.6	0.02	0.01	0.5
P92					
Min content	0.07	0.3	-	-	-
Max content	0.13	0.6	0.02	0.01	0.5

	Cr	W	Mo	V
P91				
Min content	8.0	-	0.85	0.18
Max content	9.5	-	1.05	0.25
P92				
Min content	8.5	1.5	0.3	0.15
Max content	9.5	2.0	0.6	0.25

On the other hand, the yield strength of P92 is lower than that of P91, but its tensile strength is higher than that of P91. Under the temperature 567°C to 667°C, creep strength of P92 is unvarying, and when temperature is higher 667°C, P92 is better than P91. To develop high parameter ultra supercritical unit, P92 is a good steel to choose. To boiler, when main steam temperature is

increased from 585°C to 605°C, boiler model can be same, while the steam temperature of rear-screen superheater and finishing superheater is higher, which makes operating temperature of some heating ducts, steam manifolds, pipes of rear-screen superheater higher. The performance of steel is severe. From cost of boiler, when main steam temperature is increased from 585°C to 605°C, the cost of boiler will be increased 1%. Of course, one-off cost increasing can make long higher economy. If only the manufacture technology of boiler can meet the need of boiler, the increasing of main steam temperature from 585°C to 605°C is feasible [9,10]. From steam turbine manufacture and operation, In Japan, Germany, America, and other country, the manufacture technology of 600°C steam turbine has been mature and many operating experience has been got. The unit with main steam temperature being 600°C rate can be introduced into China to meet the need of energy-saving and ejection-decreasing.

To generating unit reheat system, based on the theory analysis, the electric efficiency is related to reheat system. Increasing the reheat system will advance the electric efficiency, see Table 2. Generally speaking, there are two models of reheat system, primary reheat and double reheat. Double reheat system has many merits:

(1) Reduce exhaust steam moisture of low pressure cylinder and cavitation of exhaust stage blade;

(2) Reduce the temperature increasing of reheater. With double reheat system, temperature increasing of reheater is about 200°C, while with primary reheat system and temperature increasing of reheater is about 280°C;

(3) Reduce the enthalpy drop of high pressure cylinder. With double reheat system, the enthalpy drop of high pressure cylinder is 300 kJ/Kg, while with primary reheat system, and the enthalpy drop is 400 kJ/Kg.

Based on the analysis of reheat system, although there are many merits of double reheat system and higher electric efficiency, its constitution is very complicated. Now, considering the investment of power plant and thermal economy, primary reheat system is appropriate for ultra supercritical unit.

The reheat steam temperature affects on unit efficiency and exhaust steam moisture of low pressure cylinder. The increasing of reheat steam temperature can advance the unit efficiency, and reduce the low pressure cylinder and cavitation of exhaust stage blade. From the safety of high temperature reheater, to increase the reheat steam temperature, the problems of high heat strength of steel, high temperature corrosion of flue gas side and steam oxidation in duct must be paid attention to. When the reheat temperature is up to 600°C, the wall temperature of finishing reheater could be up to 650°C. The problems of high temperature corrosion of flue gas side and steam oxidation in duct are obvious. So, the reheat steam temperature generally controlled about 600°C. In China, to new 1000MW ultra supercritical unit, its reheat steam flow is controlled 2469.7t/h, inlet/outlet pressure 5.1 MPa/4.9MPa, inlet/outlet temperature 354.2°C/603°C.

4. CONCLUSIONS

In order to increase the economy, save the limited coal energy, reduce the pollutant emission, and protect environment, high parameter, large capacity, supercritical and ultra supercritical coal-fired power unit is now

importantly developed in China. Based on the characteristic of domestic coal-fired unit, to develop supercritical and ultra supercritical coal-fired power unit, the confirmation of thermal parameters is emphasized to be considered. The increasing of thermal parameters could enhance the electric efficiency. To choose the thermal parameters, the overseas technology development and practical engineering outstanding achievement, as well as the capacity of design and manufacture and technology accoutrement of domestic manufactory, material supply and manufacture, and nationalization must be considered. According to various factors, it is appropriate to choose the ultra supercritical unit whose main steam pressure of is less than 27.56MPa, and temperature of main steam and reheat steam is controlled about 600°C.

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