Variety-duty Characteristic Analysis and Optimal Operation of Cold-End System of 600MW Direct Air-cooled Thermal Power Unit

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Abstract
The operating backpressure of the direct air-cooled unit is a significant economic parameter, and the optimal backpressure is corresponding to the best efficiency of the unit, which is mainly affected by ambient temperature, steam turbine exhaust flow, and face velocity in the operation of the cold-end system. A calculation model of the condenser of a 600MW direct air-cooled unit using the ε-NTU method was established to analyze the off-design performance. Compared with the characteristic curve provided by the manufacturer, the maximum error of the calculation results is 1.68%, meeting the engineering accuracy requirements. In order to obtain the optimal backpressure and optimal face velocity under off-design conditions, a cold-end optimization calculation model based on genetic algorithm is established with the maximum net power output as the objective function. The influence of the exhaust steam flow, ambient temperature and face velocity on the pressure of condenser is analyzed. In addition, the changing rules of the net power output with face velocity and backpressure under different conditions are studied. The results indicated that the working pressure of the condenser increases with the increment in ambient temperature and exhaust steam flow, and decreases with the rise of face velocity. The net power output of unit increases first and then decreases with the increment in backpressure and face velocity. Moreover, the higher the ambient temperature, the larger optimal face velocity and optimal backpressure of the unit, as well as the more cooling air volume is required under the optimal air face velocity.
Keywords: Direct air-cooled unit, Off-design condition, Characteristic analysis, Optimal backpressure, Genetic algorithm
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1. Introduction

The direct air-cooled units, as a substitute for water-cooled power generation mode, have been attracting more attention (Klimes *et al.* 2019). It was found that the application of direct air-cooled units plays an important role in solving the problem of uneven distribution of resources due to abundant coal and shortage of water resources, and promoting economic and social development. Despite the obvious advantage of water saving, there are also disadvantages such as large power consumption of air-cooled fan, and the exhaust temperature of the steam turbine is usually 25-30 ℃ higher than the ambient temperature, resulting in serious heat loss of thermodynamic cold source (O'Donovan *et al*. 2019). In the actual operation of direct air-cooled units, the backpressure is greatly affected by unit load, ambient temperature and fan flowrate (Pieve *et al*. 2011; Zhou 2018), which often leads to the unit efficiency deviates from the optimal value by a large margin, thus affecting the economic benefits of the enterprises (Zhai *et al*. 2016; Guo *et al*. 2012); In addition, the backpressure of the direct air-cooled unit is also related to the safe operation of the unit (Feng *et al*. 2019; Anozie *et al*. 2011); Thence, to improve the economic performance and ensure the safety, the optimization of the cold-end system is the most common target for the direct air-cooled units. As the off-design condition characteristic model of the air-cooled condenser is the core of optimization, Zhang *et al.* (2018) considered the influence of clustering effect on air-cooled condenser, and established the calculation model of direct air-cooled condenser under off-design condition by using numerical simulation method and least square method. Deng *et al.* (2020) and He *et al.* (2013) respectively studied the off-design performance of the direct air-cooled system based on a numerical calculation model, which takes into account the influence of environmental factors, providing guidance for the unit to operate under optimal backpressure. Considering that the exhaust steam of a direct air-cooled unit flowing through a longer exhaust pipe and more elbows may cause pressure loss, Zhou *et al.* (2007) assessed the condenser characteristics under variable conditions and obtained the changing rules of performance characteristics of cold-end system. Liu *et al.* (2013) also established the off-design condition model of direct air-cooled system by using the ε - NTU method, and obtained the optimal backpressure corresponding to the best efficiency of the thermal power unit by adjusting the speed of the air-cooled fan.

In terms of the overall optimization of the back pressure of the direct air-cooled unit, when the air-cooled condenser is under certain operating conditions, the air-cooled fan is mainly adjusted to optimize the back pressure. Li *et al.* (2018) adopted the numerical simulation method to find the unit backpressure corresponding to the economical and feasible operation mode of fan, so as to achieve the purpose of energy saving. O'Donovan *et al.* (2014) found the unique performance that modular air-cooled condenser can continuously change the speed of fan by analyzing the relationships between steam turbine exhaust pressure, operating conditions of air-cooled condenser and speed of fan, and then suggested that applying advanced fixed-speed air-cooled condenser can improve the efficiency of power plant.

In recent years, intelligent optimization algorithms such as neural networks and genetic algorithms have been widely applied, which can reduce the computational complexity and computational time to a considerable extent in the optimal calculation of unit backpressure. Du *et al.* (2011) used the method of BP neural network to predict the backpressure of the direct air-cooled unit under different working conditions, considering the influence of surrounding environment. In order to solve the problem that the calculation accuracy of the direct calculation formula of steam turbine backpressure is not high or the calculation time is too long, Li *et al.* (2018) established a data-driven model by using the support vector regression method, which improved the reliability and accuracy of the calculation data.

However, the modeling methods mentioned above have shortcomings. For example, the numerical simulation method must obtain the detailed structural dimension parameters of the air-cooled condenser, and also the calculation time of this method is long; For the traditional ε - NTU method, there are some simplifications need to be made, resulting in the calculation accuracy often deviating from the actual value. The effect of cold-end system optimization depends on the calculation speed and accuracy of the direct air-cooled unit calculation model. Genetic algorithm, a typical intelligent algorithm with successful application, is an optimization algorithm with the functions of selection, crossover and mutation. Through simulating biological evolution and genetics, it has great advantages in solving constrained optimization problems such as the optimization of cold-end of direct air-cooled units (Chen *et al.* 2014).

This paper is organized as follows: Section 2 gives an overview of the cold end system of a 600MW direct air cooling unit. In Section 3, the calculation model of air-cooled condenser under off-design condition (Section 3.1) and the optimal calculation model for cold-end of direct air-cooled unit based on genetic algorithm (Section 3.2) is proposed. In Section 4, verified the accuracy of the model established in section 3.1 (Section 4.1). Then the variable conditions characteristics of air-cooled condenser (Section 4.2) are analyzed. The net power output of unit under variable conditions (Section 4.3) is calculated, and then the optimal operating backpressure and optimal face velocity (Section 4.4) are obtained. Finally, the conclusions are drawn in Section 5.

2. Overview of the cold-end system

The typical 600MW direct air-cooled units are taken as the research object. The design parameters of the air-cooled condenser are listed in Table 1. There are 56 air-cooled condenser cells in the air-cooled island, and each cell is equipped with an axial flow fan, with a total of 56 air-cooled fans configured. The design parameters of the fans are shown in Table 2.

Table 1. Design parameters of the air-cooled condenser

Exhaust pressure/ kPa	Exhaust quantity / t/h	Face velocity/ m/s	Ambient temperature/ °C	Frontal area/ m^2
30	1331	2.1	32	14131

Table 2. Fan design parameters

Fan diameter / m	Fan speed / rpm	Fan flowrate / m^3/s	Motor Power / KW	Fan pressure / Pa
9.144	69	469	110	93

3. Establishment of model

3.1 Calculation model of direct air-cooled condenser under off-design condition

Exhaust steam load, ambient temperature and face velocity of the air are the main factors that affect condenser pressure. When the unit is operating under variable conditions, the variation of the condensation temperature of the air-cooled condenser leads to the changes in the actual condensation heat of the exhaust steam. Therefore, the pressure of the condenser is not only impacted by its main parameters, but also by the enthalpy of exhaust steam. Heat release of steam condensation in condenser tube can be expressed as follows:

$$Q_n = D_n\left(h_n - h_s\right) \tag{1}$$

Where, D_n(kg/s) is the exhaust steam flow of turbine, h_n(kJ/kg) is the enthalpy of the exhaust steam, h_s (kJ/kg) is the enthalpy of the condensed water.

Heat absorption of the air outside the condenser tube can be calculated as follows:

$$Q_v = G_a C_p \left(t_{a2} - t_{a1}\right) = A_F v_{NF} \rho C_p \left(t_{a2} - t_{a1}\right) \tag{2}$$

Where, G_a(kg/s) is the air flow, A_F(m^2) is the windward area, ρ(kg/m^3) is the air density, v_{NF}(m/s) is the face velocity, C_p(kJ/(kg · K)) is the specific heat capacity of air, t_{a1}(℃) is the inlet air temperature, t_{a2} (℃) is the outlet air temperature.

According to the ε - NTU method, the heat exchanger efficiency ε with phase transition on one side is as follows:

$$\varepsilon = 1 - e^{-\mathrm{NTU}} = \frac{t_{a2} - t_{a1}}{t_n - t_{a1}} \tag{3}$$

$$\mathrm{NTU} = \frac{KA}{A_F v_{NF} \rho C_p} \tag{4}$$

Where, NTU is the number of heat transfer units, K(kW/(m^2 · K) is the heat transfer coefficient of the condenser, A(m^2) is the total heat transfer area of the condenser.

Therefore, the temperature of condensed water in the condenser can be obtained as:

$$t_\mathrm{n} = \frac{t_{a2} - t_{a1}}{1 - e^{-\mathrm{NTU}}} + t_{a1} = \frac{D_n \left(h_n - h_s\right)}{A_F v_{NF} \rho C_p \left(1 - e^{-\mathrm{NTU}}\right)} + t_{a1} \tag{5}$$

The pressure of air-cooled condenser can be calculated by an empirical formula as:

$$P_\mathrm{n} = 0.00981 \left(\frac{t_n + 100}{57.66}\right)^{7.46} \tag{6}$$

3.1.1 Calculation of heat transfer coefficient under variable conditions

Calculating heat transfer coefficient K is the key to obtain the exhaust pressure of the direct air-cooled unit under variable conditions. The heat transfer coefficient is affected by factors such as the steam velocity inside the condenser tube, the fouling thermal resistance inside and outside the tube, the thermal conductivity coefficient of the tube wall, and the air velocity outside the tube, which makes it difficult to the simulate the off-design condition of the condenser.

For the air-cooled condenser, the outside of the condenser tube is swept by air, on which side the magnitude of the heat transfer resistance is about 10^{-2}; Steam condensation happens inside the tube, with the heat transfer resistance very small, only about 10^{-4}. Moreover, the tube wall of the air-cooled condenser is thinner and its thermal conductivity is larger, so the heat transfer resistance inside the tube and the thermal resistance of the tube wall can be ignored (Zhang *et al.* 2012). Therefore, the heat transfer resistance on the outside of the tube is only taken into account. In engineering practice, it can be considered that the heat transfer coefficient is only a function of face velocity of the air. So the heat transfer coefficient under variable conditions can be expressed as:

$$\frac{K_{od}}{K} = \frac{\left(KA\right)_{od}}{KA} \approx \frac{\left(\alpha_0\right)_{od}}{\alpha_0} = \left[\frac{\left(v_{NF}\right)_{od}}{v_{NF}}\right]^{0.6} \tag{7}$$

Where, α_0 is the convection heat transfer coefficient of the air outside the tube, "od" means off-design condition.

If the heat transfer coefficient under design condition is known, it is only necessary to know the face velocity of the air under off-design conditions, and then the corresponding heat transfer coefficient can be calculated by Eqs. (7).

3.1.2. Calculation of exhaust steam pressure of unit

During the process of steam discharging, there is the loss of pressure ΔP (including the pressure loss of the exhaust pipe and the pressure difference caused by the water vapor column), then the exhaust steam pressure of the direct air-cooled unit can be obtained as follows:

$$P_c = P_\mathrm{n} + \Delta P \tag{8}$$

The pressure loss of exhaust steam under variable conditions can be calculated simply as follows:

$$\frac{\Delta \mathrm{P}_{od}}{\Delta P} = \left(\frac{D_{n\_od}}{D_n}\right)^2 \tag{9}$$

3.1.3. Calculation of enthalpy of exhaust steam and condensed water under variable conditions

The dryness fraction is needed to determine the state point of the steam, which can be calculated by an empirical formula (Xu *et al.* 2010).

$$\mathrm{x} = \frac{P_c + 13.8}{P_c + 16} A_x \tag{10}$$

Where, x is the dryness fraction of steam, P_c(kPa) is the exhaust pressure, A_x is the correction coefficient, which is 1.025 in this paper.

Based on the enthalpy-entropy diagram and linear interpolation method, the enthalpy of dry saturated steam $h_n^{'}$ and the enthalpy of the condensed water h_s can be obtained. Thus, the enthalpy of exhaust steam can be calculated as:

$$h_n = (1 - \mathrm{x}) h_s + \mathrm{x} h_n^{'} \tag{11}$$

3.1.4. Realization of calculation program for off-design characteristics

According to the heat balance between the heat release of steam condensation in the condenser tube and the endothermic of air outside the tube, the outlet temperature of air is required for the calculation, so it is necessary to assume the outlet temperature of air at first. The iterative calculation flow chart is shown in Fig. 1. In summary, on the premise that the exhaust steam flow, ambient temperature and face velocity of the air are known, and the exhaust steam pressure of the unit under any conditions can be calculated.

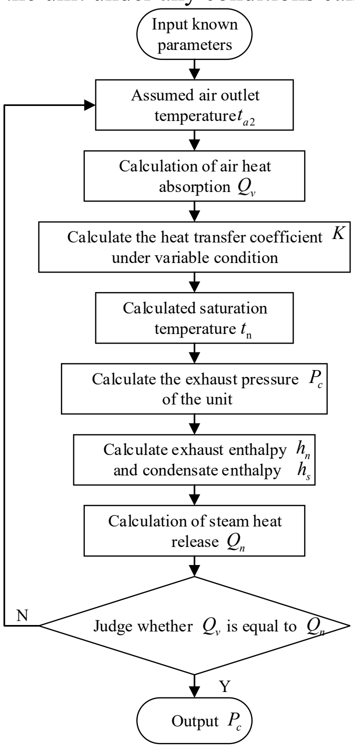


Figure 1. The exhaust pressure calculation process

3.2 Optimal calculation model for cold-end of direct air-cooled unit based on genetic algorithm

Genetic algorithm (GA) is applied in this paper to optimize the cold-end system of the direct air-cooled unit, in which the net power output is closed as the objective function. Through the optimization, the optimal face velocity under the different working conditions can be obtained, as is the corresponding optimal operating backpressure.

According to the correction curve of the backpressure to power of the direct air-cooled unit supplied by manufacturer, as shown in Fig. 2, the power change rate of steam turbine under different exhaust steam flow is obtained, as is the corresponding turbine output P_e.

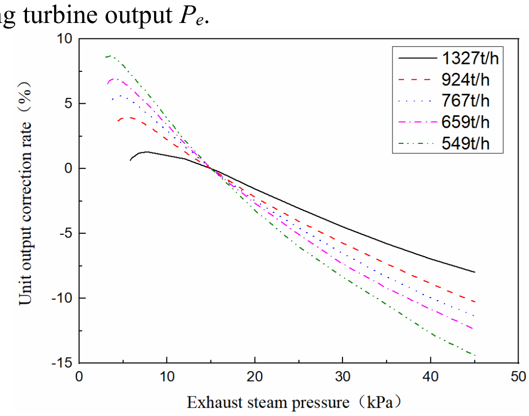


Figure 2. Correction curve of backpressure to power

According to the affinity laws (Richard *et al.* 2005), for the same type of fan, the relationship between fan power consumption and flow can be obtained as follows:

$$\mathrm{N}=\sum_{i=1}^{n}N_i=\sum_{i=1}^{n}N_0\left(\frac{\rho_i}{\rho_0}\right)\left(\frac{V_i}{V_0}\right)^3 \tag{12}$$

Where, N_i、N_0(kW) is the actual and rated power consumption of a single fan, ρ_i、ρ_0(kg/m^3) is the actual air density, air density at ambient temperature 20°C standard atmospheric pressure, V_i、V_0(m^3/s) is the actual and rated air volume of a single fan, respectively. n is the number of fans running.

In actual operation, the same speed is generally used to adjust the air-cooled fans. In order to simplify the calculation, it's assumed that all fans are running in the same state, so the power consumption of the fan group is simplified as:

$$\mathrm{N}=\mathrm{n}N_0\left(\frac{\rho_i}{\rho_0}\right)\left(\frac{V_i}{V_0}\right)^3 \tag{13}$$

According to the definition of optimal vacuum, the condenser pressure corresponding to the maximum difference between the increase in power generation and the increment in power consumption after the condenser vacuum changes is the optimal vacuum of condenser (Zhao *et al.* 2009). Therefore, when the difference ΔP between the output of the steam turbine and the power consumption of the fan group reaches its maximum, that is, the net power output of the unit is the largest, and the backpressure of unit at this time is called the optimal operating backpressure.

$$\mathrm{Max}\Delta\mathrm{P}\left(P_{\mathrm{c}}=P_{copt}\right)=P_e-\mathrm{N} \tag{14}$$

Where, P_{copt}(kPa) is the optimum backpressure.

A GA begins its search with populations usually created randomly within a specified lower and upper bound on each variable. In this work, under certain operating conditions, the initial population of face velocity of the air is formed by 100 points. The objective function to be optimized is the net power output of unit. The GA procedure enters an iterative operation of updating the current population to create a new population through the use of four main operators: selection, crossover, mutation and elite-preservation. Often there is an evaluation process of the population before using the selection operators, and this procedure usually requires a relative preference order which can be established by creating a real-valued fitness function derived from objective and constraint values. The GA parameters are set as follows: the binary code of single chromosome is 16 bits, the generation gap between the offspring and the parent is 0.9, the crossover rate is 0.7, the mutation rate is 0.01, and a predetermined number of generations are used as a termination criterion, which is set to 50.

4. Results and analysis

4.1 Verification of calculation model of direct air-cooled condenser under off-design condition

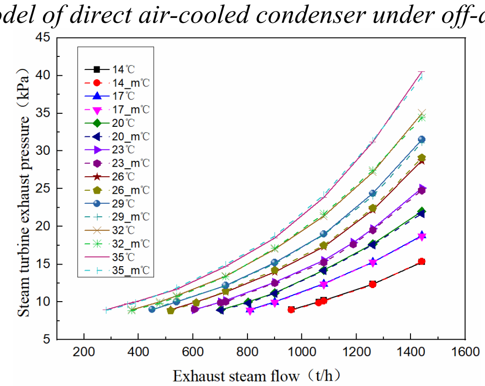


Figure 3. Comparison results

In order to verify the accuracy of the above mentioned calculation model for off-design condition of direct air-cooled condenser, the characteristic curves obtained by the model, which shows the changes in exhaust steam pressure of the unit with the exhaust steam flow under different ambient temperatures, is compared with the curves provided by the manufacturer, and the results are shown in Fig. 3.

The characteristic curves provided by the manufacturer are represented by the solid lines shown in Fig. 3, while the results calculated by the model expressed by the dotted lines. It can be seen from the figure that the corresponding curves are in good agreement, and the maximum error among them is 1.68%, which meets the engineering accuracy requirements. Therefore, the model established in this paper is reliable.

4.2. Analysis of off-design characteristics of direct air-cooled condenser

Using the mathematical calculation model established above, the influence of the exhaust steam flow, ambient temperature and face velocity of the air on the pressure of direct air-cooled condenser is analyzed. When the face velocity is 2.1m/s, the pressures of air-cooled condenser under different ambient temperatures and exhaust steam flows are shown in Figs. 4 and 6, respectively. As the exhaust steam flow is 1331t/h, the pressures of air-cooled condenser under different face velocity of the airs are shown in Fig. 5.

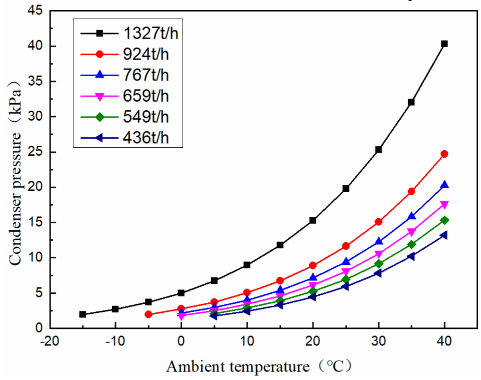


Figure 4. Curve at ambient temperature.

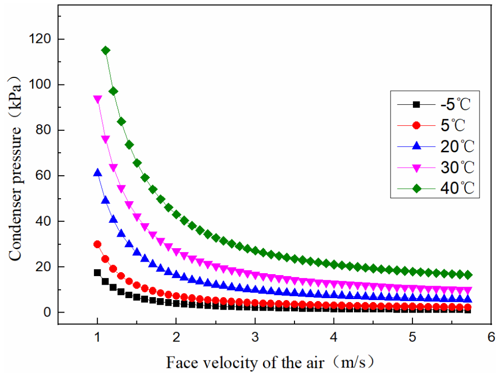


Figure 5. Curve at the face velocity.

As shown in Fig. 4, the pressure of the air-cooled condenser increases with exhaust steam flow, whereas it increases first slowly and then rapidly with the increase in ambient temperature. Under the same exhaust steam flow, as ambient temperature rises, the pressure of the air-cooled condenser increases. The reason is that the increase of the ambient temperature deteriorates the heat transfer performance of air-cooled system, which causes the vacuum of condenser to decline. When the exhaust steam flow and ventilation of the unit are fixed, the variation curve of the condenser working pressure changes smoothly at relatively low ambient temperature, while its slope increases gradually with the increment in ambient temperature, which indicates that when the ambient temperature is high, the influence of ambient temperature change on the working pressure of the condenser is more significant. At the same ambient temperature, the greater the exhaust steam flow, the steeper the curve of working pressure, showing that the condenser pressure is more sensitive to changes in ambient temperature under the larger exhaust steam flow.

It can be concluded from Fig. 5 that the pressure of the condenser increases with ambient temperature, whereas it decreases first rapidly and then slowly with the increase in the face velocity of the air. The higher the face velocity, the bigger the heat transfer coefficient is, which strengthens the heat exchange process and then the vacuum of the condenser. When the face velocity is less than 2.8m/s, the change of the face velocity has a greater impact on the condenser pressure; when the face velocity is more than 2.8m/s, the effect of enhancing the fan speed to reduce the condenser pressure is not obvious, in return it will increase the fan power consumption. At a higher ambient temperature, the decreasing rate of condenser pressure gradually increases when the face velocity increases, which indicates that the condenser pressure is more susceptible to the change of the face velocity due to the high ambient temperature in summer.

From Fig. 6 it can be seen that when the ambient temperature is constant, the condenser pressure gradually increases with the rise of exhaust steam flow, which means that the vacuum of condenser is reduced. However, it is also found that condenser pressure is significantly affected by changes in exhaust flow as the ambient temperature rise. Then if the unit is operating under relatively high ambient temperature and large thermal load, a small disturbance of exhaust flow will cause the condenser pressure to vary drastically. Therefore, in the hot summer, the exhaust flow of the direct air-cooled unit should not be too high when considering the safety and economy of the unit.

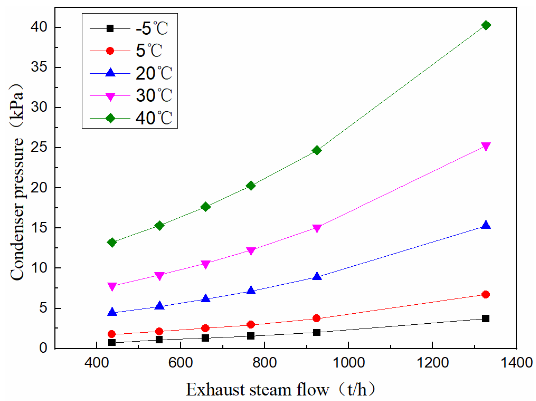
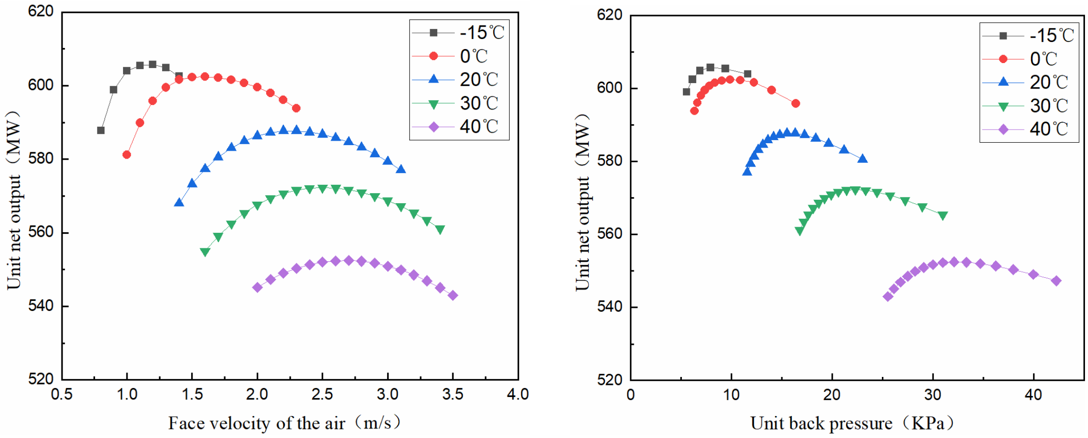


Figure 6. Curve at exhaust steam flow.

4.3. Calculation results and analysis of net output of direct air-cooled unit under off-design condition

Under the condition that the exhaust steam flow is 1327t/h and the ambient temperature is different, the net power output of the unit is calculated and its changing tendency as the face velocity of the air varies is shown in Fig. 7 (a), while Fig.7 (b) exhibits the net power output variations as the result of the back pressure changing. The curves obtained above are based on both the established mathematical model and optimization calculation model for variable conditions of the air-cooled condenser.



a). Effect of face velocity on net output of unit   b). Effect of backpressure on net output of unit

Figure 7. Curves of the face velocity, unit backpressure and unit net output

As shown in Fig. 7 (a), there is a critical value of face velocity for each ambient temperature. When the speed is lower than the critical value, the net power output of the unit decrease with the face velocity dropping. While the speed exceeds the critical value, the incremental face velocity will reduce the net power output of the unit. Such phenomena are attributed to that the increase in face velocity is achieved by boosting the speed of the fan. This can lead to the power consumption of the fan rise. As the increase in power consumption of fan is larger than that in power generation of turbine, the net power output of the unit will descend. It can also be concluded that the higher the ambient temperature, the larger optimal face velocity is. From Fig. 7 (b), it can be seen that the net power output of unit increases first and then decreases with the increment in backpressure, and this variation of net power output is similar in different ambient temperature. The backpressure corresponding to the highest point of each curve is the optimal operating backpressure under certain ambient temperature. Under the same load, as the ambient temperature rise, the optimal operating backpressure will increase.

4.4. Optimization results and analysis.

Under the restriction of choked backpressure, the established cold-end optimization calculation model of direct air-cooled unit based on the GA is used to optimize the backpressure of the unit.

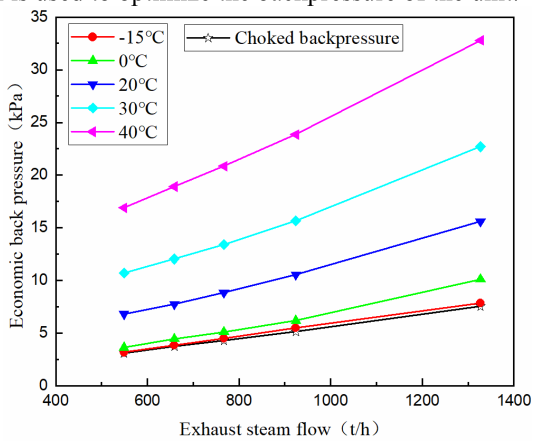


Figure 8. Optimal operating backpressure under off-design conditions

Fig. 8 shows the variation of the optimal backpressure with the exhaust steam flow. When the exhaust flow remains unchanged, as the ambient temperature rises, the optimal backpressure of the unit increases. It can be seen from the figure that the optimal backpressure is slightly larger than the choked backpressure at the ambient temperature of -15°C. When the ambient temperature increases from -15°C to 0°C, the optimal backpressure of the unit increases by about 1.4kPa; while the ambient temperature rises from 30°C to 40°C, the optimal backpressure of the unit rises by about 7.8kPa. It shows that when the ambient temperature is at a relatively high level, the optimal operating backpressure is quite sensitive to changes in ambient temperature. The calculated data is listed in Table 3.

Table 3. Optimization calculation results of genetic algorithm

Parameter		Unit	Value				
Ambient	Load	MW	600	450	360	300	240
temperature	Exhaust flow	t/h	1327	924	767	659	549
0℃	Best pressure	kPa	10.1232	6.2136	5.1282	4.4675	3.6421
	Face velocity	m/s	1.5762	1.3305	1.1451	1.0292	0.9783
	Fan flowrate	m^3/s	22273.05	18801.3	16181.41	14543.63	13400.43
20℃	Best pressure	kPa	15.6023	10.5466	8.8442	7.7552	6.8338
	Face velocity	m/s	2.2881	1.9535	1.8101	1.7058	1.5579
	Fan flowrate	m^3/s	32333.14	27604.91	25578.52	24104.66	22014.68
30℃	Best pressure	kPa	22.7027	15.6584	13.4215	12.0406	10.6922
	Face velocity	m/s	2.4561	2.1585	2.0019	1.8741	1.7336
	Fan flowrate	m^3/s	34707.15	30501.76	28288.85	26482.91	24497.5

As the results shown in Table 3, under the condition that the thermal load remains unchanged, the higher the ambient temperature, the faster the optimal face velocity is, that is, the more cooling air volume is required to maintain the exhaust pressure of air-cooled unit at the optimal backpressure. Therefore, the optimal backpressures of the units are various if the environmental conditions are different. In order to maximize the efficiency of the unit, which means it needs to be operated under the best backpressure, it is necessary to adjust the operation mode of the fan to control the cooling air volume until the backpressure reaches the optimal value.

5. Conclusion

In this paper, the characteristics of the air- cooled condenser running in off-design conditions has been studied based on a calculation model using the ε-NTU method. The influence of the exhaust steam flow, ambient temperature and face velocity of the air on the pressure of direct air-cooled condenser is analyzed. Taking the maximum net power output of the unit as objective function, an optimization calculation model for the cold-end of the direct air-cooled unit based on genetic algorithm is established. Furthermore, the optimal face velocity and operating backpressure under off-design conditions are obtained. The following conclusions are therefore drawn:

1) The calculation model of a 600 MW direct air- cooled unit under off-design condition is established. Being compared with the characteristic curve provided by the manufacturer, the result obtained by the model meets the requirements of engineering accuracy with its maximum error is 1.68%.

2) The working pressure of the condenser increases with the increment in ambient temperature and exhaust steam flow, and decreases with the rise of the face velocity. When the ambient temperature is at a relative high level, the condenser pressure appears having weaker robustness with the change in ambient temperature, exhaust steam flow, and face velocity of the air. For different thermal loads and ambient temperatures, there is a specific optimal face velocity. When the face velocity exceeds the optimal value, the effect of increasing the fan speed to reduce the pressure of the condenser is not obvious. Instead, it will increase the power consumption of the fan, resulting in the net power output of the unit reduced.

3) When the exhaust flow of the unit is constant, as the ambient temperature rises, the optimal backpressure of the unit increases, demanding more cooling air volume to maintain itself. Meanwhile, the higher the ambient temperature, the more sensitive the optimal back pressure is to the temperature. The optimal operating backpressure obtained under different ambient temperatures and exhaust steam flows can be closed as a reference value for setting the backpressure of the unit during actual operation.

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