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Analysis of Heat Transfer Characteristics of Shell-and-Tube Condenser

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Abstract. In order to enhance operating efficiency of power plants and reduce operating costs of power plants, it is necessary to study heat transfer characteristics of shell-and-tube condensers. A model of shell and tube condenser was built through Simulink software in this paper. The correlations of T_{in}, V_c, G_s with K of the condenser, heat exchange capacity of condenser, and condensation was established, also the impact of these factors on heat transfer characteristics of condenser was analyzed. The calculation results show that the higher T_{in} and G_s is, the higher K of the condenser is, and the lower the heat exchange capacity and condensation of the condenser are. With the increase of V_c, and K, the heat exchange capacity and condensing volume of condenser are increased.

1. Introduction

In the process of thermal power generation, the condenser equipment is an important part of the steam turbine generator set. Its performance is not only affecting safety and economy of generator set, but also directly affects the reliability of the unit operation[1]. Douglas[2] analyzed the back pressure of evaporative condenser system was lower than water cooling system and air cooling system Evaporative condensers have been used in the power generation system of the US Tradewinds Sawmill and the combined power generation system of Trans Alta Energy of Canada, and the application effect is remarkable[3]. Guo Changqing et al[4] concluded that evaporative condenser has the advantages of reducing condensation temperature, increasing power generation, water saving and energy saving. The effects of T_{in}, V_c and G_s on the heat transfer characteristics of the condenser were studied in this paper.

Nomenclature

T_{in} cooling water inlet temperature(℃)

V_c cooling water flow rate(m/s)

G_s steam load(t/h)

K   total heat transfer coefficient(W/(m^2·k))

r   latent heat of vaporization

2. Analysis of condensation heat transfer of condenser

At present, the cooling water in most power plant condensers flows inside the pipe, the exhaust steam from the steam turbine flows outside the pipe. The circulating water pump continuously supplies cooling water into the cooling pipe, and the cooling water continuously absorbs and takes away r released when the steam is condensed. The steam is condensed on the outer surface of the cooling pipe, and a good deal of r is released; the heat is exchanged for heat conduction through the metal of the pipe wall itself and the dirt on the inner and outer surfaces of the pipe; the cooling water absorbs the heat released by the steam by convection heat exchange.

3. Calculation procedure and Simulink model diagram

The calculation process is as follows: 1. Read the data; 2. Calculate the cooling water inlet temperature T_{in}, heat transfer coefficient on the water side surface a_w, arrangement of the cooling pipe and influence coefficient of the tube bundle form $\overline{S}$, air leakage in the condenser G_a; 3. Set the specific steam load $(G_s)_1$; 4. Calculate the G_s of the condenser q, the logarithmic average heat transfer temperature difference between steam and cooling water Δt_m, K, the heat exchange capacity of condenser Q; 5. Calculate $(G_s)_2$; 6. Compare $(G_s)_1$ and $(G_s)_2$, if the relative difference is less than or equal to 1%, the calculation ends. Otherwise use the average to get new G_s, continue the iterative calculation until the sixth step is met. The model diagram of the condenser condensate steam heat exchange system is shown in Figure. 1.
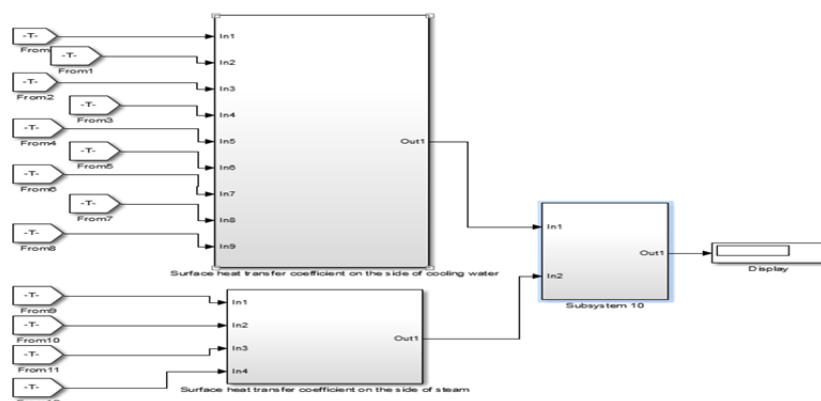

Figure 1. Condense heat exchange system model of condenser.

4. Analysis of calculation results

4.1. The influence of T_{in}

Figure. 2 shows that the higher T_{in} is, the larger K is. When the T_{in} increases to a certain value, the growth rate of the total heat transfer coefficient is gradually decreasing.
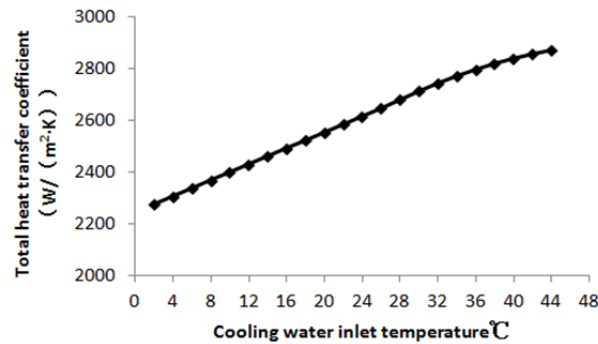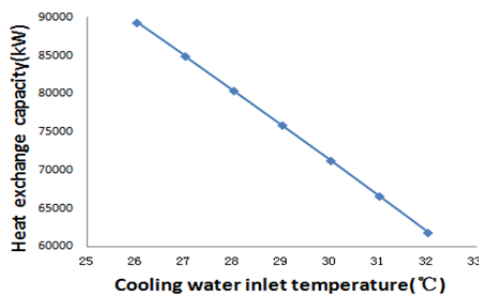

Figure 2. Curve of K with T_{in}

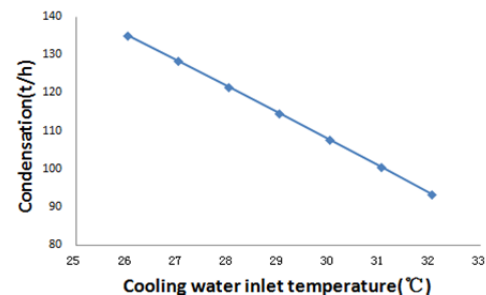**Figure 3 .**Curve of heat exchange capacity with T_{in}

Figure 4. Curve of condensation with T_{in}

Figure. 3 and Figure. 4 shows that the higher T_{in} is, the lower heat exchange capacity and condensation of condenser are, and the lower temperature of cooling water promotes the steam flow between the tube bundles and promotes the heat exchange of the condenser.

4.2. Influence of cooling water flow rate

Figure. 5 and Figure. 6 shows that as V_c increases, K and condensation of the condenser increases continuously when T_{in} is 20℃, 26℃, and 30℃, respectively. T_{in} is higher, K is larger. When T_{in} is constant, the condensation of the condenser increases as V_c increases. Figure. 7 shows that when T_{in} is constant, V_c is higher, the heat exchange capacity of the condenser is higher. This is because the increase of V_c is beneficial to carry more heat and promote steam condensation heat transfer under the same conditions.
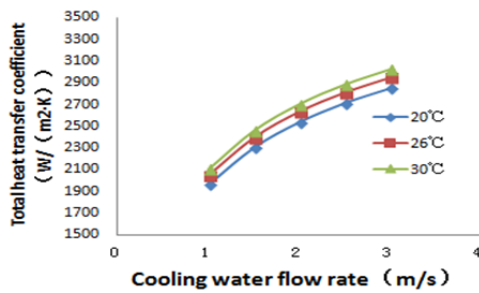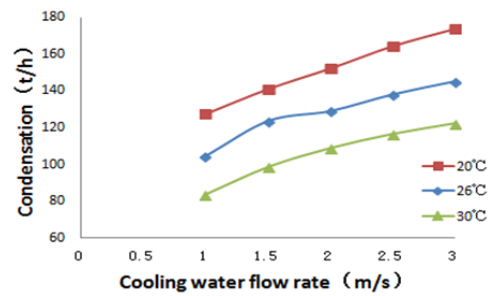
Figure 5. Change curve of K with V_c

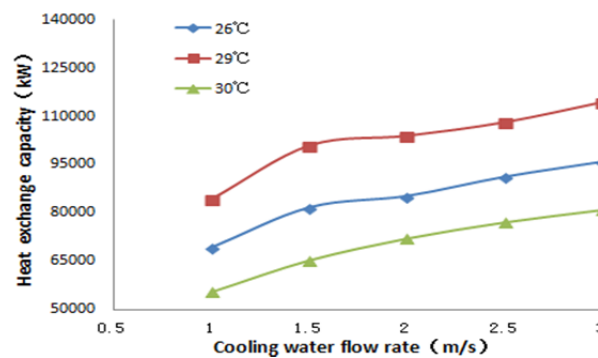**Figure 6.** Change curve of condensation with V_c

Figure 7. Change curve of heat exchange capacity with V_c

4.3. Influence of steam load

Figure. 8 shows that K of the condenser is positively correlated with G_s when T_{in} is 20℃, 26℃, and 30℃, respectively. The higher the steam load is, the larger the velocity of the steam is. The steam will continuously wash the cooling tube bundle in the condenser, which is beneficial to reduce the condensed liquid membrane on the cooling tube wall surface and reduce the heat transfer heat resistance. The heat transfer coefficient of the steam side surface is larger, K of the condenser is larger, and T_{in} is higher, K is larger. Figure. 9 and Figure. 10 shows that the higher G_s is, the higher the heat exchange capacity and condensation of the condenser are.
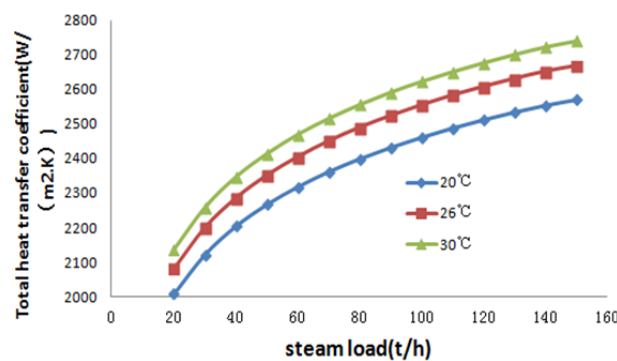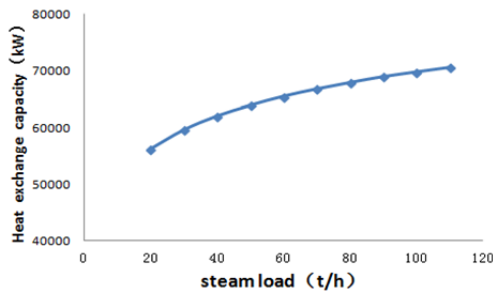
Figure 8. Change curve of K with G_s

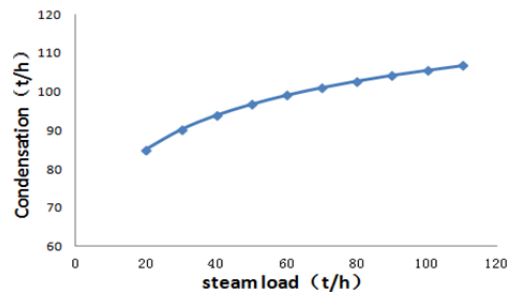**Figure 9.** Curve of heat exchange capacity with G_s

Figure 10. Curve of condensation with G_s

5. Conclusions

1. T_{in} is higher, K of the condenser is larger, while the heat exchange capacity and the condensation of the condenser is lower. This is because T_{in} is higher, the cooling water outlet temperature is higher, and K of the surface on the cooling water side is larger, and K of the condenser is larger. However, the average heat exchange temperature difference will be reduced, and the ability of the cooling water to remove heat will be reduced. The heat exchange capacity and condensation of the condenser will decrease under the same conditions.

2. When V_c is larger, the convective heat transfer of the surface of the cooling pipe is higher, so that K is larger. Under the condition that other parameters remain unchanged, K of the condenser increases, and the heat exchange capacity and the condensation of the condenser increase with the increase of V_c.

3. The higher G_s is, the larger K is, and the lower the heat exchange capacity and condensation of the condenser are.

Acknowledgments

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