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Research Article

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The Discussion on Influenced Factors of Recirculation for a Direct Air-Cooled Power Plant

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ABSTRACT

The main factors which influence the recirculation under cooling tower are analyzed theoretically, the experimental model tests are also carried out to discuss the affect extent of factors to recirculation under cooling tower, the results can provide theoretical direction in decreasing and avoiding recirculation under cooling tower.

Key words: power plant; air-cooled condenser; recirculation; iinfluence factors

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INTRODUCTION

Recently years many large direct air-cooled condenser (ACC) has been constructed in power plants where cooling water is unavailable or costly in nearby areas [1]. However, many factors affect the air-cooled system, such as environmental factors, geometrical dimension of air cooling tower, fan performance et al. When the wind flows over the air cooling tower, recirculation would be formed in the bottom of tower. In the hot summer time, recirculation seriously influenced the heat dispersal to the direct air cooled condenser, and even caused system to shutdown. Literature [2] report the shutdown issues of ACC in home and abroad , Literature [3] analyzed of the problem, and pointed out that in the hot summer temperatures hours, back pressure of air-cooling units sudden changed, mainly caused by recirculation results from the ambient wind. Meanwhile, if the air cooling tower and surrounding buildings arranged improperly, recirculation also will be generated in the bottom of cooling tower. Therefore, correct understanding the recirculation and the influence factors is key problem to reduce and avoid recirculation, which has a theoretical significance but also has engineering applications.

THEORETICAL ANALYSIS

2.1 Reasons of Recirculation Forms

The reasons of the recirculation causes under the air cooling tower are analyzed by Literature [4]. The main reason that heat spreading efficiency of ACC influenced by the surroundings (such as the temperature, degree of humidity of the air, the wind velocity and direction, etc) is the cold air forced by fans passes through finned tubes, exchanges heat with finned tubes, and then, the cold air absorbs heat of the wings slice, becomes hot air to ascend, in the absence of a cross wind, the hot air raises only by hot buoyancy, and appearance of hot air looks like plumes; however when crosswind is present, especially when wind blows from the turbine house to cooling tower at the speed of 3m/s or large than 3m/s, a large tail flow will be formed at the back of boiler house, and the flow is very complex, and even appears to adverse flow (the direction is downward) above the air-cooled platform. Then plumes are acted not only by hot buoyancy, but also by inertial force come from the tail flow; so the configuration of the plumes flow will be changed, at the same time, air separated from the top of boiler house and boundary of platform far away from the turbine house, so two large eddies formed at the back of boiler house and backward position of the platform. Under the action of eddy, plumes will be drawn into the bottom of cooling tower, so recirculation forms. The recirculation causes temperature at entrance of the ACC to increase. When heat dispel (generate electricity quantity) keeps constant, the temperature at the output of ACC will increase, which leads to back pressures of air-cooled units increase acutely, and even causes the system to shut down.

2.2 The Main Factors Affecting the Recirculation

Many factors affect the recirculation, summarized up: environmental factors, ambient air temperature, humidity, wind velocity, wind direction included. Geometrical factors: the length, width, height of air cooling tower, width of the corridor and height of wind wall included; fan factors: fan diameter, flow rate, airfoil of the blade, installation angle, twist angle and fan unit included, etc.; and these factors are interrelated, it involves aerodynamics, meteorology and engineering thermodynamics heat transfer and many other disciplines[5].

T_i the temperature in the inlet of ACC、 ρ_i air density in inlet of ACC、T_a ambient temperature、 ρ_a ambient density、V_a wind velocity、T_o the temperature in the outlet of ACC、ρ_o air density in outlet of ACC、 V_o faced velocity, V_j velocity of duct outlet, R recirculation, L the length of the platform、W the width of the platform、 H the height of the platform、H_w the height of the wind wall, L_w the width of the corridor 、 L_{he} the length of finned tube; θ half-angle of two tubes; D_N diameter of fan, N fan number of units, The use of dimensional analysis can be obtained:

$$R = f(V_j, V_a, \beta, \rho_a, \upsilon, \rho_o, L, W, H, H_w, L_w, D_N, \theta, N) \tag{1}$$

In where, υ movement viscosity of air; β the direction of wind. For non-uniform, $\Delta\rho_o / \rho_a$ can be considered into Fr_D:

$$R = f\left(F_D, K, R_e, \beta, \frac{L}{D_N}, \frac{W}{D_N}, \frac{H}{D_N}, \frac{H_w}{D_N}, \frac{L_w}{D_N}, \frac{L_{he}}{D_N}, \theta, N\right) \tag{2}$$

In where, $K = V_a / V_j$ is the wind speed ratio, express the ratio of wind velocity to velocity of duct outlet; $Fr_D = V_j / \sqrt{gD_N(\rho_a - \rho_o)/\rho_a}$ is density Froude number, denotes the ratio of inertial force to gravity; When Fr_D is small, that denotes that the gravity is large than inertial force.

2.3 Influence of Recirculation on Back Pressure

Studies have shown that the back pressure of steam turbine change with ambient atmospheric temperature, and back pressure frequently change as diurnal temperature changes. Back pressure increases will cause the generator output of the unit to decline, in order to ensure its operation at rated load, the steam flow must be increased, when the flow increases to a certain extent, all levels blade of steam turbine will be overloaded, and axial thrust will be increased as well; otherwise, back pressure increases will cause the exhaust temperature to increase, and easy caused the low-pressure cylinder deformation, which resulting in enhanced vibration to unit. For the air cooling units, high back pressure and low-load may also lead to the leaf of final stage flutter, which will cause a huge impact to the strength of the system structural.

Literature [6,7] respectively analysis the calculation model for variable operating conditions on pressure of the direct air-cooled system, in the absence of a cross wind, the fitting curve between the back pressure and the corresponding environmental temperature of a 600MW direct air-cooled unit is shown as:

$$P_b = 6.0674e^{0.0501T_i} \tag{3}$$

Literature[4] analyzed the existing definition of the recirculation and gave the evaluation criteria of recirculation:

$$R = \frac{T_{in} - T_a}{T_{out} - T_a} \tag{4}$$

In where, average air temperature influenced by recirculation under cooling tower, outlet air temperature in louver, environmental air temperature. Substitute formula (4) into formula (3), we can get

$$P_b = 6.0674e^{0.0501[T_a + R(T_{out} - T_a)]} \tag{5}$$

Figure 1 shows the relationship between back pressure of steam turbine and ambient temperature for a direct air-cooled unit at full capacity operating. It can be seen from the figure, given the amount of fan flow and heat conditions, the back pressure of steam turbine increased with the ambient temperature increased, the increasing in back pressure steam turbine will cause power generation capacity decline; coupled with environmental strong winds, especially in adverse wind direction angles, wind shear occurred in fan entrance, which will cause back pressure rise further sharp, resulting in a sudden drop in unit load. Meanwhile, the recirculation caused under the environment cross wind, which made the temperature in fan inlet raise, back pressure of steam turbine increase, and even lead to system shutdown.

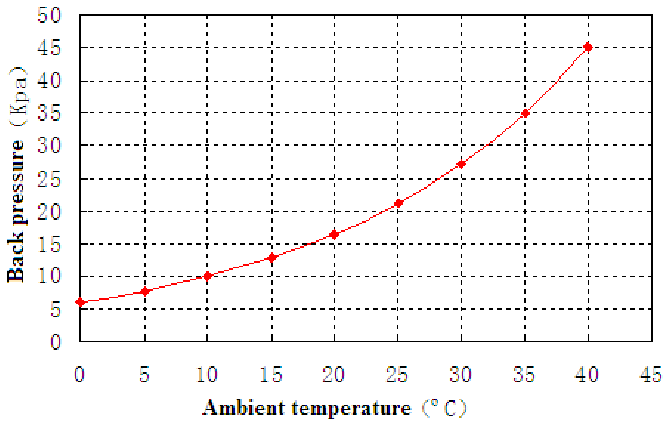

Figure1 relationship between back pressure and ambient temperature for a 600MW ACC unit at full capacity operating

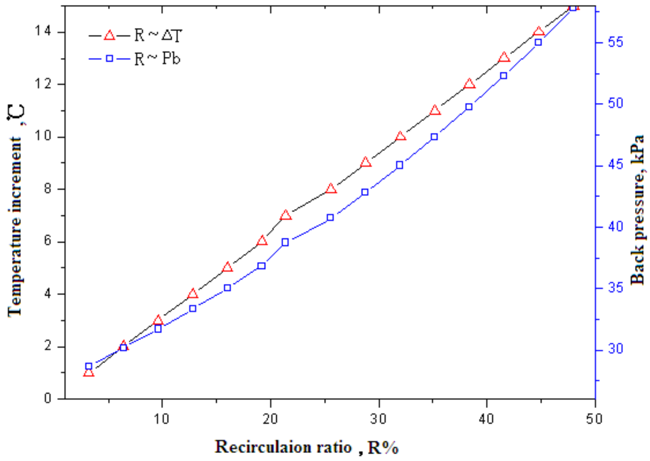

Figure2 the influence of different air temperature increments in fan inlet on recirculation and back pressure of steam turbine

Figure 2 shows the influence of different air temperature increments in fan inlet on recirculation and back pressure of steam turbine when the ambient temperature is 30 ℃, heat discharge and fan speed keep constant, when the recirculation occurs.

It can be seen from the Figure 2, fan speed and heat discharge kept constant, when the temperature remains constant, the recirculation under cooling tower increased with inlet temperature increased of fan entrance, back pressure of steam turbine increased when recirculation under cooling tower increased, so when fan speed and heat discharge kept constant, reducing the air temperature of fan entrance, the efficiency of air-cooled condenser can be improved[8].

RESULTS AND DISCUSSION

Literature [8,9] supplied the direct air-cooled with the constant temperature hot water, and carried out the model experiments in low-speed wind tunnel for the first time. In the experiments, the wind speed, wind direction, air-cooled platform geometry, fan speed and other parameters were changed; the influence of parameters on the recirculation is discussed.

3.1 The Influence of Environmental Factors on the Recirculation

1.The influence of Wind speed ratio and wind direction angle on recirculation

Literature[8] gave the experimental results of recirculation changed with wind speed ratio K, As wind speed ratio increasing, average recirculation ratio under cooling tower is increasing as well.This is because flow separated at the top of boiler house and boundary of wind wall far from the turbine-house. At the back of boiler house and backward position of wind wall, two eddy come into being. At the boundary of vortex, strong turbulent entrainment mixes up, which causes more and more plumes roll into the vortex. When which leads to enhancing of inertial force increases, that is, vortex strength is augmented; more and more plumes are coiled to bottom which causes recirculation increase.The rules of recirculation changed with wind direction angle was given by Literature[8], and the most adverse direction angle was given, this can provide the experimental basis for the practical engineering to take measures to reduce or avoid recirculation.

2.The influence of density Froude number on the recirculation

Literature[9] gave the relationship between average recirculation ratio and density Froude number, as shown in Figure 3.

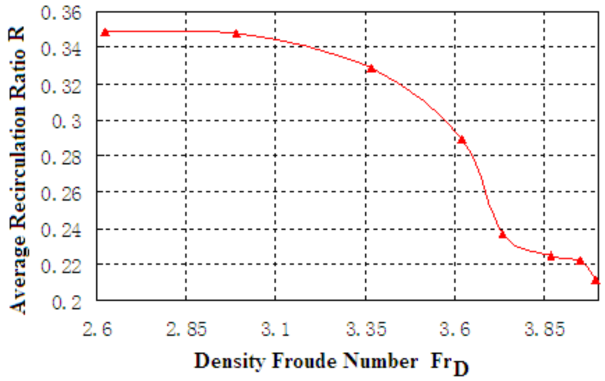

Figure3 the relationship between average recirculation ratio and density Froude number

It can be seen from the Figure 3, with the density Froude number increased, the average recirculation decreased. This is mainly because of the thermal buoyancy effect increases, the momentum of the hot air discharged from ACC increased, when the wind velocity kept constant, the hot air diffuse away from the ground to the top right of the downward position, so the hot air sucked into the cooling tower was reduced, and thus, the average recirculation under the cooling reduced.

3.2 The influence of Geometry of the tower on recirculation

1.The Influence of the height of the wall on recirculation

Literature [9] got the rules of height of wind wall on recirculation through the wind tunnel model tests, meanwhile, the influence of height of wind wall on the thermal flow field was also revealed. The experiments denote that increasing the height of wind wall can reduce the average recirculation under the cooling tower, and there was an optimum value of l height of wind wall, this result is validated by numerical simulation of Literature [11].

2.The Influence of widen or lengthen the platform on recirculation

Literature [10] installed some certain length (or width) baffle to margin of the platform, The results found that the installation of some certain length (or width) baffle to margin of the platform can reduce the average recirculation ratio under the tower.

3.3 The influence of fan performance on recirculation

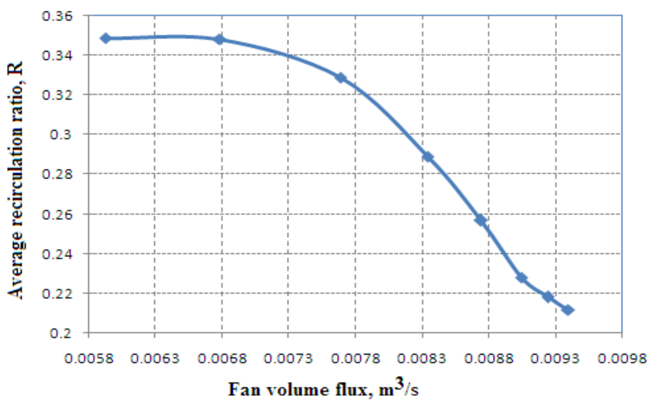

Figure 4 relationship between fan volume flux and average recirculation ratio

Literature [1] gave the relationship between fan volume flux and average recirculation ratio. It can be seen from the Figure 4, as fan flux increased, the average recirculation ratio reduce as well. This is because the thermal buoyancy force of the air flow increased, when incoming wind velocity kept constant, the thermal buoyancy force of the air flow increased can help the hot air to diffuse to top right of the downward position, so the hot air sucked into the cooling tower was reduced, and thus, the average recirculation under the cooling reduced.

CONCLUSION

The impact factors of the recirculation under cooling tower for ACC is discussed, and the influence factors affect the recirculation is analyzed respectively, this can provide theoretical guidance and technical support to reduce or avoid recirculation for practical engineering.

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