Applied Thermal Engineering 90 (2015) 684–693

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research paper

# A numerical study on the effect of roof windbreak structures in an air-cooled system

Hongfang Gu*, Zhang Zhe, Haijun Wang, Chen Qi

State Key Laboratory of Multiphase Flow in Power Engineering, Xi'an Jiaotong University, Xi'an 710049, China

## HIGHLIGHTS

- This paper presents the effect of roof windbreak structures in air-cooled systems.
- The optimal windbreak structure ensures power plants operating effectively.
- Effect of air flow and hot air recirculation was studied on roof windbreaks.
- Parameters of the roof windbreak affect the performance of the DACC significantly.

## ARTICLE INFO

*Article history:*
Received 8 April 2015
Accepted 5 July 2015
Available online 30 July 2015

*Keywords:*
Direct air-cooled unit
Windbreak line screen
Ambient wind
Numerical simulation

## ABSTRACT

The ambient wind velocity seriously affects the heat transfer performance in a Direct Air-Cooled Condenser (DACC). The heat transfer rate of an upstream heat exchanger unit is lower than that in other heat exchanger units under unfavorable ambient winds. The current work uses Computational Fluid Dynamics (CFD) to numerically simulate and analyze the effect of roof windbreak system on the DACC in a 2 × 350 MW power station. The distortion of the air flow, and the hot air recirculation rate at the fan inlet surface were studied at different ambient wind velocities. Our results show that the vertical length L1, inclined length L2, and inclination angle $\alpha$ on the roof windbreak line screen affect the performance of the DACC significantly. The analysis further shows that the optimal performance of the DACC can be achieved under the structure size of L1 = 30 m, $\alpha = 60°$, and L2 = 5 m. The air flow decreases at the no wind or low wind velocity due to setting of the windbreak line screen. Therefore, the height of the platform needs to be adjusted to meet the suction space requirement for the fan.



## 1. Introduction

Direct air-cooling condenser (DACC) is among the most popular methods to cool the exhaust steam in power plants because it offers superior heat transfer performance compared to other methods.

Several factors such as fan performance and the heat transfer efficiency affect the characteristics of the DACC. Van Rooyen and Kröger [1] demonstrated that the performance of the air-cooled steam condensers is sensitive to the wind conditions and high ambient temperature. Stinnes and Von Backstrom [2] showed that the drop of the fan static pressure is proportional to the dynamic pressure due to the cross-flow velocity at the fan inlet. Owen and Kröger [3] proved that an increase in the fan inlet temperature would cause adversely the air-cooled condenser performance. As the plume recirculation flows into the fan at higher wind speeds, the local inlet temperature increases above its reference temperature. As a result, the air-cooled condenser performance drops below the design value. Meyer and Kröger [4] numerically investigated the effect of an axial flow fan used in specialized forced draught air-cooled heat exchanger. The result indicated that the characteristics of an axial flow fan affect the aerodynamic behavior of a forced draught air-cooled heat exchanger. He et al. [5] studied the effect of the fan speed on the performance of the whole air-cooled power plant with a capacity of 2 × 600 MW. They found that increasing the fan speed improves the performance of the fan array and the heat transfer efficiency of the air-cooled steam condenser.

A literature survey also reveals that the ambient wind has a significant effect on the air cooling condenser performance. Hotchkiss et al. [6] studied the effect of cross flow on the fan performance in an air-cooled condenser. Their experimental results

* Corresponding author. Tel.: +86 29 82667998; fax: +86 29 82669033.
*E-mail address:* hongfang.gu@gmail.com (H. Gu).

http://dx.doi.org/10.1016/j.applthermaleng.2015.07.030
1359-4311/

**Nomenclature**

| | |
|---|---|
| k | turbulent kinetic energy, $m^2/s^2$ |
| L1 | windbreak line screen vertical length, m |
| L2 | windbreak line screen inclined length, m |
| m | air mass flux, kg/s |
| *P* | pressure, pa |
| q | heat transfer rate, w |
| u | air velocity, m/s |
| V | face velocity, cooling air velocity across the heat exchanger section, m/s |
| x, y, z | the Cartesian co-ordinates |

*Greek symbols*

| | |
|---|---|
| $\Delta T$ | temperature difference between fan inlet surface temperature and ambient temperature, °C |
| $\alpha$ | windbreak line screen inclined angle |
| $\varepsilon$ | turbulent dissipation rate, $m^2/s^3$ |
| $\mu$ | molecular viscosity (Pa·s) |
| $\rho$ | density, $kg/m^3$ |

*Subscripts*

| | |
|---|---|
| a | air |
| av | average |
| b | steam turbine outlet pressure |
| t | turbulent |

show that the off-axis inflow affects the fan-blade loading characteristics and the fan static pressure rising. Meyer [7] investigated the flow field associated with the system comprising a single-row and two-rows of an air-cooled heat exchanger. Their results show that the inlet flow loss of the periphery fan is dominated by the flow separation occurring around the inlet lip of the fan inlet section. Furthermore, the flow loss can be reduced by the installation of a walkway at the edge of the fan platform or by the removal of the periphery fan inlet section. Liu et al. [8] demonstrated that the hot air recirculation is caused by the ambient wind speed and its flow direction. Salta and Kröger [9] experimentally investigated the effect of the fan platform height on the air flow rate. They observed that reducing the platform height results in reducing flow rate through the fans. They also observed that any flow disturbances or distortions at the fan inlet reduce the air cooled heat exchanger effectiveness. Yang et al. [10] utilized a wind-screen in different positions and fan regulation to optimize the performance of the air-cooled condenser in a 2 × 600 MW direct air-cooled power plant. Their numerical results show that the air-cooled condenser performance improves, which results the turbine back pressure decrease. Bredell et al. [11] used the CFD method to simulate the flow field of the fans in an air-cooled steam condenser. Their simulations show that any inlet flow distortion adversely affects the fan flow rate. Furthermore, they observed that an uneven air distribution into the fan may cause the fan blade to stall, and the off-axis inflow condition reduces the static pressure. Yang et al. [12] numerically analyzed the effect of wind-break wall configurations on the thermo-flow performance of air-cooled condensers. The authors used three different configurations of the wind-break wall in a representative 2 × 600 MW DACC power plant. Their results showed that the thermo-flow performance of the air-cooled condenser can be improved by the extending the inner and outer walkway or by increasing the elevation of the wind-break wall. Owen et al. [13] used CFD to investigate the effect of porous wind

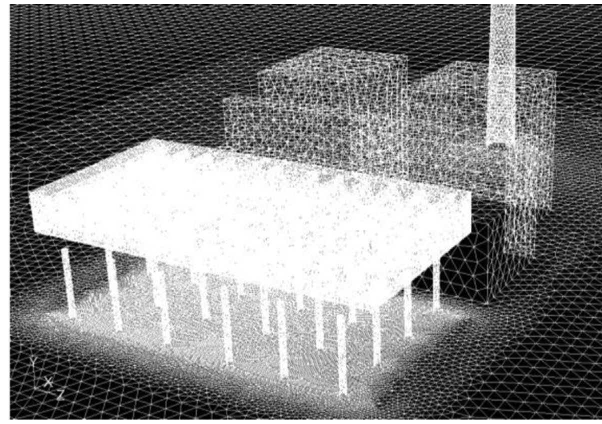

**Fig. 1.** Grid configuration with 2 × 350 MW power station.

screens which was installed in a cross-arrangement below the fan platform on the DACC at the El Dorado Power Plant. They found that the wind screen increases the DACC performance under windy conditions. Gao et al. [14] proposed a new method by adding deflection plates under the air-cooled platform to ensure the fans in the upwind region getting adequate cooling air. The deflecting plates improve the inlet flow distortion, and hence increase the mass flow rate in fans.

The literature investigation shows that the direct air-cooling condenser (DACC) has significant impact of the environmental wind condition. Since the DACC does not have the large water storage volume, the drop in the radiator cooling capacity promptly increases the back pressure in the steam turbine. Such quick drop of the back pressure has seriously safety concerns on the unit operation, and will decrease the unit efficiency as well. To ensure high efficiency of the DACC system, it is advisable to select suitable windbreak structures for DACC in a high wind areas. A line-screen windbreak structure was installed on the DACC platform of 2 × 350 MW power unit located in Xinjiang (China), where 300 MW power can be produced at the ambient temperature of 43 °C with the wind velocity of 40 m/s. By using numerical method, this paper reports the simulation results for the roof form windbreak structure of the DACC system in a 2 × 350 MW power plant under high wind conditions.

## 2. Numerical simulation

### 2.1. Numeric model

In this paper numerical simulations were performed on a single row tube condenser with aluminum fin tubes in a direct air-cooled system. If the wind flow around the power plant is assumed as incompressible, the external flow field around the building should be governed by the following equations:

Continuity equation:

$$\frac{\partial}{\partial t}(\rho) + \frac{\partial}{\partial x_j}(\rho u_j) = 0$$

Momentum equation:

**Table 1**
Main structure size of an air-cooled condenser.

| Item | Size |
|---|---|
| Height of windbreak wall, m | 13 |
| Height of platform, m | 35 |
| ACC heat exchanger unit layout(row × column) | 6 × 6 |
| Fan diameter, mm | 9750 |