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Effects of pressure loss coefficients of heat exchanger on thermal performance of the dry cooling tower

Huan Ma[a], Fengqi Si[a,*], Xuebo Li[b], Junshan Wang[b]

[a]*Key Laboratory of Energy Thermal Conversion and Control of Ministry of Education, School of Energy and Environment, Southeast University, Nanjing 210096, PR China*
[b]*CPI Shentou Power Generation Co., Ltd., Shuozhou 036800, PR China*

Abstract

Crosswind deteriorates thermal performance of the natural draft dry cooling tower (NDDCT) mainly due to the unfavorable pressure distribution at tower entrance. Thus, effects of air cooled heat exchanger with various pressure loss coefficients are investigated with numerical simulation. The vortex inside the tower would cut down air inflow of heat exchanger of sideward and leeward parts. A quite large exponent of pressure loss coefficient expression of heat exchanger contributes to reduce heat transfer unevenness among cooling deltas, and would generate a small enhancement for the overall thermal performance of the tower.

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Keywords: Crosswind; dry cooling tower; numerical simulation; pressure loss coefficient; thermal performance

1. Introduction

Owing to the energy-efficient and water-saving advantages, natural draft dry cooling tower (NDDCT) has been widely applied in the regions with rich coal and lack of water [1,2]. With the delta-form air cooled heat exchanger bundles, the tower rejects the waste heat of circulating water to ambient atmosphere. As a result, performance of the NDDCT is highly sensitive to the environment conditions, particularly the crosswind.

* Corresponding author. Tel.: +86 25 83790579.
E-mail address: fqsi@seu.edu.cn

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Nomenclature

h	convective heat transfer coefficient of heat exchanger (W m^{-2} K^{-1})
k	turbulence kinetic energy(m^2 s^{-2})
k_l	non-dimensional pressure loss coefficient
Q	heat rejection (W)
S	source term
t	temperature (K)
v	velocity of air (m s^{-1})
Greek symbols	
ρ	density (kg m^{-3})
ε	turbulent dissipation rate (m^2 s^{-3})
ε_{th}	dimensionless parameter describing heat rejection variation of the tower caused by crosswind
Γ	diffusion coefficient (kg m^{-1} s^{-1})
φ	scalar variable for airflow
ϕ	dimensionless parameter describing maximal heat transfer difference among cooling deltas
Δ	the drop of a variable
Subscripts	
cw	crosswind
D	cooling delta
n	normal direction
w	circulating cooling water
2	outlet

As a key issue, crosswind has been thoroughly investigated involving its unfavorable impacts on thermal performance of the tower. Using wind tunnel modeling, Wei et al. [3] explained the main reasons of thermal performance deterioration caused by crosswind, that is, an unfavorable pressure distribution at the tower entrance, breaking of the plume rising at the tower exit, and cool air induced by leading edge separation entering the tower. By numerical simulation, Su et al. [4] revealed that the unfavorable pressure distribution, the internal secondary flow induced by the shock of inflows, and the influence of wind-cover played by crosswind on the top of the tower would reduce cooling efficiency of the tower. Ma et al. [5] indicated that the nonuniform variation of flow intensity around the heat exchanger causes the nonlinear variation of cooling water temperature with crosswind speed, with numerical simulation coupling the tower and condenser. Yang et al. [6] indicated that thermal performances of upwind cooling deltas are superior to others under crosswind, and for side cooling deltas, flow rates of cooling air decrease rapidly as the wind speed increases, but at high wind speeds, the flow rates remain almost constant. Zhao et al. [7] found crosswind deflects the inflow air from the inverse radial direction at delta entry especially in tower lateral. Under crosswind, heat transfer performances of cooling deltas at all sides of tower base determine the overall thermal performance of the tower. Therefore, as a key equipment, the characteristic of air cooled heat exchanger directly influences the economic and safe operation of the whole system.

Fin-and-tube heat exchangers are mostly applied in the dry cooling towers, with the advantages of compact structure, strong heat transfer capability, high material utilization ratio and less scaling. Generally, in-tube convective heat transfer coefficient is much larger than the air-side one, and pressure loss and heat transfer coefficients are two important performance parameters evaluating the characteristics of heat exchangers. Geometry size of the fin [8, 9] has great impacts on the performance of air-side heat transfer, and fin pitch, number of tube row and tube alignment [10,11] are other significant factors. However, the influences on heat transfer caused by these factors are closely related to Reynolds number [12], the type and material of the fin [13, 14]. So far, air cooled heat exchangers mostly adopt aluminous and steel finned tubes, and the shape and structure parameters of these air cooled finned tubes are similar. As a consequence, the expressions of performance parameters of air cooled heat exchangers are similar as well, written as Eqs. (1) and (2), or Eqs. (3) and (4).