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Performance improvement of natural draft dry cooling system by interior and exterior windbreaker configurations

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ABSTRACT

Ambient winds are basically unfavorable to the thermo-flow performances of natural draft dry cooling system, and may result in a reduced thermal efficiency for the power generating unit in power plants, so it is of benefit to the natural draft dry cooling system to propose the measures against the adverse effects of ambient winds. For a typical natural draft dry cooling system, the computational models of the flow and heat transfer of cooling air coupled with the energy balances of circulating water and exhaust steam are developed, by which the performance improvement due to the interior and exterior windbreaker configurations is investigated. The flow and temperature fields of cooling air, the flow rate and heat rejection of each sector, the outlet water temperature of heat exchanger for the natural draft dry cooling systems with and without windbreaker configurations, and the corresponding turbine back pressures are obtained. The results show that the exterior windbreakers are superior to the interior ones in thermo-flow performances. The turbine back pressure can be reduced by the windbreaker configurations in the presence of ambient winds, especially at high wind speeds.

1. Introduction

In the past years, natural draft dry cooling system in power plants has been increasingly developed and widely used in arid places thanks to its superiority in water saving [1]. Dry-cooling tower is one of the most important parts of natural draft dry cooling system, with air-cooled heat exchanger bundles vertically arranged around the circumference of cooling tower, or horizontally configured inside cooling tower. Cooling air flows through the heat exchanger bundles under the action of buoyancy force, removing the heat rejection of circulating water. As is well known, the thermo-flow performances of natural draft dry cooling system are sensitive to ambient conditions, especially the crosswinds. More attentions have been paid to the unfavorable wind effects on the performances of air-cooled heat exchangers and dry-cooling towers.

With CFD methods, Al-Waked and Behnia [2] investigated the effects of crosswinds and windbreakers on the thermal performance of natural draft dry cooling system, finding that the windbreakers can weaken the adverse impacts of crosswinds. Goodarzi [3] proposed a tower exit configuration to restrain the throat effect of deflective plume, by which the cooling efficiency is improved up to 9 percent. He also [4] introduced a method to utilize a variable tower height, which can reduce the structural wind loads without a considerable thermal performance reduction. Goodarzi and Keimanesh [5] studied the effect of a radiator-type windbreaker on natural draft dry cooling system, pointing out that a higher cooling efficiency can be achieved compared with the solid-type windbreaker. Goodarzi and Ramezanpour [6] proposed an elliptical geometry for natural draft dry cooling tower, which can bring on a higher cooling efficiency under crosswind condition. Zhai and Fu [7] put forward the windbreaker solutions in and around cooling towers, finding that 50% of cooling capacity can be recovered by placing side windbreakers of cooling tower. Lu et al. [8,9] studied the effects of tri-blade-like windbreaker and its orientation on natural draft dry cooling tower performance, suggested that one symmetry axis of the windbreaker should be in alignment with the prevailing wind direction. Zhao et al. [10] investigated the outlet water temperatures for different sectors with air deflectors under crosswind conditions, indicating that the air deflectors can weaken the air inflow distortion and improve the cooling performance of natural draft dry cooling tower.

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Nomenclature

A	heat transfer surface area (m^2)
c_p	specific heat (J $kg^{-1}K^{-1}$)
d	diameter (m)
e	exponent of the wind speed in the power-law equation
g	gravitational acceleration (m s^{-2})
G_k	turbulence kinetic energy generation due to mean velocity gradients (m^2 s^{-2})
G_b	turbulence kinetic energy generation due to buoyancy (m^2 s^{-2})
h	convection heat transfer coefficient (W m^{-2} K^{-1})
h_n	polynomial coefficient for the convection heat transfer coefficient
h_s	enthalpy of the exhaust steam (J kg^{-1})
h_{wa}	enthalpy of the condensate (J kg^{-1})
H	height (m)
I	turbulence intensity
k	turbulent kinetic energy (m^2 s^{-2})
k_L	flow loss coefficient
K	overall heat transfer coefficient (W m^{-2} K^{-1})
L	length of fin perpendicular to air flow direction (mm)
m	mass flow rate (kg s^{-1})
n	number
p	pressure (Pa)
P	fin spacing (mm)
q	heat flux (W m^{-2})
r_n	polynomial coefficient of non-dimensional loss coefficient
S_1	tube spacing perpendicular to air flow direction (mm)
S_2	tube spacing along air flow direction (mm)
S_φ	source term
t	temperature (°C)
u_f	frontal velocity (m s^{-1})
u_j	component of velocity (m s^{-1})
u_z	ascending velocity inside the tower (m s^{-1})
u_w	wind speed (m s^{-1})
W	width of fin along air flow direction (mm)
x_j	Cartesian coordinate (m)
z	height above the ground (m)

Greek symbols

δ_1	thickness of tube wall (mm)
δ_2	thickness of fin (mm)
ε	turbulence dissipation rate (m^2 s^{-3})
μ	dynamic viscosity (kg m^{-1} s^{-1})
μ_t	turbulent viscosity (kg m^{-1} s^{-1})
ρ	density (kg m^{-3})
σ	turbulent Prandtl number
Γ	diffusion coefficient (kg m^{-1} s^{-1})
Φ	heat rejection (W)
φ	scalar variable

Subscripts

1	inlet
2	outlet
a	air
avg	average
B	back
c	condenser
s	steam
t	tower
w	wind
wa	water

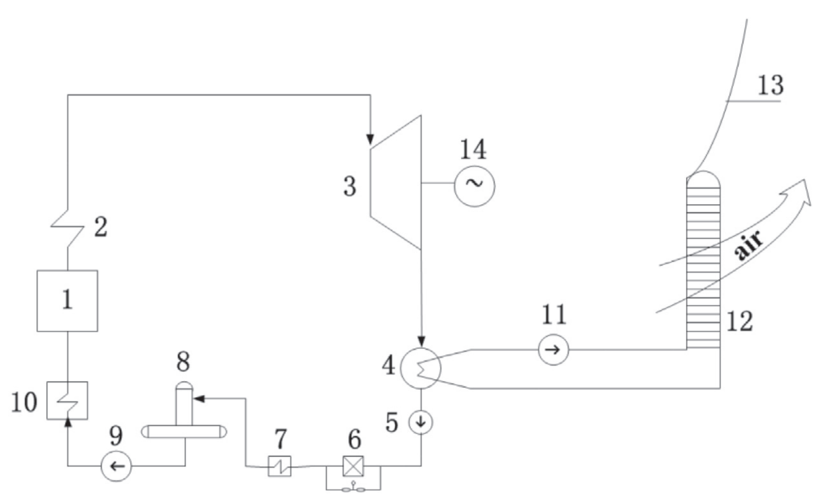

Fig. 1. Schematic of the power generating unit with natural draft dry cooling system. 1-boiler, 2-superheater, 3-turbine, 4-condenser, 5-condensate pump, 6-condensate-scavening installation, 7-low pressure heater, 8-deaerator, 9-feed pump, 10-high pressure heater, 11-circulation water pump, 12-air-cooled heat exchanger, 13-dry-cooling tower, 14-generator.