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Adoption of enclosure and windbreaks to prevent the degradation of the cooling performance for a natural draft dry cooling tower under crosswind conditions

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ABSTRACT

Crosswind degrades the cooling performance of a natural draft dry cooling tower (NDDCT) by affecting the air flow field at the inlet and outlet and inducing complex vortices inside and outside the tower. The distribution of the vortices along the flow streams is found to be a key factor for the ventilation rate. The parameter of flow loss factor (FLF) is proposed to quantitatively identify the effect of the vortices and unbalanced flow on the ventilation rate. Approaches of the installations of windbreaks and enclosure on the cooling performance of the NDDCT are numerically studied. It is found that both approaches can individually reduce the size of the inner wall vortex, improving the flow field characteristics. However, they have different strengths in breaking up the side low pressure areas and reducing the swirling intensity of the mainstream vortices. Results show that the approaches of windbreaks and enclosure can effectively prevent the degradation of the cooling performance for the NDDCT in a wide crosswind velocity range, and their combination could nearly eliminates the negative effect of the crosswind.

1. Introduction

Waste heat of the steam turbine units is generally rejected from wet cooling towers (WCTs) in coal-fired power plants, bringing forth a large quantity of water consumption [1]. Due to the serious water shortage, dry cooling technology has been increasingly used for power generation in arid countries and regions [2]. However, dry cooling is found to be sensitive to weather condition, and ambient crosswind can significantly alter the flow field around a natural draft cooling tower (NDDCT) and introduce a maximum output variation in the range of 5–10% of the nominal capacity in intraday operations [3–5]. NDDCT is one of the most important parts of a 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 [6].

Crosswind at 20 m/s decreases the ventilation rate of a NDDCT by 40.4%, and increases the temperature of circulating water by 11.6 °C [7]. It is also reported that the impacts of the crosswind could cause 7.5 °C increment of the air temperature inside the tower [8], or more than 25% decrement of the heat transfer efficiency [9]. Generally, the crosswind above 4 m/s, a gentle breeze level crosswind can be seen almost at any time, would have an obvious impact on the cooling performance of a NDDCT [10].

Consequently, many researchers have studied the crosswind influence. As summarized by Wang et al. [7, 11], the crosswind affects the cooling performance of a NDDCT generally via three parts: radiators, tower chamber and tower outlet [12,13]. Under crosswind condition, the flow fields outside the radiators [8], inside the chamber [14] and around the outlet of the NDDCT [15] are changed greatly. Vortices are formed at the back of the tower [16] and inside the tower chamber [17], and plume flow is squeezed [18], leading to unfavourable pressure distribution [19] and even suck-back of cold air [20].

According to the theoretical studies, some approaches were purposed to prevent the degradation of the cooling performance for NDDCT under crosswind condition. Based on the extensive

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Nomenclature

error	The relative error between simulation results and reference data (%)
FLF	Flow loss factor
ITD	Initial temperature difference between the cycling water and environment (K)
k	turbulent kinetic energy (J)
NDDCT	Natural draft dry cooling tower
P	Pressure (kPa)
Q	The overall heat released from the radiators (MW)
q	Mass flow rate (kg/s)
T	Air temperature (K)
t	Temperature of the circling water (K)
$\vec{V}$	Velocity (m s^{-1})

Subscripts

a	Environmental air parameter
bottom	Section below the tower chamber
chamber	Section inside the tower chamber
Piror	Flow field prior to the inlet of the tower
radiator	Radiators section
ref	Reference data
s	Source term
Sim	Simulation results
total	Total flow field through the tower

literature research, installation of windbreaks is widely recommended as an effective way [9,21–23] to reduce the degradation effect, and has been verified through numerical and experimental investigations [6,24,25]. Numerical calculation by Wang et al. [27] found an enclosure arranged outside the radiators bundle is also effective to increase the pressure level, thereby preventing the cooling performance degradation [26]. Guiding channel outside the radiators [28] and cross-wall inside the radiators [29] could also promote the cooling performance of a natural draft wet cooling tower (NDWCT). Besides, an elliptical cross section type [30], a variable height type [3], and solar enhanced NDDCTs [31–33] are reported to be effective.

In order to find out a more effective approach with better feasibility, and based on the previous research result that the pressure distribution outside the heat exchanger bundle is the main factor to the overall cooling performance of a NDDCT under crosswind condition [27], we extend the study to incorporate the adoptions of widely recommended windbreaks and the combination of windbreaks and an enclosure on the ground of the previous study of the enclosure approach presented in Ref. [11]. Hence, the advantages of each adoptions, and their interacting mechanism can be evaluated. With the help of additional research results and newly proposed data processing method, many interesting conclusions are drawn.

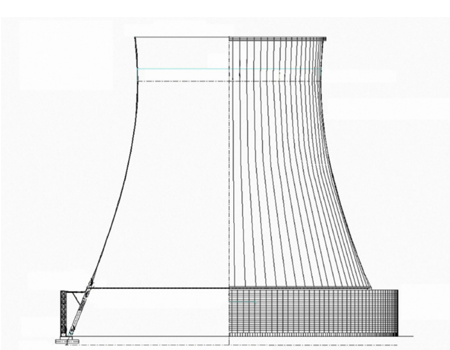

Fig. 1. Schematic of a NDDCT.

Table 1
The dimensions/details of the NDDCT.

Items	Values
Total height (m)	170
Bottom height of the chamber (m)	27.5
Thickness of the expansion platform (m)	1.5
Radiators' height (m)	24
Radiator support's height (m)	2
The outlet diameter (m)	84.47
The throat diameter (m)	82
The diameter of the base of the radiator bundle (m)	146.17
Number of radiator sectors	10
Number of deltas	183
Number of cooling columns	366
Number of radiators	1464
Radiator height (m)	6
Radiator width (m)	2.41
Radiator thickness (m)	0.15
Radiator tube type	Staggered
Dimension of the tube (mm)	80 × 6
Spacing between the adjacent fins (mm)	3.1

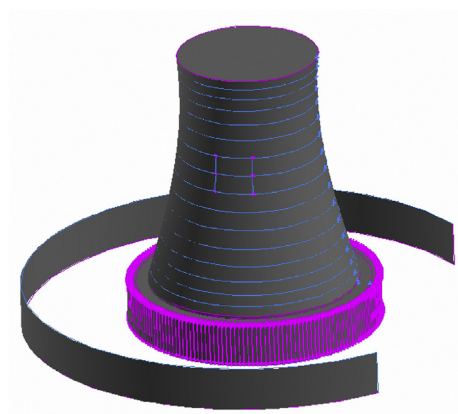

Fig. 2. Schematic of the NDDCT with an enclosure.

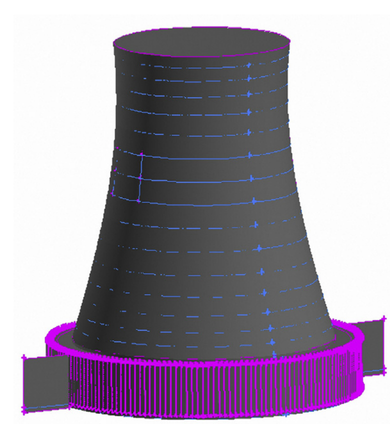

Fig. 3. Schematic of the NDDCT with windbreaks.

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