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Experimental and numerical analysis of solar enhanced natural draft dry cooling tower

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Abstract

Solar enhanced natural draft dry cooling tower(SENDDCT) is a new heat rejection device that uses solar energy to increase the cooling efficiency of natural draft dry cooling tower. In this paper, an experiment study was carried out t under natural conditions to investigate the effect of solar radiation intensity on the performance of SENDDCT. Meanwhile, a same-size CFD model was developed by using FLUENT to analyze the influence of ambient temperature on the cooling performance of SENDDCT. The results verified that SENNDCT can enhance heat transfer rate of natural draft dry cooling tower when ambient temperature was high at noon, solar radiation increased heat transfer rate by an average of 16.5% during the experiment. Air mass flow and heat transfer rate decreased with the increase of ambient temperature .

Keywords: Natural draft dry cooling tower; Solar enhancement; Heat transfer rate; CFD modeling

1. Introduction

Natural Draft Dry Cooling Towers (NDDCTs) are used widely in thermal plants to cool the the cooling water through condensers, for its characteristic of water conservation[1]. Compared to wet cooling towers and mechanical draft cooling towers, the cooling efficiency of NDDCTs is lower, especially ambient temperature is high[2]. He investigated performance of three natural draft cooling towers, i.e, a natural draft dry cooling tower(NDDCT), a pre-cooled NDDCT and a natural draft wet cooling tower(NDWCT), he found the performance of the NDDCT,the pre-cooled NDDCT and the NDWCT are significantly affected by ambient conditions; the NDWCT provides the highest

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cooling efficiency, followed by the pre-cooled NDDCT and the NDDCT; the pre-cooling can increase the NDDCT heat rejection rate by 46%, consumes 70% less water than the NDWCT[3].

To enhance performance of NDDCTs at high ambient temperature, a novel dry cooling concept, namely Solar Enhanced Natural Draft Dry Cooling Tower (SENDDCT) was proposed by Zou. Zou compared the performance of NDDCT and SENDDCT, and found that SENDDCT can increase cooling efficiency by using solar energy when ambient temperature was high[4]. Zou also developed a 3-D model for SENDDCT in ANSYS FLUENT, investigated effects of different structure of sunroof and tower shape, different height of heat exchangers and the introduction of a partial blockage on cooling performance of the SENDDCT[5-7]. Yuan analyzed the influences of the collector diameter and the types of heat exchangers on the thermal performance of the SENDDCT[8]. However, no experiment has been carried out to research SENDDCT. In this paper, the author set up a laboratory system for SENDDCT, investigated the main influential factors by numerical simulation and experiment.

Nomenclature			
A	heat transfer surface area (m^2)	T_{ac}	air temperature in collector (K)
c_{pa}	air specific heat (J/kg·K)	T_{aci}	inlet air temperature of collector (K)
c_{pw}	water specific heat (J/kg·K)	T_{aco}	outlet air temperature of collector (K)
h	convective heat transfer coefficient in collector ($W/m^2 \cdot K$)	T_{ai}	air temperature at tower inlet (K)
		T_{ao}	air temperature at tower outlet (K)
H_t	tower height (m)	T_g	ground temperature (K)
k	thermal conductivity of air (W/m·K)	T_{wi}	inlet water temperature (K)
g	gravity factor (m/s^2)	T_{wo}	outlet water temperature (K)
M_a	air mass flow rate (kg/s)	u	speed of air (m/s)
M_w	water mass flow rate (kg/s)	U	overall heat transfer coefficient ($W/m^2 \cdot K$)
Q_{ah}	heat transfer rate of air in heat exchanger (W)	v	kinematic viscosity of air (m^2/s)
Q_{ca}	heat flux, collector to air (W)	Greek symbol	
Q_{ha}	heat flux, heat exchanger to air (W)	ρ_{ai}	air density at tower inlet (kg/m^3)
Q_{ga}	heat flux, ground to air(W)	ρ_{ao}	air density at tower outlet (kg/m^3)
Q_w	heat transfer rate of water (W)	β	thermal expansion coefficient of air (k^{-1})
R	collector radius (m)	μ	dynamic viscosity of air ($N \cdot s/m^2$)

2. Experiment system and principle

As shown in Fig.1, the experiment system consists of the tower, the heat exchanger, the solar collector and the water loop. The solar collector consists of sunroof and ground. The sunroof is a transparent circular organic glass which is placed around the foot of the tower at the tower inlet height. The heat exchanger are placed horizontally along the outer edge of the solar collector, as shown in Fig.2. The major geometric of the SENDDCT studied in this paper is shown in Table 1.

In order to investigate the effect of solar radiation intensity at natural conditions on the cooling performance of SENDDCT , the experiment was carrried out in the outdoors. The experiment site located in the Tianjin area and the experiment time was sunny and windless days. By using black cloth to cover completely upper face of the collector, so that solar radiation cannot through the collector to represent no solar radiation experiment. Solar radiation intensity reaches the maximum and ambient temperature changes little during 11:00～15:00. Solar radiation intensity is the main factors influencing the performance of SENDDCT and an experiment was carried out at this moment.

The operation principle of the experiment is: hot water is cooled by natural convection heat transfer with air[9]. Solar radiation heats the ground. After passing through heat exchangers, the ambient air is further heated by the ground along its way to the tower entrance. Increasing the temperature difference between the air inside and outside the tower enhances the buoyancy force, which generates more air flow across the heat exchanger[10]. Therefore, natural convection heat transfer is enhanced and a higher cooling rate is achieved.