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Experimental study on the air flow field in the water collecting devices

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GRAPHICAL ABSTRACT

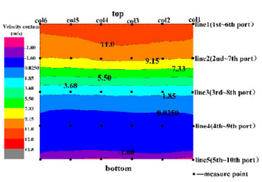


Fig.1 Velocity contours of 45° inclined slab WCDs

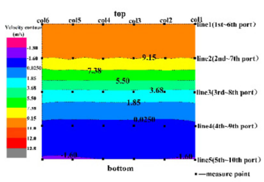
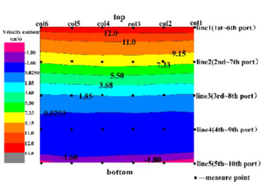


Fig.2 Velocity contours of 50° inclined slab WCDs



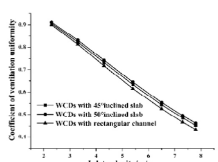


Fig.3 Velocity contours of the rectangular channel WCDs Fig.4 C_u of three different WCDs at different inlet velocities

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ABSTRACT

This paper deals with the experimental analysis on the air flow field inside the different water collecting devices (WCDs). The wind tunnel experiment is first employed in the WCDs research. The resistance to the airflow caused by the WCDs is analyzed. The stability of the air flow field in the experimental model is studied. Coefficient of the ventilation uniformity is proposed to qualitatively reveal the airflow uniformity. Compared with the conventional natural draft wet cooling tower, the cooling performance of the cooling tower with WCDs can be enhanced due to the greater air mass flow rate caused by the Venturi effect of the WCDs. The air flow field in the WCDs with rectangular channel is the most turbulent, and this kind of WCDs is recommended not to be used in practical application. Preliminary study on the numerical simulation is conducted. The CFD models for both the scaled size WCDs and the real size WCDs are developed and validated in comparison to the experimental measurements. Studies in the paper indicate that the numerical analysis on the WCDs is feasible. These conclusions lay an experimental foundation for the numerical research on the air flow field inside the WCDs.

1. Introduction

The power demand has drastically increased in recent years, which has urged the capacity of the power plant to be enhanced as well [1]. The capacity of the power plant can be enhanced by intensifying the cooling performance of the cooling system [2–5]. Therefore as the key cooling equipment, it is very necessary to enlarge the cooling tower. Currently, a lot of power plants with high capacity are planned, commissioned or even under construction in China. They are all equipped with ultra-large cooling tower for both environmental and economic reasons [6]. In the conventional

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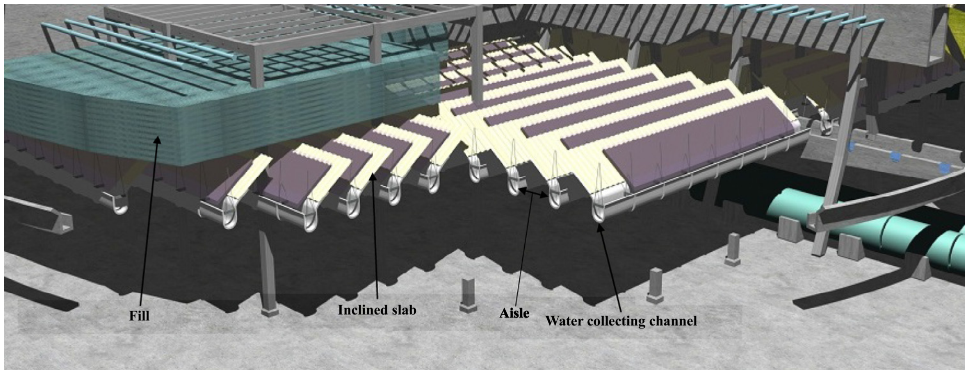

Fig. 1. Sketch map of the installation of the WCDs.

ultra-large natural draft wet cooling tower (NDWCT), the diameter at the air inlet is oversized, making the rain zone huge in scale. The resistance induced by the raindrops in the rain zone is insurmountable, so it is difficult for the air to flow into the central area of the tower. This will not happen in the natural draft wet cooling tower with WCDs. In this kind of tower, the WCDs are installed under the fill as appeared in Fig. 1 [7]. The cooling water is directly collected by the WCDs after flowing through the fill [8]. The rain zone is eliminated so the air will not be impeded by numerous raindrops and can flow easily to the center of the tower. The air distribution in the air inlet is more uniform compared with the conventional NDWCT accordingly. The pond is removed so the tower foundation can be protected from soaking. The stability of the tower shell is consequently reinforced. Without the pond and the rain zone, the acoustic pressure in air inlet also decreases. The main parts of the WCD consist the inclined slab and the water collecting channel [9] depicted in Fig. 1. Compared with the conventional NDWCT, the working performance of this kind of tower will be changed on account of substituting the WCDs for the rain zone. These changes are intimately related to the air flow field in the WCDs. It is therefore extremely important to study the air flow field in the WCDs. At present, there are still no investigations on the air flow field in the WCDs or in the similar objects although this kind of tower has been used for years. As a consequence, in this paper the air flow field in three different WCDs is analyzed based on the wind tunnel experiment. Preliminary studies involving air flow field in the WCDs via CFD research are also conducted subsequently.

2. Experimental investigations

2.1. Experimental descriptions

The wind tunnel experiment is one of the basic methodologies in hydrodynamics. It has many advantages such as convenience and high accuracy. In this paper, the wind tunnel experiment is utilized to provide the uniform inlet airflow. The wind tunnel of Shandong University is the low speed wind tunnel. Its outlet area is 1.2 m^2. The maximum wind velocity it can provide is 40m/s. The geometric similarity between the model and the prototype WCDs is 7/200. The orthogonal projection area of the model is 0.34 m^2 (0.58m $\times$ 0.58m). The ratio of the orthogonal projection area between the model and the wind tunnel outlet is 28.3%. This dissatisfies the blockage ratio that is often required (1% ~ 10%) in the wind tunnel testing [10–12]. It is because the function of the wind tunnel in this paper is just to provide the uniform airflow to the testing model. The blockage effect has no effect on the air flow field inside the model. The experiment has been conducted with three different models, each of them has eight WCDs and seven aisles as can be seen in Fig. 2. The model inlet is designed to be flaring to increase the inlet air mass flow rate. The feature sizes of different models are shown in Table 1.

During this experiment, the main parameters and the measuring instruments are detailed in Table 2.

The experimental system is outlined in Fig. 3(a,b,c). The testing regions are the two cross sections in the experimental model. In each

Fig. 2. Sketch map of the WCDs (45°, U type).

Table 1
Feature sizes of the experimental model.

Structure feature	Model 1	Model 2	Model 3
Angle of the inclined slab/°	45°	50°	45°
Thickness of the inclined slab/mm	5	5	5
Length of the inclined slab/mm	99	109	99
Water collecting channel type	U type	U type	Rectangular type
Length of the fore straight section/mm	900	900	900
Length of the rear straight section/mm	900	900	900
The cross-sectional area/mm^2	581 $\times$ 581	581 $\times$ 581	581 $\times$ 581