Key Technology of Evapotranspiration Recovery in Cooling Tower Based on Biomimetic Principle

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Abstract: In order to solve the current shortage of fresh water resources, considering the practical application, the water loss of the evaporative radiator circulating water cooling tower in industrial or refrigeration air conditioning is huge. Has great potential for freshwater recycling. This paper attempts to use air extraction technology based on the principle of bionics to study the energy saving of industrial cooling towers. In order to improve the technical measures for using the air intake water for the structure of the existing evaporative circulating water cooling tower, it is creatively proposed to install a mesh preparation network structure at the outlet of the evaporative circulating water cooling tower. It promotes the discharge of water vapor containing a large amount of water, condenses into droplets at this structure, and collects and recovers, thereby achieving the purpose of saving water resources.

1. Introduction

The traditional air intake technology is mainly divided into two types. One is achieved by an air cooler. When wet air is in contact with a cooler having a lower surface temperature, when the temperature is lower than the dew point of the air, the water vapor in the air will condense, thereby producing a water film on the surface of the cooler. The other is to absorb moisture from the air with a hygroscopic solid or liquid desiccant, heat and desorb, and condense the water vapor to obtain fresh water.

A cooling tower is a device that uses water as a coolant to circulate heat from the system and discharge it to the atmosphere, thereby reducing the temperature of the water. The principle is to use the water and air to contact and then exchange cold and heat to generate steam. The steam volatilizes away heat to achieve the principles of evaporative heat dissipation, convective heat transfer and radiant heat transfer to dissipate the waste heat generated in the industrial or refrigeration air conditioner to reduce the water temperature. Evaporative heat dissipation to ensure the normal operation of the system.

During the operation of the cooling tower, the circulating water is gradually lost due to the following factors:

1) When hot water and cold air are in the process of heat exchange in the tower, part of the water will become vaporized;

2) Because the cold air is mechanically powered and at high wind speeds, some of the water will be pumped out. Based on this, the design of reducing the fog and rain visibility of the cooling tower is adopted.

Cooling tower evapotranspiration condensation recovery device design aims to rationally recycle water resources. When designing the cooling tower condensate recovery device for the cooling tower, the bionics principle is used to treat and apply the water resources that do not meet the re-recycling, so as to avoid waste of resources. In comparison, if it can be processed into a resource

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that can be directly utilized, the waste of resources is reduced from the root. Such measures are also in line with the purpose of energy conservation and emission reduction, and should be considered in specific practice.

1) Reduce the total energy consumption. The amount of water in the circulating water cooling tower of the evaporative heat sink in the industrial or refrigeration air conditioner, especially the evaporation loss accounts for 30% to 55% of the water consumption of the whole plant, and the total amount of water consumed per year on the air conditioning cooling tower is very large, so In the current shortage of water resources, it is particularly important to recycle the cooled water from the cooling tower.

2) Maintain the surrounding natural ecological environment. In the construction and post-operation of traditional industrial cooling towers, the local natural ecological environment is often destructive. In order to change this situation from the root cause, the design ideas at this stage should conform to the green concept, and all pollution sources should be controlled and reduced.

2. Cooling Tower Evapotranspiration Condensation Recovery Device Design

2.1. Permeability

From Ma Tongze and other heat pipe network capillary core capillary force and permeability study, it can be concluded[1]

$$K_0 = \frac{a^2 t}{2.817t + 4.604a} \quad (1)$$

The permeability coefficient K0 of the capillary core composed of different meshes is calculated by the formula (1), wherein a is the mesh length and the weft wire diameter, and t is the adjacent two wire pitch.

$$K = K_0 + 0.0262 \times \left(\frac{H - H'}{m} \right)^2 \times \left[1 - \left(\frac{H'}{H} \right) \right]^{-1.26} \quad (2)$$

The accuracy obtained by calculating the range outside the average gap of 16 - 49% from the equation (2) constitutes the permeability coefficient of the actual core by the net.

Based on the above formula, it is calculated that the effect of recovering evapotranspiration is best under the condition that the gap between the meshes is about twice the thickness of the mesh.

2.2. Research and Development Content

First, a large mesh is woven so that tiny water droplets in the air are condensed into large water droplets after the encountered fine mesh lines are collected. This is a natural phenomenon that draws on the swirling of the mesh surface around the mesh in the desert. Use very fine stainless steel wire as the mesh weaving mesh, and the gap between the meshes is twice the thickness of the mesh, and the surface of the mesh is coated with a chemical coating that easily sinks the water drops. Air is taken from the water.

The mesh preparation network uses a “metal-organic framework” (MOF) porous composite material. This material is “stitched” from organic molecules and metal atoms and has very unique properties. [2]The size and chemical characteristics of the pores can be tailored to capture or pass through specific types of molecules. This material also has a large specific surface area, and the surface area per gram of material is almost as large as a football field, which allows it to be combined with a large number of particles.

In this study, materials synthesized earlier to effectively capture water molecules were used. The prototype of the material can be combined with water at night or in the shade, but during the day, sunlight provides energy to the material, converting water molecules into water vapor. The water vapor then escapes the pores of the material and enters the adjacent acrylic envelope. The condenser at the bottom of the container collects the water droplets and transports them to the lower container, thus obtaining pure water.

The process is completely spontaneous and does not require the use of additional energy, whereas previous water enrichment techniques can only be used in fog or other high humidity conditions.

This design utilizes the principle of bionics to simulate the structure of a spider web. A device for extracting moisture from the hot and humid air circulating in the cooling tower exhaust fan and recycling it has been developed.

2.3. Theoretical Basis of Thermodynamics

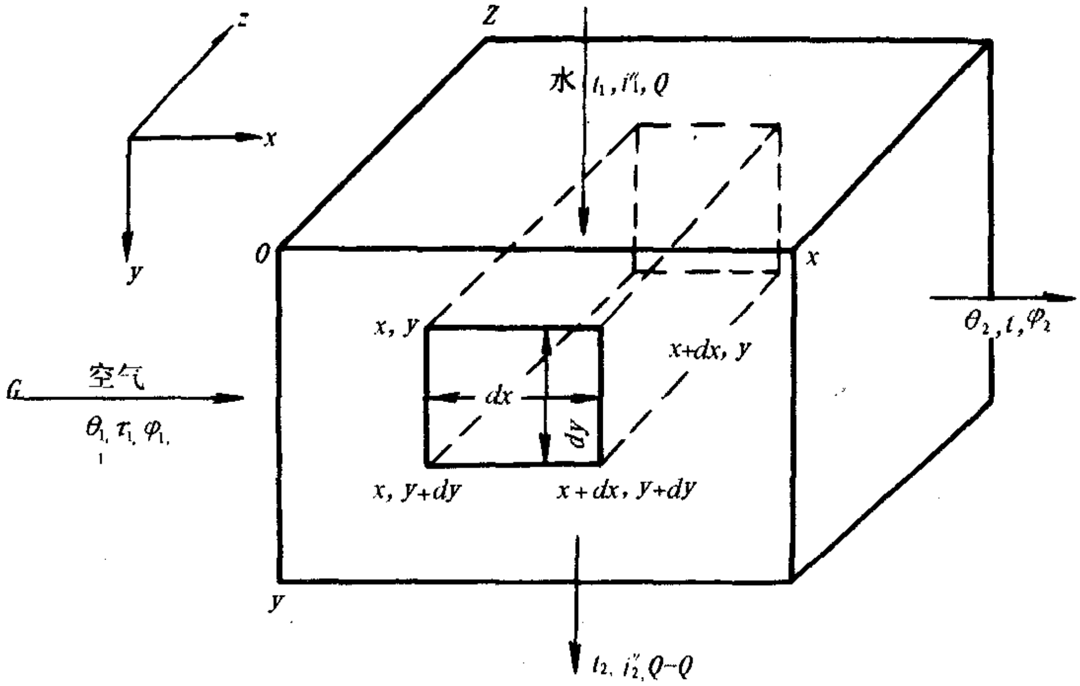

Figure 1 Cross-flow cooling tower analysis diagram.

As shown in Figure 1, we can get the following conclusions:

The amount of heat dHs emitted by water per unit time in the micro-element:

$$dH_s = -\frac{q}{K} \cdot \frac{C_w \partial t}{\partial y} dxdyz \quad (kJ/h) \tag{3}$$

$\frac{\partial t}{\partial y}$ - The change in water temperature along y.

The amount of heat dHk absorbed by the air per unit time in the micro-element:

$$dH_k = g \cdot \frac{\partial i}{\partial x} dxdyz \quad (kJ/h) \tag{4}$$

$\frac{\partial i}{\partial x}$ - Changes in the enthalpy along x.

The water temperature also changes in the x direction: $\frac{\partial t}{\partial x}$

The change of air enthalpy i in the y direction: $\frac{\partial t}{\partial y}$

Theoretical air demand: the moisture content of the tower air reaches saturation ($\varphi = 1.0$)

Theoretical gas-water ratio: the ratio of theoretical gas demand to water flow λ_T

$$\lambda_T = \frac{C_w \Delta t}{K\left(i_2'' - i_1\right)} \qquad (5)$$

i_2'' - saturated air ($\varphi = 1.0$) enthalpy when the tower air is at the tower temperature θ_2.
Out tower temperature:

$$\theta_2 = \theta_1 + \left(t_m - \theta_1\right)\frac{i_2 - i_1}{i_m'' - i_1} \qquad (°C)$$

i_m''—saturated air enthalpy kJ/kg at the average water temperature in the tower
Θ_1—the dry bulb temperature of the tower air °C

The hot and humid air of the cooling tower is accelerated by the exhaust fan power, and rises into the water-saving collecting device. The façade around the collecting device is added with an air inlet window to introduce cold air, and the two are mixed in the device. When the mixed air reaches the dew point of the cooling tower outlet plume and passes through the mist water collecting mesh device, it becomes condensed water, and the cooling tower is defogging and recovering water. [3]

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3. Cooling Tower Evapotranspiration Condensation Recovery Unit Core Design

The condensed mesh wire is woven by simulating the structure of the spider web using the principle of bionics. The common spider web is not a simple thread, and there are spirals of wet silk around it. The wet wire is distributed with a fine bead-like adhesive liquid, a hydroxy acid ester, which is an extremely hydrophilic substance that absorbs moisture in the air very easily and is used to prepare condensed water.

In order to enable the condensate wire to effectively absorb moisture from the hot and humid air flowing through the cooling tower exhaust fan, the water condensing ring and the ribs are all made of a circular wire. The surface of the condensate rib is coated with a hydrophilic coating. The circular steel wire is conducive to condensing the water droplets suspended on the surface of the steel wire to settle under the action of gravity. The hydrophilic coating is beneficial to the hot and humid air flowing through the cooling tower exhaust fan. The water condenses on the surface of the steel wire. In order to reduce the loss rate of the hot and humid air, the gap between the condensation rings of the condensed mesh wire in the design is about twice the diameter of the steel wire. [5]

The condensate structure comprises two longitudinally arranged condensed mesh wires, wherein the two condensed mesh wires are respectively composed of a plurality of concentric condensation water rings, and the condensed mesh wires have inclined steel connection meshes. The two ends of the steel wire are respectively connected to the corresponding two side edges of the two condensed water wires. The connection of the mesh wire is mainly for increasing the condensed water on the condensed water mesh located above the condensed mesh wire, and can be settled along the connecting wire to the condensed water mesh below, and finally settle into condensed water.

As shown in the schematic structural view of the apparatus of Fig. 2, the connecting mesh may also be a plurality of longitudinally distributed steel wires between the condensed mesh wires. The condensate structure shown in Fig. 3 has two longitudinally arranged condensed mesh wires, and a plurality of concentric condensation circles between the condensed mesh wires form a funnel shape.

Compared with the condensed mesh wire provided by the concentric condensation water ring, the ribs of the funnel-shaped condensed mesh wire are inclined with respect to the water condensing ring, and the rib ribs become the condensed water passages of different water condensation circles, and the condensed water continuously Accumulate to speed up the settling of condensate.

The funnel-shaped condensation ring can be designed to be opposite to the two buckets, or to be designed to be opposite to the bottom of the bucket, and can also be designed as a structure in which the bucket mouth is opposite to the bucket bottom.

In order to accelerate the settling of the condensed water on the condensate wire, a connecting shaft can also be provided between the two condensing wires. The top end of the connecting shaft is sleeved with a driven bevel gear, and the driven bevel gear is meshed with the active bevel gear, and the active bevel gear is disposed on the output shaft of the driving motor. The driving motor is in a regular starting mode, that is, the driving motor is started after a certain amount of condensed water is condensed on the condensed wire, so that the condensed wire is rotated radially under the action of the connecting shaft, and the condensed water on the condensed wire is rotating. Settling during the process. The condensation ring at the ends of the connecting shaft can be designed in a coplanar form or in the shape of a funnel. [6]

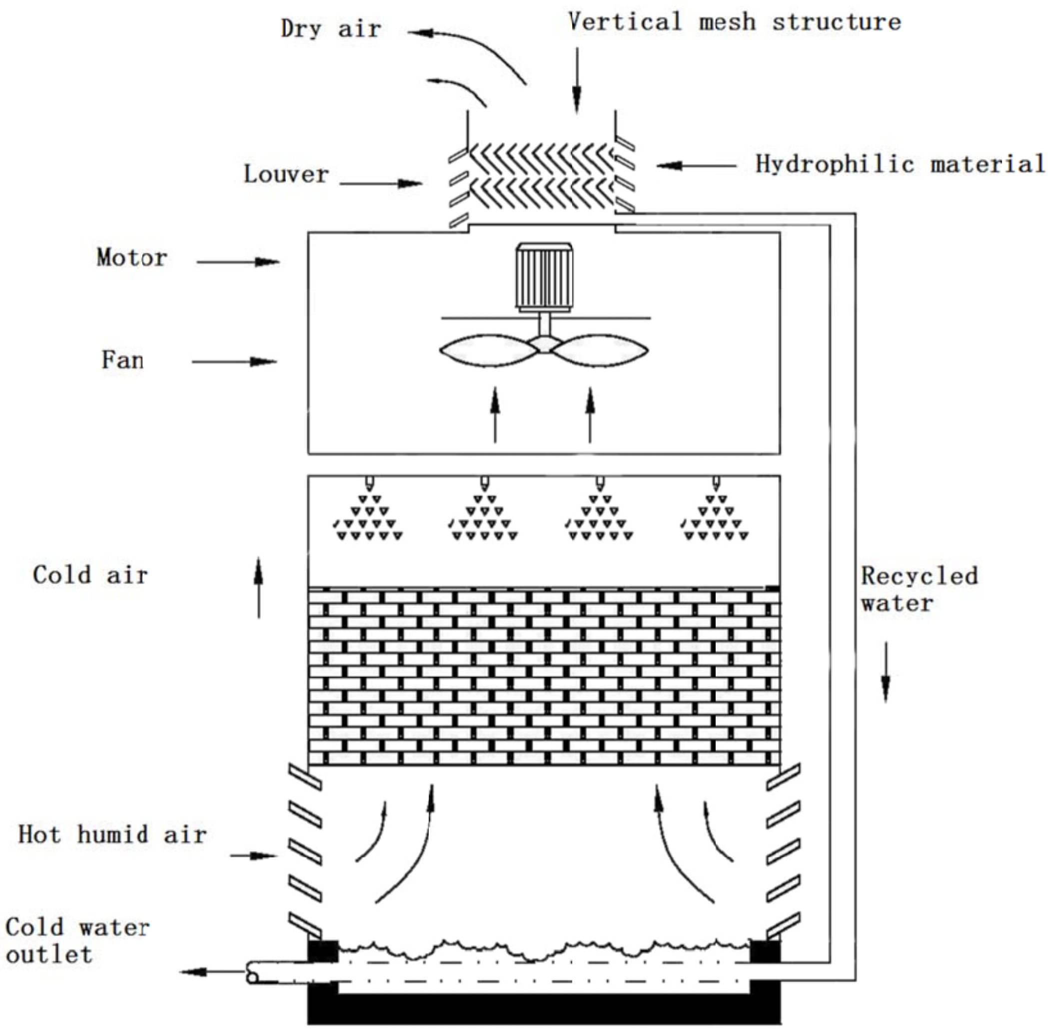

Figure 2 Schematic diagram of the device structure.

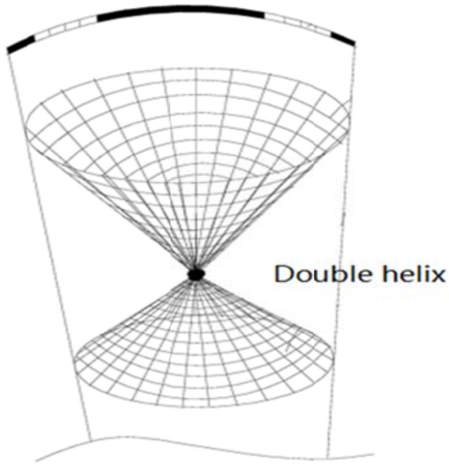

Figure 3 Schematic diagram of double helix.

4. Conclusion

The cooling tower is a kind of equipment that uses water as a circulating coolant and exchanges air and water for heat exchange. It is widely used in more and more industries and enterprises. In this paper, by reforming the structure of the cooling tower, the condensed water of the cooling tower is condensed and recovered, which is of great significance for saving water resources.

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