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Experimental Study on Solution Regeneration Performance of Closed-type Heat-source Tower

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Abstract

To prevent frosting of air source heat pump used for space heating in winter, heat-source tower heat pump has been developed for its advantages such as frost-free, stable and reliable. Due to the mass transfer process between air and solution, however, the solution can continue to absorb the moisture of air, which results in the decrease of solution concentration and the increase of freezing point. It's very essential to regenerate the dilute solution to ensure the stability and reliability of the operation of heat-source tower heat pump. Therefore, in this paper, the experimental test of closed-type heat-source tower is built to study the effect of inlet parameters of three fluids on heat and mass transfer performance under low temperature condition. According to the experimental results, with the increase of air volume, flow rate of internally heating water, so does the solution regeneration performance of closed-type heat-source tower.

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Keywords: Heat and mass transfer; Heat-source tower; Solution regeneration; Heat pump; Space heating.

1. Introduction

With many advantages such as energy-saving and environmental friendly, air source heat pump is widely used in China. In hot summer and cold winter region of China, however, due to the low temperature and high humidity of outdoor air, evaporator surface may produce severe frost, which can lead to attenuation of heat capacity and

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reduction of indoor comfort. Therefore, many scholars have carried out a majority of related research on how to prevent frosting, namely frost-free. Wang and Liu [1] firstly proposed a method to realize frost-free by dehumidifying the air using solid adsorbent before the air entering the evaporator. Similar with it, Zhang et al. [2] retarded frosting using liquid desiccant dehumidifier to decrease the humidity ratio of air. Furthermore, Zhang et al. [3] developed Wang's method by setting two evaporators, one of which is coated desiccant to dehumidify the air and the other one extracted the sensible heat of air. Jiang et al. [4] proposed a new frost-free method by spraying anti-freezing solution on the surface of outdoor heat exchanger of conventional air source heat pump. In addition, based on the cooling tower of water chiller, the heat-source tower heat pump is developed and applied for space heating in South China since 1990s[5], which can also supply heat without frosting problem by spraying anti-freezing solution in-stead of water in winter. Li et al. [6] tested the energy efficiency of closed-type heat-source tower heat pump and found that the COP was between 2.58~4.34. Cheng [7, 8] also did the similar work and found that the system efficiency increased 5%~11%. Wen et al. [9] investigated the heat and mass transfer performance of cross-flow packed heat-source tower and developed the correlation expression of heat transfer coefficients.

Due to the heat and mass transfer between solution and air, solution can continue to absorb the moisture of air, which results in the decrease of solution concentration and the in-crease of freezing point. It's very essential to regenerate the dilute solution to ensure the stability and reliability of the operation of heat-source tower. However, existing researches on solution regeneration is mainly related to the regeneration of a desiccant solution. Liu et al. [10] established a cross-flow regenerator of structured packings using LiBr aqueous solution and analysed the effects of air and desiccant inlet parameters, based on which a dimensionless mass transfer correlation was proposed. Koronaki I.P. et al. [11] developed a theoretical model of a counter flow internally heated liquid desiccant regenerator and compared the three most commonly used liquid desiccant solutions and two different flows. Relevant studies on regeneration of liquid desiccant are also carried out by other researchers [12-16].

The working condition of heat-source tower is obviously different from that of a liquid desiccant solution system [17]. Therefore, the solution regeneration in a heat-source tower is different from that of a liquid desiccant solution system, which has its own distinctive characteristics. However, the research about heat-source tower regeneration is mainly focused on the open-type packing heat-source tower [17]. And little work has been carried out on the closed-type heat-source tower regeneration. Therefore, in this paper, the heat and mass transfer performance of closed-type heat-source tower solution regeneration was investigated experimentally, in which the influencing factors were analysed in detail.

Nomenclature

c_{pw}	specific heat capacity of water, kJ/(kg °C)
k_{mv}	volumetric mass transfer coefficient between air and solution, kg/(m^{3}s)
m	mass flow rate, kg/s
r	latent heat of vaporization of water, kJ/kg
t	temperature, °C
V	volume of the device, m^3
W	moisture removal rate, kg/s
η_R	energy utilization efficiency(dimensionless)
η_m	regeneration efficiency(dimensionless)
ω	humidity ratio, kg/kg
$\Delta\omega$	logarithmic mean humidity ratio difference between air and solution, kg/kg

Subscripts

a	air
e	air in equilibrium with solution
in	inlet
out	outlet
w	water