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Preliminary investigations on a novel rotating media liquid-air contacting device without liquid pool

Jignesh R. Mehta*[,a], Tushar K. Desai[a], Akshay K. Patel[a], Hardik B. Diyora[a], Akash S. Rabadiya[a]

[a]*The Maharaja Sayajirao University of Baroda, Vadodara, 390001, India*

Abstract

Contacting device is a system that bring air and water in contact with each other in evaporative cooling systems while it brings liquid desiccant and air in contact with each other in case of liquid desiccant-based air conditioning systems. They should provide high surface area density for heat and mass transfer and also provide high heat and mass transfer rates in smaller volume with lower electrical power consumption. A novel design of contacting device is presented in this work, where plastic porous cylindrical contact media is used and unlike previous designs, the liquid pool in lower part of the device is eliminated. This would help to utilize the contact surfaces more effectively and reduce power consumption of motor used for rotation of the media as compared to earlier designs in literature. The novel contacting device and the experimental set up were developed and preliminary testing was done. The contact media is 230 mm long with diameter equal to 145 mm, providing surface area density equal to 445 m^2/m^3. In a preliminary experiment, the device provided evaporative cooling rate up to 288 W and effectiveness of 33.1%. The performance can be further improved by increasing mass flow rate of water for better wetting, increasing surface density by decreasing porosity and increasing path length of air.

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Keywords: Air conditioning; Contacting device; Evaporative cooling; Heat and mass transfer

* Corresponding author. Tel.: +91-942-637-2403;
E-mail address: j.r.mehta-med@msubaroda.ac.in

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Nomenclature

h	enthalpy
t	temperature, ^{o}C
W	humidity ratio, g_w/kg_{da}

Subscript

a	air
amb	ambient
ao	air outlet
da	dry air
ws	supply water
wo	water outlet
w	water

1. Introduction

Air Conditioning demand has increased sharply in recent times due to increased comfort expectations and development of economies in various parts of the world [1]. Rapid rise of electrical power consumption is not sustainable due to steep rise in consumption of fossil fuels given their limited reserves and climate change due to greenhouse gas emissions caused by their use [2,3]. Energy efficiency and eco-friendly technologies of air conditioning need to be developed and promoted. Evaporative cooling, desiccant cooling, absorption and adsorption cooling are some of the alternative air conditioning technologies [4-6]. In case of evaporative cooling and liquid desiccant-based air conditioning systems, liquid is brought into contact with air in a liquid-air contacting device for required heat and mass transfer. Spray tower, packed bed and falling film configurations are conventional configurations for such contacting devices [7,8]. Higher pressure drop on liquid or air side, higher liquid flow rates, difficulty in a uniform distribution of liquid etc. are some of the limitations of above conventional devices [9,10]. Rane and Reddy developed a rotating disc type contacting device, which has a trough partially filled with liquid [11]. Rane et al. used such a device for drying purpose using liquid desiccant [12]. Multiple discs are mounted on a shaft and partially submerged in the liquid pool. The disc assembly is rotated slowly, at a few rpm and brought in contact with air and liquid alternatively. This device has lower air side pressure drop and does away with liquid distribution and carryover problem. But the path of air is very short and in the cross direction to liquid flow in the trough. So, the effectiveness can be low for a single device and achieving a uniform distribution of air can be difficult.

2. Current Device

Mehta et al. modified the rotating disc type of contacting device and used counter-flow of air and liquid with liquid pool at the bottom of the cylindrical envelope [13,14]. It was tested for evaporative cooling, simulated indirect evaporative cooling and liquid desiccant-based dehumidification and regeneration. The device was tested without the flow of liquid to and from the device, which would eliminate all external heat losses but doesn't represent the actual application of the device. The liquid pool halves the contact surface area of the device and is responsible for the slow response of the device. The current device eliminates the liquid pool inside the device. This offers advantages like higher effective surface area density, lower motor power for rotation and faster response of the device. The cross-sectional area, as well as the length of the device are more and higher capacity fan is used to induce more air in order to achieve higher capacity.

A nozzle was used to spray water over the contact media from the top as the discs do not dip into the liquid pool now. The air passes through the wet media, which is again cylindrical in shape but is made from plastic to reduce the mass of the device. The contact media is made from plastic mesh with cross-wires having average 1.3 mm width