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Experimental study on cooling performance of air conditioning system with dual independent evaporative condenser

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ABSTRACT

Evaporative condenser is an energy efficient and environmentally friendly air conditioning equipment. This paper proposed an air conditioning system using dual independent evaporative condenser and investigated the cooling performance. Many factors, such as evaporator water inlet temperature, compressor frequency, air dry-bulb temperature, air velocity and water spray rate, which influenced the cooling performances of air conditioning system with evaporative condenser have been investigated. The results indicated that cooling capacity and coefficient of performance (COP) increased significantly with the increasing of evaporator water inlet temperature (12–25 °C), the air velocity (2.05–3.97 m s^{-1}) and the water spray rate (0.03–0.05 kg m^{-1} s). However, COP decreased with the increasing ambient air dry-bulb temperature (31.2–35.1 °C) and the compressor frequency (50–90 Hz). Furthermore, the heat transfer coefficient (K_0) was 232–409 W m^{-2} K^{-1} in different air velocity and water spray rate.

Etude expérimentale des performances de refroidissement d'un système de conditionnement d'air à double condenseur évaporatif indépendant

Mots-clés : Double condenseur évaporatif indépendant ; Performance de refroidissment ; Economie d'énergie ; Coefficient de transfert de chaleur

1. Introduction

In order to increase the performance of an air conditioner, one of the best solutions is to decrease the condensing temperature and pressure. Reducing the condensing temperature reduces the pressure ratio of the compressor, which results in reduction in power consumption. To reduce the condensing temperature, the evaporative condenser is widely used. Evaporative condenser

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Nomenclature

C	physical property parameter, constant
COP	coefficient of performance
C_m	physical property parameter
C_p	specific heat (kJ (kg °C)$^{-1}$)
d	tube diameter (m)
F	heat exchange area (m^2)
h	specific enthalpy (kJ kg^{-1})
k_0	heat transfer coefficient (W m^{-2} K^{-1})
$\dot{m}$	mass flow rate (kg s^{-1})
m	physical property parameter, constant
P	pressure (Mpa)
Pr	Prandtl Number
Q	heat rate (kW)
Q_c	cooling capacity (kW)
Re	Reynolds Number
RH	air relative humidity (%)
r_s	physical property parameter
T	temperature (K)
t	temperature (°C)
t_k	condensing temperature (°C)
t_w	cooling water temperature (°C)
V	air velocity (m^3 h^{-1})
W	power consumed (kW)

Greek

α_k	refrigerant heat transfer coefficient (W m^{-2} K^{-1})
α_w	water heat transfer coefficient (W m^{-2} K^{-1})
α_{wa}	air heat transfer coefficient (W m^{-2} K^{-1})
Γ	water spray rate (kg s^{-1} m)

Subscripts

a	air
com	compressor
i	inside tube
in	fluid inlet
o	outside tube
out	fluid outlet
pump.e	evaporator water pump
pump.c	evaporative condenser water pump
fan.c	evaporative condenser fan
r	refrigerant/working fluids
w	water
wa	water to air
1,2,3	exit conditions from evaporator, compressor and condenser

requires very little power to operate a small water pump and an air fan (Santamouris and Kolokotsa, 2013; Qureshi and Zubair, 2006a,b, 2011; She et al., 2014; Youbi-ldrissi et al., 2007). Meanwhile, evaporative cooling is one of the energy-saving, environmentally friendly and sustainable air-conditioning technologies, which is now widely used in residential and commercial buildings, especially in hot and arid areas, such as the northwest of China (Li et al., 2011; Xuan et al., 2012a,b).

Several researchers conducted experimentation and modeling of evaporative cooling system. Hajidavalloo and Eghtedari (2010) proposed an application of evaporatively cooled air condenser. The results showed that the power consumption could be reduced up to 20% and the coefficient of performance could be improved around 50% in hot weather conditions. Sarntichartsak and Thepa (2013) proposed an inverter air conditioner using R410A with evaporative cooled condenser, and tested the performance of this air conditioner under the condition of frequency range of 30–90 Hz and different water injection rate. The proposed models were also verified with test data. Beshkani and Hosseini (2006) modeled and investigated the performances of the rigid media evaporative cooler. The results indicated that the efficiency was improved by decreasing the air velocity and increasing the depth of media, and efficiency was approximately independent of velocity with increasing depth to a certain value. Hajidavalloo (2007) investigated the application of evaporative cooling system in a window air conditioner. The test results showed that power consumption decreased by about 16% and COP increased by about 55%. Heyns and Kröger (2010) investigated the performance characteristics of an evaporative cooler consisting of 15 tube rows with 38.1 mm outer diameter galvanized steel tubes arranged in a 76.2 mm triangular pattern. The results showed that the pressure drop across the bundle was a function of the air mass velocity and the deluge water mass velocity. Xiaoli Hao et al. (2013) investigated an evaporative air-cooled chiller (EACC) including an evaporative air cooler and a conventional air-cooled chiller. The results showed that the maximum energy saving potential of EACC in China was between 2.4% and 14.0% depending on the climatic condition.

Frank Bruno (2011) proposed a novel dew point evaporative cooler. The results showed that the temperatures of the incoming air could approach its dew point temperature. Shahram Delfani et al. (2010) proposed a combined experimental setup consisting of an indirect evaporative cooling system and packaged unit air conditioner. The results indicated that indirect evaporative cooling system could reduce cooling load to 75%. Gaosheng Wei et al. (2012) designed an evaporative condenser for steam condensing of mini-turbine of steam feeding pump for 1000 MW air-cooled unit. The relationships between condensing temperature and air temperature, water film temperature increasing and velocity of the wind were also analyzed.

Jia Yang et al. (2012) investigated the effect of operating water mist system to enhance the performance of air-cooled chillers under various operating conditions. The results showed that the entering condenser air temperature could drop by up to 9.4 K, and the condensing temperature could drop by up to 7.2 K, furthermore, chiller COP in various degreed up to 18.6%. Sheng and Agwu Nnanna (2012) evaluated the relationship between system parameters (speed of frontal air, the dry-bulb temperature of frontal air, and the temperature of the incoming water) and cooling performance. The results showed that lower velocities, lower cooling water temperatures, and higher heating unit temperatures all resulted in higher efficiencies. Nasr and Salah Hassan (2009) proposed an innovative evaporative condenser and tested a vapor compression cycle incorporating this evaporative condenser. The results showed that condensing temperature