Energy Conversion and Management 138 (2017) 518–525

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Experimental study of a novel integrated system of indirect evaporative cooler with internal baffles and evaporative condenser

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ARTICLE INFO

Article history:
Received 25 December 2016
Received in revised form 25 January 2017
Accepted 10 February 2017

Keywords:
Experimental work
Indirect evaporative cooler
Evaporative condenser
Cross flow heat exchanger
Baffle plate
Cooling load

ABSTRACT

In this study, the performance of a novel integrated system of indirect evaporative cooler with internal baffles as air pre-cooling unit and evaporative condenser has been experimentally investigated. For this purpose, the experimental setup consisting of an indirect evaporative cooler with internal baffles followed by an evaporative condenser contains the hot water serpentine tubes with external thin film cotton layer was designed, constructed and tested. The influences of pre-cooling unit and the external thin film cotton layer on the performance of the evaporative condenser are investigated. The experimental results show that, for increasing the air flow rate from 250 to 1450 m^3/h, the temperature difference of hot water through the evaporative condenser change in the ranges between 13 and 24.9 °C for the case without pre-cooling unit, 17.6–38.4 °C for using the pre-cooling unit with internal baffles and with use the thin film cotton layer. Also, the rate of change of the cooling load is in the ranges between 166 and 318 kW for case without pre-cooling unit, but for using the pre-cooling unit with internal baffles and with use the thin film cotton layer the cooling load change between 224.7 and 490.3 kW. For using the external thin film cotton layer on the tubes of cross flow heat exchanger and with use the pre-cooling unit with internal baffles before the evaporative condenser the percentage increases in the cooling load change between 35.4 and 54.2% compared to the evaporative condenser without pre-cooling unit.

1. Introduction

Decreasing energy utilization in vapor compression systems represents an essential requirement, particularly in zones with extremely hot climate conditions. The rate of electrical energy consumption of these systems and the performance of these systems diminish strongly in hot climate conditions. To improve the performance of vapor compression systems the evaporative condenser used to improve the heat rejection process, and therefore the decline in the rate of consumption of electrical energy and improved performance of the system. In the vapor compression system, the condenser used to reject the heat energy gained during evaporation and compression process of refrigerant to ambient air. The condenser can be classified based on the type of the cooling medium into three types named water cooled, air cooled, and combination of both types known as the evaporative condenser.

Liu et al. [1] experimentally studied the influence of evaporative condenser on the energy efficiency for air conditioning system. The experimental results show that, the system performance increase with increases the air velocity and water spray rate. Liu et al. [2] experimentally investigated the impact of evaporative condenser on the energy saving and cooling performance of the gas engine. The results showed that, the performance of the system with evaporative condenser increase with increase the air velocity and decrease the ambient air temperature. Martínez et al. [3] used the evaporative cooling pad to enhance the performance of air conditioning unit. The experimental studied showed that, the cooling capacity is increased by 1.8%, power consumption is reduced by 11.4%, and COP is increased by 10.6%. Harby et al. [4] presented the impact of evaporative condenser on the heat rejection and the system performance for air-conditioning, refrigeration and heat pump systems. It is found that, the reduction in the power consumption up to 58% and the improvement on the coefficient of performance up to 113.4%.

Several researchers studied the development of indirect and direct evaporative systems. Pescod [5] studied the characteristics of indirect evaporative cooler with small thermal behavior of thin plastics plates. The behavior of the indirect evaporative cooler calculated by using the model was conducted by Alonso et al. [6]. This model is general and used to study the performance of various

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http://dx.doi.org/10.1016/j.enconman.2017.02.025
0196-8904/

evaporative coolers. Joudi and Mehdi [7] calculated the performance of direct and indirect evaporative system. They conducted four modes to study the system performance in the summer. They found that the system performance very high because the small amount of energy consumed. Ren and Yang [8] developed the mathematical model used to calculate the mass and heat transfer in an indirect evaporative cooler. This model is one of the each model for mass and heat transfer in indirect evaporative cooler. Heidarinejad and Bozorgmehr [9] theoretically studied the performance of indirect/direct evaporative air cooler for some cities. Heidarinejad et al. [10] investigated the behavior of indirect evaporative cooler integrated with direct evaporative cooler. They found that, the power saving about 60% for using indirect and direct evaporative cooler in comparison to the conventional vapor compression system.

Heidarinejad et al. [11] theoretically studied the behavior of a ground-assisted direct evaporative system. In this study a ground loop used to cooling the inlet air before it supplied to direct evaporative cooling. They found that the hybrid system is capable to achieve the conditions of thermal comfort whereas direct evaporative cooling alone did not. Khalajzadeh et al. [12] theoretically investigated the behavior of a novel coupled system consists of a ground-coupled circuit and an indirect evaporative cooler. They found that the combination of this system could easily provide comfort conditions. Woods and Kozubal [13] investigated the results on an air conditioner consist of indirect evaporative cooler and liquid desiccant dehumidifier.

Cui et al. [14] studied the behavior of evaporative cooler based on a new log mean temperature difference method. Buker et al. [15] experimentally studied the performance of a solar energy assisted liquid desiccant dehumidifier. Pandelidis and Anisimov [16] numerically studied the mass and heat transfer in eight-type of the M-Cycle mass and heat exchangers. They found that the behavior of the mass and heat exchanger depends on the parameters of intake air. Younis et al. [17] conducted the models to study the behavior of the displacement ventilation integrated with evaporative cooling system. They found that the energy saving about 36.2% for using displacement ventilation system integrated with a novel evaporative cooling ceiling compared to the displacement ventilation integrated chilled ceiling.

Riangvilaikul and Kumar [18] experimentally conducted the behavior of an indirect evaporative cooler under different running conditions. The system was working in humid and hot region and it found that the effectiveness change from 92 to 114%. Maheshwari et al. [19] conducted the impact of using the direct evaporative cooler in a hot and dry region. The indirect evaporative cooler used for pre-cooling the ambient air. Zhan et al. [20] theoretically and experimentally investigated the behavior of heat exchanger for indirect evaporative cooler.

Kabeel and Mohamed Abdelgaied [21] studied the influence of internal baffles on the behavior of indirect evaporative cooler, the resulted showed that, the outlet cooling air temperature decreased by 20.5% and average wet bulb effectiveness increased by 43% for using the internal baffles compared to the case without internal baffles.

From the above-mentioned researchers, the energy consumption can be reduced and the system performance can be improved for air conditioning systems, gas engine and refrigeration by using the evaporative condenser. The objective of the present work is improve the performance of the evaporative condenser by using an indirect evaporative cooler with internal baffles as air pre-cooling unit and external thin film cotton layer on the tubes of cross flow heat exchanger. In this study, the performance of a novel integrated systems of indirect evaporative cooler with internal baffles as air pre-cooling unit and evaporative condenser has been experimentally investigated. For this purpose, the experimental setup consisting of an indirect evaporative cooling with internal baffles followed by an evaporative condenser contains the hot water serpentine tubes with external thin film cotton layer was designed, constructed and tested. The influences of pre-cooling unit and the external thin film cotton layer on the tubes of cross flow heat exchanger on the performance of evaporative condenser are investigated. The experimental results have been evaluated to quantify the system performance in terms of the hot temperature difference through the heat exchanger, cooling load and percentage increase in the cooling load for the novel integrated system compared to the conventional evaporative condenser.

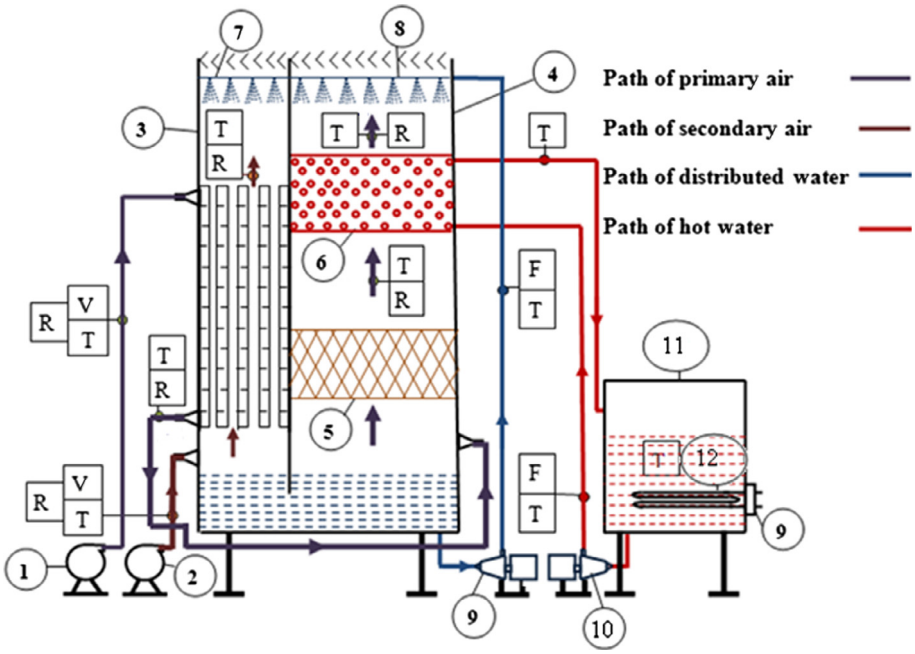

Fig. 1. Schematic diagrams of novel integrated system of indirect evaporative cooler with internal baffles and evaporative condenser.