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Performance enhancement of air-cooled chillers with water mist: Experimental and analytical investigation

Jia Yang [a,b,*], K.T. Chan [a], Xiangsheng Wu [b], Xiaofeng Yang [b], Hongyu Zhang [b]

[a] Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong, China
[b] Department of Real Estate Management and Environmental Engineering, Logistical Engineering University, Chongqing, China

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ABSTRACT

This paper investigates how water mist evaporative pre-cooling can be applied to air-cooled chillers to improve the chiller efficiency by on-site experimental studies. There is a lack of detailed experimental studies on the application of water mist system on air-cooled chillers. The experiment was conducted on a chiller plant with water mist system in a subtropical climate. The experimental results showed that the dry bulb temperature (DBT) of entering condenser air with water mist pre-cooling could drop by up to 9.4 K from the ambient air temperature, and the approach could be as low as 0.5 K. A thermal effectiveness of up to 0.91 was obtained in using the water mist system. The pre-cooled condenser air enabled a drop of the condensing temperature by up to 7.2 K, and the chiller coefficient of performance (COP) could be improved in varying degrees by up to 18.6%. This study demonstrates that the water mist system coupled to air-cooled chillers is an energy-efficient and environment friendly technique, which has significant potential to improve the efficiency of air-cooled chillers and reduce the electricity demand for the commercial and industrial sector.

1. Introduction

Large commercial buildings in Hong Kong typically require cooling year round, and centralized water chillers are commonly used for providing space cooling. The operation of chillers accounts for about 40% of the annual total energy use in commercial buildings in a subtropical climate [1,2], which contributes considerable greenhouse gas emissions. The chiller efficiency is a matter of concern, which is subjected to influence by the heat rejection method, load ratio, external conditions and compressor efficiency. Air-cooled chiller systems are commonly used in commercial buildings due to its flexibility, the ease of installation, the simplicity of operation and maintenance, especially for the cities with water shortage problem. Compared with water-cooled chillers, air-cooled chillers are generally energy inefficient. The deficient performance of air-cooled chillers is mainly due to the traditional operation under head pressure control (HPC), whereby minimal condenser fans are staged to control the condensing temperature to float around a high set point of 50 °C. The use of HPC is due to a convention that the proper function of thermostatic expansion valves needs a high pressure differential of at least 690 kPa to control refrigerant flow properly. The use of electronic expansion valves enables the required differential pressure to be as low as 290 kPa for ensuring compressor lubrication [3]. Under such control strategies, the condenser fan power can be minimized, but the compression efficiency becomes lower and the compressor power remains high, which causes a considerable decrease in COP when the chillers operate under part load conditions. It is, therefore, desirable to increase the chiller COP through improving the operational control of their components. Some researchers have stated the opportunity to lower the condensing temperature to improve the operating efficiency of air-cooled chillers [2,4,5].

As condenser fans force ambient air to condense and slightly subcool the refrigerant, the extent of the condensing temperature drop is constrained by the dry bulb temperature (DBT) of ambient air. Evaporative cooling can pre-cool the ambient air before entering the condenser, which is effective for improving the performance of air-cooled chillers. This concept is enhanced at present in consideration of energy saving and environmental protection.

Refrigeration systems with evaporative condensers have been applied for years. For the evaporative condensers, ambient air is drawn or blown through a porous wetted surface with a film of cool water. The air stream is cooled by the evaporation of water, and its DBT drops to approach its wet bulb temperature (WBT). With

* Corresponding author. Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong, China. Tel.: +852 2766 5837; fax: +852 2765 7198.
E-mail address: 07901070r@polyu.edu.hk (J. Yang).

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