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Numerical study of a M-cycle cross-flow heat exchanger for indirect evaporative cooling

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ABSTRACT

In this paper, numerical analyses of the thermal performance of an indirect evaporative air cooler incorporating a M-cycle cross-flow heat exchanger has been carried out. The numerical model was established from solving the coupled governing equations for heat and mass transfer between the product and working air, using the finite-element method. The model was developed using the EES (Engineering Equation Solver) environment and validated by published experimental data. Correlation between the cooling (wet-bulb) effectiveness, system COP and a number of air flow/exchanger parameters was developed. It is found that lower channel air velocity, lower inlet air relative humidity, and higher working-to-product air ratio yielded higher cooling effectiveness. The recommended average air velocities in dry and wet channels should not be greater than 1.77 m/s and 0.7 m/s, respectively. The optimum flow ratio of working-to-product air for this cooler is 50%. The channel geometric sizes, i.e. channel length and height, also impose significant impact to system performance. Longer channel length and smaller channel height contribute to increase of the system cooling effectiveness but lead to reduced system COP. The recommend channel height is 4 mm and the dimensionless channel length, i.e., ratio of the channel length to height, should be in the range 100 to 300. Numerical study results indicated that this new type of M-cycle heat and mass exchanger can achieve 16.7% higher cooling effectiveness compared with the conventional cross-flow heat and mass exchanger for the indirect evaporative cooler. The model of this kind is new and not yet reported in literatures. The results of the study help with design and performance analyses of such a new type of indirect evaporative air cooler, and in further, help increasing market rating of the technology within building air conditioning sector, which is currently dominated by the conventional compression refrigeration technology.

1. Introduction

Air conditioning of buildings is currently dominated by conventional compression refrigeration system, which takes over 95% of the market share in this sector. This kind of system is highly energy intensive due to extensive use of electricity for operation of the compressor, and therefore, is neither sustainable nor environmentally friendly. The use of indirect evaporative cooling has a high potential for meeting air conditioning needs at low energy costs. This, however, is dependent on the capacity of additional water vapour that can be held by the cooling air stream. Whilst more commonly applied in hot, arid climatic regions such as the Middle East, part of the Far East, North/South America and Europe, there is an increasing trend for such systems to be applied in 'low energy' building designs in less suited climatic regions such as in the UK. Recent research associated with projected future climate in the UK shows at least a probable increased potential for evaporative cooling in this region, particularly when being jointly operated with desiccant dehumidification [1,2].

Indirect evaporative cooling systems have the advantage of being able to lower the air temperature without increasing humidity of the conditioned space and avoid potential health issues from contaminated water droplets entering occupied spaces (as associated with direct evaporative cooling systems). These systems usually require much less electric power that mechanical vapour compression uses for air conditioning [3]. Therefore, such systems will help reduce electricity consumption, and thus contribute to reducing greenhouse gas emissions. It has widely been used as a low energy consuming device for various cooling and air

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