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Indirect Evaporative cooling systems: modelling and performance analysis

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Abstract

Nowadays, there are a lot of ongoing research activities about cooling technologies which can lead to a significant reduction in primary energy consumption of air handling units, in both residential and commercial applications. In this context, one of the most interesting technologies is the indirect evaporative cooling (IEC) system. In this work a phenomenological model of the component, based on a cross flow heat exchanger, has been developed and validated in typical summer operating conditions, at different air streams temperature, humidity ratio and flow rates. Using this tool, performance of the IEC system has been analyzed in different working conditions. Results highlight the advantage of using the IEC unit, which leads to significant energy savings in almost all the investigated conditions.

Keywords: indirect evaporative cooling, performance, cross flow, heat exchanger;

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1. Introduction

The indirect evaporative cooling technology (IEC) is a solution that can be used in the air handling units to reduce the energy consumption during the summer period, both in residential and commercial applications.

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In this system, the exhaust air, at ambient conditions, is humidified with water sprayed by the nozzles installed in proximity of the heat exchanger entrance; at the same time, the supply air, at outdoor temperature and humidity, is cooled down by the fresh and humid air of the opposite side.

Nowadays there are a lot of ongoing research activities about the IEC solutions; at the moment, main works have focused on studying prototypes [1, 7, 8] or particular operative conditions [5, 6]. Anyway there aren't works analyzing performance of IEC systems based on cross flow plate heat exchangers in typical summer conditions.

Nomenclature

$A_{HE,net}$	Heat exchanger net cross section area, m^2
cp	Specific heat, J kg^{-1} K^{-1}
Cw	Wettability coefficient, -
f_{eva}	Fraction of the adsorbed water, -
h	Net channel height, m
h_M	Convective mass transfer coefficient, kg s^{-1} m^{-2}
h_T	Convective heat transfer coefficient, W K^{-1} m^{-2}
k_W	Plate conductivity, W m^{-1} K^{-1}
L	Net heat exchanger length, m
$\dot{m}$	Specific mass flow rate, kg s^{-1} m^{-2}
N_{HE}	Number of heat exchanger plates, -
pt	Heat exchanger plates pitch, m
$\dot{Q}$	Flow rate, m^3 h^{-1}
$\dot{Q}w$	Water flow rate sprayed on the heat exchanger, l h^{-1}
T	Temperature, °C
v	Velocity, m s^{-1}
x	Primary air flow direction, m
X	Humidity ratio, kg kg^{-1}
y	Secondary air flow direction, m
Greek symbols	
δ	Heat exchanger plates thickness, mm
ΔT	Temperature difference, °C
ε	Heat exchanger effectiveness, -
ε_{wb}	Wet bulb IEC effectiveness, -
ρ	Density, kg m^{-3}
σ	Wettability factor, -
φ	Relative humidity, -
Subscript	
a	Air
ex	Exhaust air
HE	Heat Exchanger
in	Inlet
out	Outlet
su	Supply air
W	Wall heat exchanger plates
wb	Wet bulb temperature
Superscript	
N	In reference conditions (ρ = 1,2 kg m^{-3})