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Practical thermal performance correlations for molecular sieve and silica gel loaded enthalpy wheels

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Abstract

The central thrust of this research was to develop practical enthalpy wheel effectiveness correlations useful for enthalpy wheel integrated systems design and analysis. In this research, enthalpy wheel performance data generated using established fundamental enthalpy wheel models were statistically analyzed. And then, first order linear regression equations were derived to estimate the enthalpy wheel sensible and latent effectiveness at normal operating rotational speeds (i.e. over 20 rpm). The two most common desiccant materials, silica gel and molecular sieve on aluminum substrate, were analyzed. Each correlation relates the enthalpy wheel sensible and latent effectiveness as a function of six parameters; incoming outdoor air and exhaust air temperature and relative humidity, face velocity, and air flow ratio. The enthalpy wheel leaving air conditions can then be simply estimated by employing the practical effectiveness correlations. Predicted effectiveness values corresponded well with published manufacturer's data and existing fundamental enthalpy wheel models.

Keywords: Enthalpy wheel; Desiccant cooling; Dedicated outdoor air system; Molecular sieve; Silica gel

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Nomenclature

A	cross-sectional area of one flute, m^2
A_s	heat and mass transfer surface area on the supply or exhaust side, m^2
A'_s	heat and mass transfer surface area of one flute, m^2
C	constant describing the sorption curve shape
$C*$	ratio of heat capacity rate of the air streams
C_p	specific heat, J/kg K
Cr_o^*	overall matrix heat capacity ratio
Crm_o^*	overall matrix moisture capacity ratio
D_h	hydraulic diameter of a flute, m
h	enthalpy, J/kg
h_c	convective heat transfer coefficient, $W/m^2 K$
h_{fg}	heat of vaporization, J/kg
h_m	mass transfer coefficient, m/s
k	thermal conductivity, W/m K
L	length of the enthalpy wheel, m
M	total mass, kg
m	mass flow rate of dry air, kg/s
m'	rate of phase change per unit length, kg/s m
N	wheel rotating speed, cycles/s
NTU_o	overall number of transfer unit
Q	air flow rate, L/s
Q_R	air flow ratio, Q_{ea}/Q_{oa}
T	temperature, °C
t	time, s
U	mean air velocity in the flute, m/s
u	mass fraction of water in the desiccant
V_{fi}	face velocity, m/s
W	humidity ratio, g_w/kg_{da}
W_m	empirical coefficient describing the maximum moisture content of the desiccant, kg/kg
x	axial coordinate, m

Greek symbols

α	thermal diffusivity, m^2/s
ε	effectiveness
ϕ	relative humidity, %
η	fraction of the phase change energy delivered directly to the air
ρ	density, kg/m^3

Subscripts

a	air