PERFORMANCE EVALUATION OF ROTARY DESICCANT WHEELS USING A SIMPLIFIED PSYCHOMETRIC MODEL AS DESIGN TOOL

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ABSTRACT

In the present communication, a psychometric model has been presented to evaluate the performance of rotary desiccant wheels based on different kind of desiccants e.g. silica gel and LiCl. The developed psychometric model is based on simple correlations between the relative humidity and enthalpy of supply and regeneration air streams. The model is used to predict the performance of three type of desiccant rotors (Type-I, II and III). The model is tested corresponding to a wide range of measurement data. The developed psychometric model is simple in nature and can be used as design tool for performance evaluation of different kind of desiccant rotors.

KEYWORDS

Building comfort, desiccant rotary wheel, psychometric model, performance evaluation

INTRODUCTION

Desiccant cooling (Lof et al., 1985, Waugaman et al., 1993, Lof, 1992) is basically an open cooling cycle consisting of a dehumidifier, sensible heat exchanger and evaporative water spray cooler. In a desiccant cooling system (DCS), the potential for the application of evaporative cooling is increased by means of air dehumidification. The other interesting feature of this technology is that the low temperature heat (around 50-80 °C) required for regeneration can be obtained by integrating it with a solar thermal plant or utilizing waste heat from industrial or cogeneration process (Henning et al., 2001).

In a DCS system, the air dehumidifiers utilize either liquid or solid desiccants viz. silica gel, LiCl etc. In the literature, many mathematical models have been proposed to assess the performance of rotary desiccant for a given operating conditions (Maclaine-Cross, 1988, Davanagere et al., 1999, Collier and Cohen, 1991, Zheng, 1999, Dai et al., 2001). Generally the mathematical models developed for simulating the performance of rotary desiccant wheels are based on detailed heat and mass transfer phenomena inside the system and are very complex. The research work on solar assisted air-conditioning of buildings is being carried out at Politecnico di Milano under IEA-Task 25 Programme. In this respect, extensive work has been carried out on the performance evaluation of various kinds of rotary desiccant wheels available in the market.

In the present paper, a psychometric model has been presented to evaluate the performance of rotary desiccant wheels based on different kind of solid desiccants e.g. silica gel and LiCl. The developed psychometric model is based on simple correlations between the relative humidity and enthalpy of supply and regeneration air streams. The model is used to predict the performance of three type of desiccant rotors manufactured by using different kind of solid desiccants (Type-I, II and III). The model is tested corresponding to a wide range of measurement data. The developed psychometric model is simple in nature and able to predict very well the performance of different kind of desiccant rotors.

PSYCHOMETRIC MODEL

The measurement data for different kind desiccant wheels (Type-I,II and III) has been obtained from the industry. The performance data is available corresponding to a wide range of inlet temperature (20-32°C), regeneration temperature (40-80°C), inlet absolute humidity (7-16 g/Kg) and regeneration humidity (7-16 g/Kg). The measured data is analysed and the various equations have been derived from interpolations of measured data related to the performances of Silica Gel solid desiccant wheel. It has been observed that the measured parameters the UR (relative humidity) and enthalpy (h) can be expressed through a linear correlation of the following type:

$$\Delta UR = (UR_{in} - UR_{out}) = m\,(UR_{in} - UR_{reg}) + q \qquad (1)$$

$$\Delta h = (h_{out} - h_{in}) = m'\,(h_{reg} - h_{in}) + q' \qquad (2)$$

where the enthalpy (h) is a function of absolute humidity and the temperature.

For the calculation of relative humidity, following empirical relation has been developed (Beccali et al., 2002):

$$UR=(18.6715\,X + 1.7976)\,e^{-0.053T} \qquad (3)$$

The above equations (1-3) are valid for each kind of desiccant wheel and m, q, m', q' are the only parameters to be calculated. In the present work, the coefficients m, m', q, q' have been calculated by analysing the field data obtained from the industries for three different kind of desiccant wheels. We named them Type-I, II and III, and among them two are based on silica gel solid desiccant and another one is based on LiCl as solid desiccant.

The system of equations (1-3) has been solved for calculating outlet absolute humidity (X_{out}) and temperature (T_{out}) and the following solution is obtained:

$$X_{out} = \frac{[e^{0,053\,T_{out}}\,(0.9428\,UR_{reg} + 0.0572\,UR_{in}) - 1.7976]}{18.671} \qquad (4)$$

$$\frac{(UR_{out}\, e^{0.053\, T_{out}} - 1.7976)}{18671.0} = \frac{(h_{out} - 1.006\, T_{out})}{(2501 - 1.805\, T_{out})} \quad (5)$$

It is to be noted that for calculating the outlet temperature (T_{out}), the equation (5) has to be solved by iteration.

On analysing field data for three different kind of desiccant wheel, it has been found that the equation (3) for relative humidity difference (UR) can be expressed by following equation which is valid for all kind of desiccant wheel:

$$UR_{out} = (0.9428\, UR_{reg} + 0.0572\, UR_{in}) \quad (6)$$

However, for enthalpy calculations, there is a need to find out coefficients m_ and q_ corresponding to different type of desiccant wheels. We have developed following equations for enthalpy calculations corresponding to various types of desiccant wheels, which can be expressed as follows:

Desiccant Wheel Type-I

$$h_{out} = (0.1312\, h_{reg} + 0.8688\, h_{in}) \quad (7)$$

Desiccant Wheel Type-II

$$h_{out} = (0.1861\, h_{reg} + 0.8139\, h_{in}) \quad (8)$$

Desiccant Wheel Type-III

$$h_{out} = (0.1148\, h_{reg} + 0.8852\, h_{in}) - 0.9474 \quad (9)$$

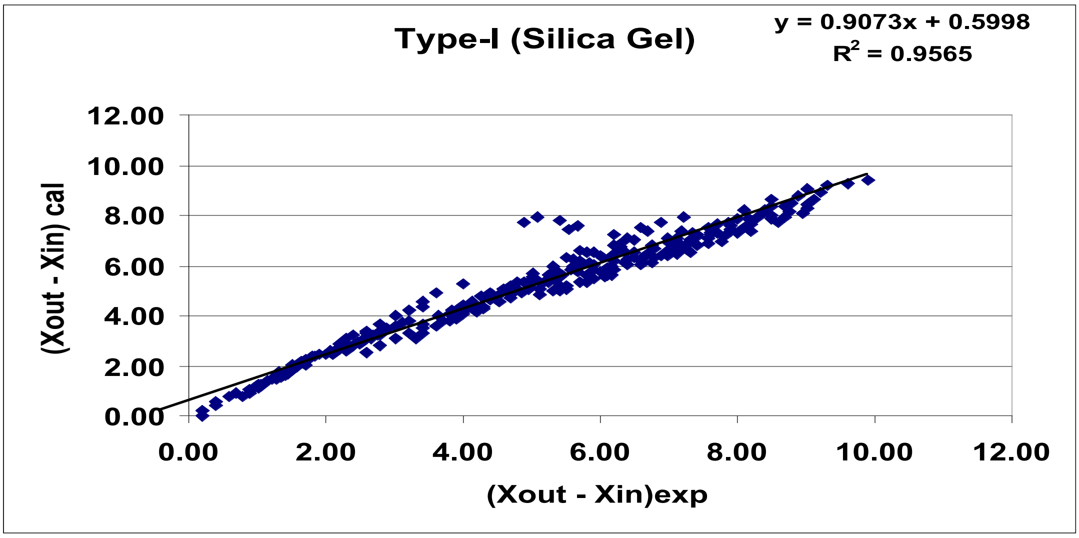

Figure 1 : Measured and calculated values of ΔX ($X_{out} - X_{in}$) for Type-I desiccant wheel.

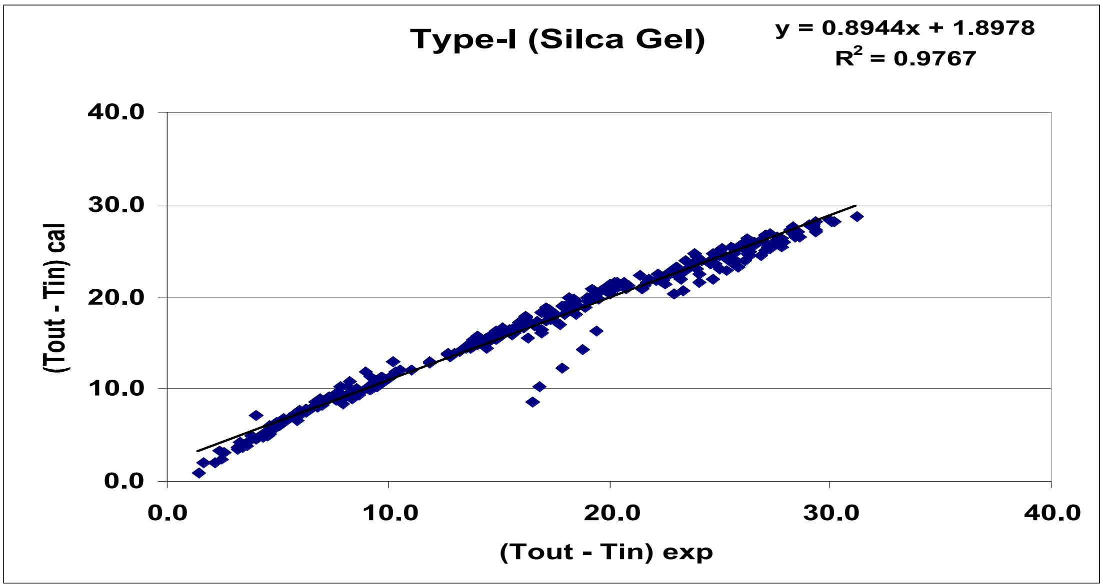

Figure 2 : Measured and calculated values of ΔT ($T_{out} - T_{in}$) for Type-I desiccant wheel.

The calculated values of ΔX and ΔT along with experimental values for different kind of desiccant wheels are shown in Figs. 1-6. It can be observed that the developed psychometric model calculate reasonably well the ΔX and ΔT for all kind of desiccant rotors.

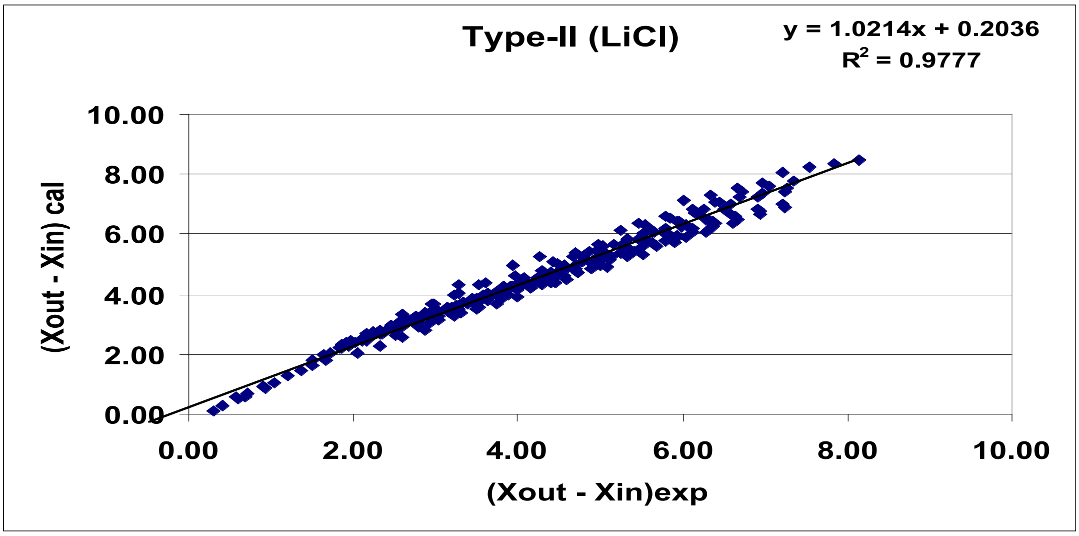

Figure 3 : Measured and calculated values of ΔX ($X_{out} - X_{in}$) for Type-II desiccant wheel.

CONCLUSION- FINAL REMARKS

The developed mathematical model serves as a useful tool for designing a desiccant technology for building climatization. It is further envisaged that the model can be included in the simulation tools, which would allow for comparing desiccant technology vis-à-vis other conventional air conditioning technologies. Moreover, it also allows selecting the appropriate heating source available for desiccant technology.

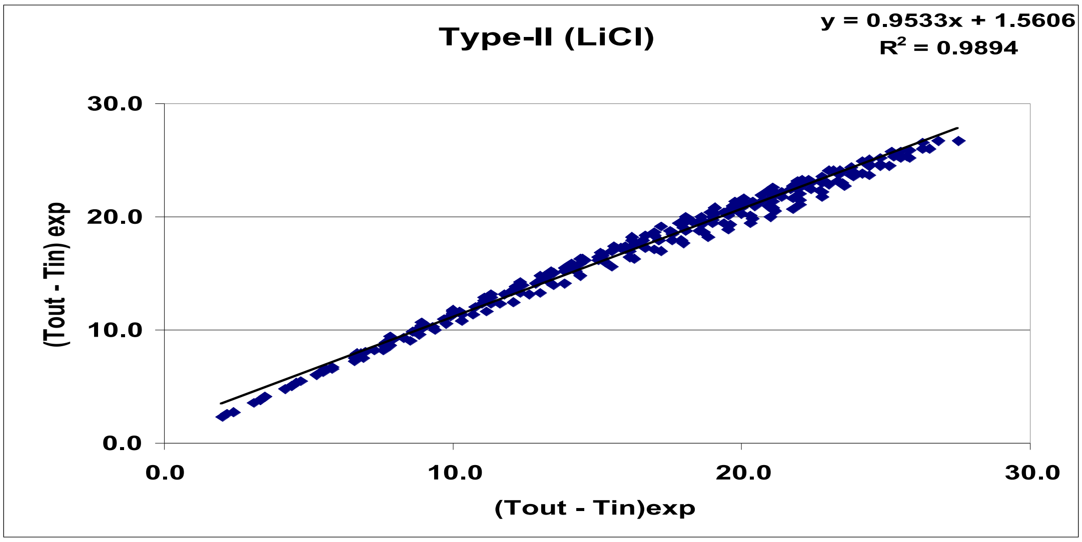

Figure 4 : Measured and calculated values of ΔT ($T_{out} - T_{in}$) for Type-I desiccant wheel.

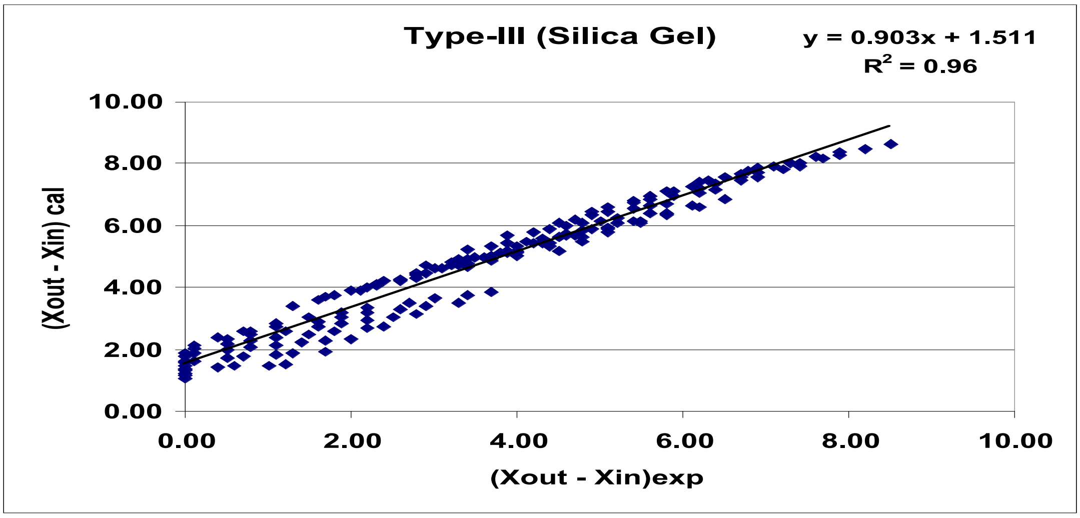

Figure 5 : Measured and calculated values of ΔX ($X_{out} - X_{in}$) for Type-III desiccant wheel.

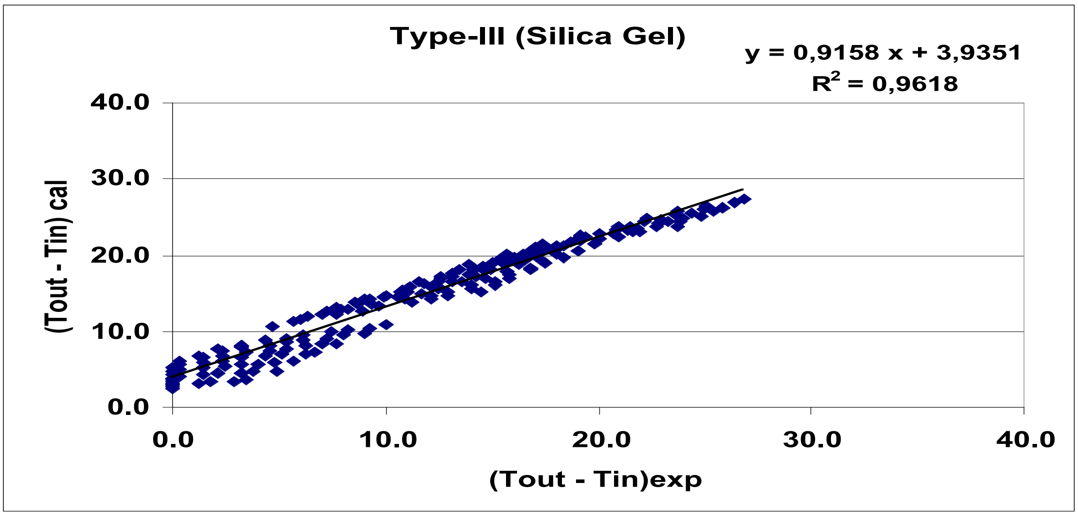

Figure 6 : Measured and calculated values of ΔT ($T_{out} - T_{in}$) for Type-III desiccant wheel.

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NOMENCLATURE

Symbols

h	enthalpy (KJ/Kg)
T	temperature (°C)
UR	relative humidity (%)
X	absolute humidity (g/Kg)

Subscripts

in	inlet (in the process side of the wheel)
out	outlet (in the process side of the wheel)
reg	in the regeneration side of the wheel