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EXPERIMENTAL INVESTIGATION ON SENSIBLE EFFECTIVENESS OF DESICCANT ROTARY ENERGY RECOVERY UNIT

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Temperature and humidity based experimental testing will be conducted in this experiment to get the sensible effectiveness values of air-to-air energy recovery wheel coated with 3Å molecular sorption sieve. The optimal wheel rotation speed, resulted an energy efficiency operation by the maximum sensible effectiveness values, will be searched under extreme difference ambient air conditions parameters.
The scientific results will conclude the effect of wheel rotation speeds (as a significant operating parameter) to the sensible effectiveness of an air handling unit effectiveness of the energy recovery ventilation unit under difference ambient air conditions and will show the optimal operating parameters in the point of view of energy saving.

Keywords: *Energy Recovery, Rotary Wheel, AHU, Sensible Effectiveness.*

1. Introduction

There is a vast importance of studying different solutions for the goal to reduce energy consumption. The energy consumption in the air conditioning systems became significant in the recent years especially when it comes to large scale like air handling unit [1]. These days many of air-handling units are used on the aim to lower the energy consumption like using energy recovery units. The effectiveness of the these energy recovery units indicates for how these units are effective in terms of increase the energy savings.

Ukai et al. investigated the energy performance of desiccant air handling unit depends on the inlet air condition to dehumidification wheel and on designed supply air humidity. The results show the optimum inlet air condition entering dehumidification wheel under various supply air absolute humidity which is determined by design room conditions and it provide useful information desiccant air handling unit during design and operation phase of buildings. [2]

The performance of solid desiccant wheel was studied by Goodarzia et al. air humidity ratio, mass flow rates, wheel rotational speed and air process temperatures, were the factors investigated in this study. Simulation program was used to calculate output conditions. The performance of a rotary desiccant wheel was investigated based on effectiveness parameters that includes moisture removal capacity, sensible and latent coefficient of performance and afterwards calculating the total coefficient of performance (COP). In conclusion, all the factors influenced on the COP and the MRCs with a positive relation expect inlet temperature. [3]

Li et al. assess the energy savings from sensible heat recovery in residential apartment buildings across Canada by modeling the building thermal demands and the HVAC system's energy use. They compare the annual performance of a commercial air-to-air heat pump coupled to a balanced ventilation system with and without the Heat Recovery Ventilator (HRV). A hypothetical residential suite was modeled under eight different building orientations for fifteen Canadian cities. Results showed that HRV use always reduces the annual heating energy consumption; however, energy consumption may increase in cooling seasons. [4]

In previous researches there was no deep investigated the sensible effectiveness of air-to-air energy recovery wheel under extreme difference ambient temperatures by detailed experimental tests.

In this research. A scientific experimental investigations will be performed on the effect of energy wheel rotation speed to obtain the sensible effectiveness of the energy recovery wheel under difference ambient air conditions and air volume flow rate to show the highest effectiveness at the optimal rotation speed in terms of energy saving.

2. Test Facility Description

The test facility located at the Indoor Air Quality and Thermal Comfort Laboratory of Budapest University of Technology and Economics, The Air Handling Unit Stand that is equipped with the energy wheel was installed as per (Fig. 1.) Below to be used in the experimental test. [5]

Fig. 1. The experimental test facility

The process goes in the experiment. A heat plate direct evaporation type exchanger used to generate the desired ambient air by a connected heat pump. Supply air was produced from indoor air through the exhaust air, thus the direct evaporator exchange air already pre-cooled or pre-heated by the heat exchanger. Therefore, more extreme supply input range with less energy consumption will be established with the available cooling/heating capacity.

A high-efficiency Energy wheel was installed in the AHU section, that transfer sensible and latent energy between air streams of the supply and return streams to recover the heat and generate a good air quality. Hovel ENVENTUS [6] produced the energy wheel used with the following specifications given by the producer as per Table 1.

Table 1. Specifications of the investigated sorption wheel

Material of sorption wheel	**Aluminium**
Coating of sorption wheel	Molecular sieve, 3
Coefficient of thermal conduction of the wheel	230 W/m K
Geometrical diameter of the wheel	540 mm
Geometrical width of the wheel	200 mm
Height of corrugated plates in the wheel	1.5 mm
Width of corrugated plates in the wheel	3 mm
Size of surfaces capable of heat-, and moisture transfer	170 m^2

Ambient temperature T_a, Supply temperature T_s and extract temperature T_{et} [°C] values were measured by TESTO type temperature metering instruments, that was placed at the two air streams crossing the wheel. These temperature measurement points were located in the mid-plane of air ducts in the mixing chamber before and after the energy wheel.

A data recorder from the same manufacturer TESTO recorded data measured by the metering devices and it was recording data every second. The data recorded was imported from the recorder to the computer by application software. The volume flow rate of the air was measured by another TESTO instrument with type hot-wire anemometer that was located in the centre of the air duct.

3. The Experimental Process

The ambient input air temperature (Ta) was be able to generate by SINCLAIR SCMI-01 type PID controller. It is connected to DC inverter compressor to regulate the power input in the heat pump with a goal to be able to carry out the measurements within the widest temperature possible range. As it could be regulated between the 10 to 100%. Under 10 %, (on/off) compressor begin to operate instead of the DC-Inverter compressor. The suitable selection of the P (proportional), I (integral) and D (derivative) parameters of the PID controller selected to minimize the instability of the system. Therefore, a PID parameter values under different conditions was determined to obtain the desired temperatures with minimum fluctuations in the PID signal.

The temperature of extract air (Tet [°C]) was controlled with the use of a portable fan heater that was placed in the return duct. The extract air (Tet [°C]) could only increase the temperature to the desired range that is between (22-24)^{o}C.

The speed of rotation of the wheel (ω [rpm]) was controlled with a potentiometer connected to the control panel. The speed of the wheel deducted from the voltage screen shown on the control panel. The speed-values was obtained through measurement, using a VOLTCRAFT DT30LK type laser tachometer

4. Test Plan of Experimental Test

The measurement plan was set on the basis of the following aspects:

- The indoor ambient conditions was selected as per recommended inside design values in ASHRAE HVAC Application. [7]
- The Winter indoor conditions was selected to be as follows: T_{et} = 22 °C While the Summer indoor conditions was selected to be as T_{et} = 24 °C.
- The target values of fresh air temperature were conducted by a step of T_a = 5 °C in the range of T_a = (-15 to 40) [°C]
- All temperature values T_a [°C] were measured under different five rotational speeds (2, 6, 10, 15 and 20 rpm).
- The input variable parameters for volume flowrate was (400, 600, 800, 1000 and 1200 m^3/h)
- The duration of measurements was at least 300 sec. with a rate of one measurement per second.

5. Energy Wheel Sensible Effectiveness Calculation

The effectiveness equation proposed by ASHRAE Standard 84 [7] that is used in this work is defined in the equation below as the effectiveness is given as sensible effectiveness (heat transfer process).

$$\varepsilon_s = \frac{m_s \times (T_a - T_s)}{Min\ [m_s, m_{et}] \times (T_a - T_{et})} \qquad (1)$$

Where:
T = Dry bulb temperature (°C)
m_s, m_{et} = Supply and Exhaust dry air mass flow rate (kg/s) and it is calculated form the following equation

$$\dot{m} = \rho_a \times \dot{V} \qquad (2)$$

Where:
ρ_a = Density of the air (m^3/kg)
$\dot{V}$ = Volume flowrate (m^3/s)

6. Results and Discussion

The measured data of the tested energy wheel at different operation and ambient parameters will be presented in this section to calculate the sensible effectiveness of the energy wheel and relationship between the wheel and different parameters.

Sensible Effectiveness vs. Wheel Speed

It can be shown in (Fig. 2.) the Sensible effectiveness vs. wheel speed for different dry bulb temperature (°C) at V = 400 m^3/s. it can be realized, from trending data, the maximum sensible effectiveness is around (86%) occurs at the highest wheel speed. However, the sensible effectiviness begin to decrease at wheel speed ω = 6 rpm. Moreover, temperatures shows almost the same trend at different wheel speeds.

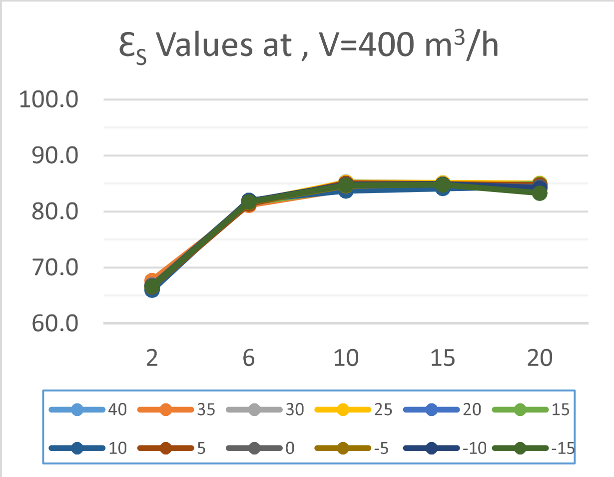

Fig. 2. Sensible effectiveness (%) vs. wheel speed (rpm) for different dry bulb temperature (°C) at V = 400 m^3/h

Sensible Effectiveness vs. Ambient Temperature

(Fig. 3.) shows the sensible effectiveness vs. dry bulb temperature (°C) at ω = 20 rpm. it can be realized, from obtained data, the maximum sensible effectiveness which is equal to 86% occurs at the lowest volume flowrate. However, the effectiveness values shows almost the same at 600 and 800 m^3/h.

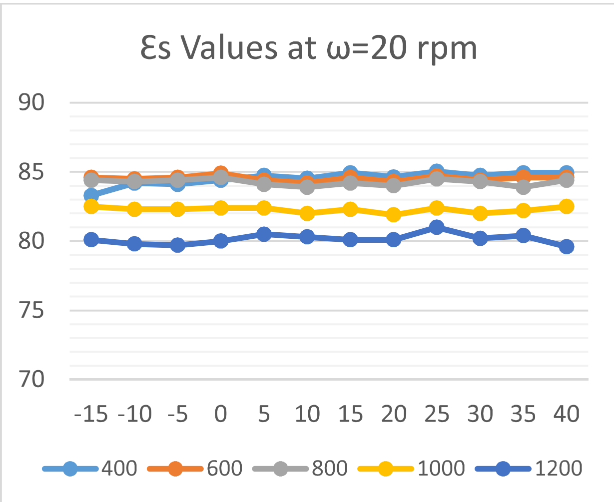

Fig. 3. Sensible effectiveness (%) vs. ambient temperate (°C) for different volume flowrate (m^3/h) at ω = 20 rpm

7. Uncertainty Analysis

The method used for estimating uncertainty in experimental results is shown in the equation below. [8]

$$\omega_R = \pm\sqrt{\left(\frac{\partial R}{\partial x_1}\times\omega_{x_1}\right)^2+\left(\frac{\partial R}{\partial x_2}\times\omega_{x_2}\right)^2+\cdots+\left(\frac{\partial R}{\partial x_n}\times\omega_{x_n}\right)^2} \quad (3)$$

Where:
R = Function of a some desired result of an experiment
x = independent variables in the R function
ω_R = Uncertainty for R function

Uncertainty Calculations

After substituting the given values into the equation, the uncertainty for the sensible effectiveness was around 3.75%.
(Fig. 4.) Shows the uncertainties for the sensible effectiveness values vs. generated ambient temperature Temperature at volume flowrate ($\dot{V}$ = 400 m^3/s) and maximum wheel speed (ω = 20 rpm)

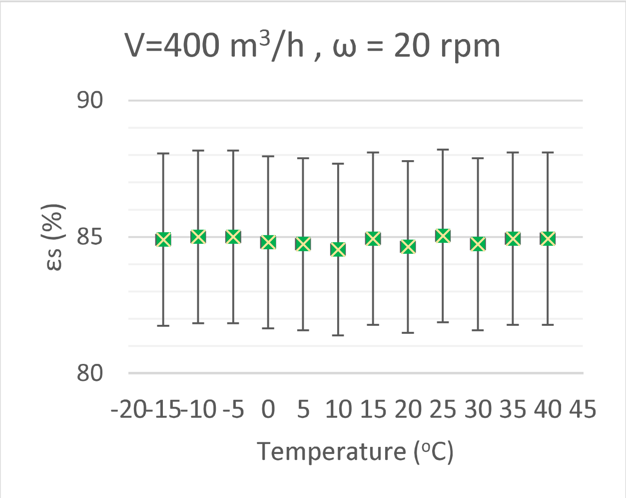

Fig. 4. Uncertainty in effectiveness (%) vs. generated ambient temperature (°C) for Sensible effectiveness at ω = 20 rpm and at V = 400 m^3/h

8. Summery and Conclusion

The operation performance of the studied energy wheel under extreme climate conditions summarized as follows:

1- The sensible effectiveness obtained from experiment shows decreasing trend when increasing the volume flowrate of the air. However, it shows the almost the same values under different dry bulb temperatures the same wheel speed.

2- It could be obtained that the values of the sensible effectiveness begin to reduce from wheel speed 10 rpm and lower.

3- The sensible effectiveness at a certain wheel speed and volume flowrate trend shows that they have almost the same values at different generated ambient temperature.

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