Optimization of Operating Parameters of Desiccant Wheel for Rotation Speed

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Abstract

Desiccant wheels are used in commercial and industrial applications to perform air dehumidification operations by utilizing low grade heat source. Software provided by the manufacturer is used to select a honeycombed rotary desiccant wheel as per requirements of the client on the website by Novel Air Technologies. The performance of the software has been verified by comparing the results obtained by the software with those published in reputed journals. Using the software, the performance of an adiabatic rotary dehumidifier is parametrically studied and the optimal rotational speed is determined by examining the moisture removed by process area in the desiccant wheel. Also the effect of air flow rate on the reactivation air and process air has been studied. The basic parameters for a particular wheel of thickness 200 mm and diameter 550 mm are: ambient air at 30 ^{0}C DBT and 17 g/kg humidity ratio, process air flow rate vary between 1.5 m/s to 5.5 m/s, reactivation air flow rate lies between 1.5 m/sec to 5.5 m/sec and rotational speed of wheel varies from 10 RPH to 40 RPH. On the basis of results the following recommendations have been made: It was observed that for low velocity of process air (1.5 m/s to 2.5 m/s), 10RPH and 20RPH are found to be optimum for operation. In case of high velocity (>2.5), little effect of RPH is observed, however the most optimum RPH is found to be 20. For both high and low reactivation inlet velocity, 20 RPH is the most optimum rotation speed. However, the best results are observed at 3.5m/s to 4.5m/s reactivation inlet velocity.

Keywords: *Desiccant wheel, Process inlet velocity, Reactivation inlet velocity, Rotation speed*

1. Introduction

Air condition plays a major role in human life and in the coming time. So we can say that high grade energy is required. However production of high grade energy involves high costs and causes pollution due to the use of coal and gas as raw materials.

Conventional air conditioning is based on vapour compression system. In which CFC and HCFC are used and these are harmful for our environment. The above mentioned reasons force research into alternative air-conditioning systems.

Desiccant cooling system is one of the best option of air conditioning system because it is driven by low grade energy and low grade energy is easily available such like solar energy. Desiccant wheel is major part (heart) of desiccant cooling system so this paper presents an optimization of operating parameters for desiccant wheel.

The performance of wheel has been experimentally and numerically investigated in many researches, standing out the experimental studies of characterization of the performance of desiccant wheels (JY San et al 1993, YJ, Dai et al 2001, JL Niu et al 2002, LZ Zhang et al 2002 ,X.J.Zhang et al 2003,Zhiming Gao et al 2005,TS Ge et al 2010) Many configurations of air handling units using desiccant wheels are known for combining conventional air-conditioning system with desiccant wheel and evaporative coolers, Sanjeev Jain et al in 1995 and S.E.Aly et al 1988, PL Dhar and Singh in 2001 are examples of such hybrid systems. Some scientists, MH Ahmed (2005) and AE Kabeel (2007), have also worked on solar assisted Desiccant Dehumidifiers.

In solid desiccant air dehumidification, the desiccant wheel can be seen as the key equipment. Thus, for detailed simulations of the real behavior of the installation, it is important to take into account the accurate information concerning the composition and configuration of the desiccant wheel, given by the manufacturer.

NOMENCLATURE

P_{in} Process Air Inlet
P_{out} Process Air Out
R_{in} Reactivation Air Inlet
R_{out} Reactivation Air Outlet
T Temperature (^oC)
W Humidity ratio (Kg/Kg of dry air

2. Desiccant Wheel

Desiccant wheel is an air to air heat and mass exchanger, with a relatively low rotation speed.

Wheel has a frame with film of desiccant material layered on the same. The channels in the frame come in various shapes such as sinusoidal, honeycomb, triangular etc. The frame Wheel is axially crossed by two main streams. The porous desiccant medium of the matrix is cylindrically operated for adsorption and desorption. In process part of the wheel, dehumidification of air takes place, and in the reactivation part of the wheel humidification of the air takes place. The rotation of the wheel causes periodic reactivation of the adsorption part.

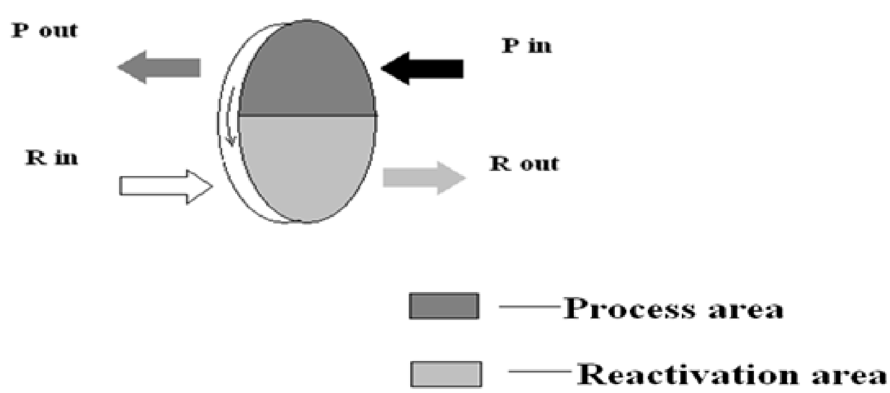

Figure 1 . Desiccant Wheel is Equaly Divided for Adsorption and Desorption

The psychromtric changes occuring in the desiccant wheel

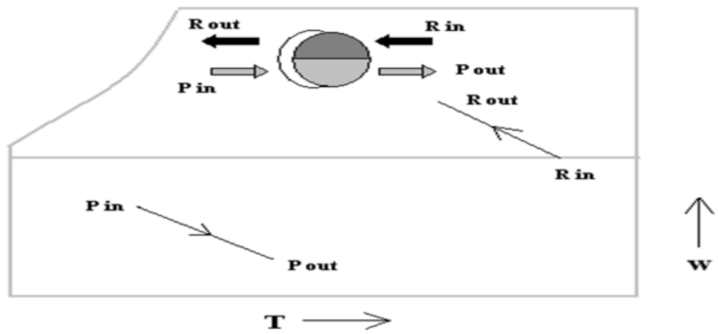

Figure 2. Psychrometric Changes in Desiccant Wheel

3. Case Study

The desiccant wheel is 550x200 having a rotor diameter of 0.55 m and a channel length of 0.2 m., location-Delhi. INDIA

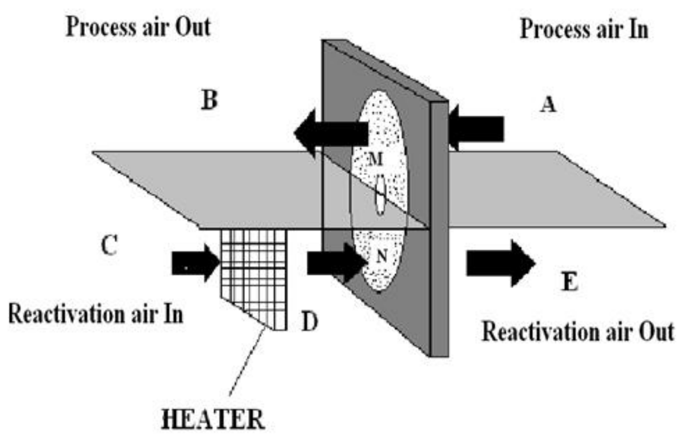

Figure 3. Sketch of the Studied Desiccant Dehumidification Unit.

In the figure point A indicates process inlet from ambient conditions and after that B indicates dehumidified air through M section of wheel. In the other section heater is needed to regenerate desiccant, i.e. N section of wheel

Case I: Effects of Process inlet air velocity and Rotation Speed:

Some parameters have been fixed in this case, like

1. Process Inlet Temperature = 30^{o}C
2. Process Inlet Moisture = 17g/kg
3. Reactivation Inlet Velocity = 2.5m/s
4. Reactivation inlet temperature = 30^{o}C
5. Reactivation inlet moisture = 17g/kg

6. Process / Reactivation area ratio = 50:50
7. Regeneration Temperature = 65^{o}C

The effect of change in process removed moisture has been studied for the following process inlet velocities 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6 m/s in relation with following rotational speed 10, 20,30,40 rph.

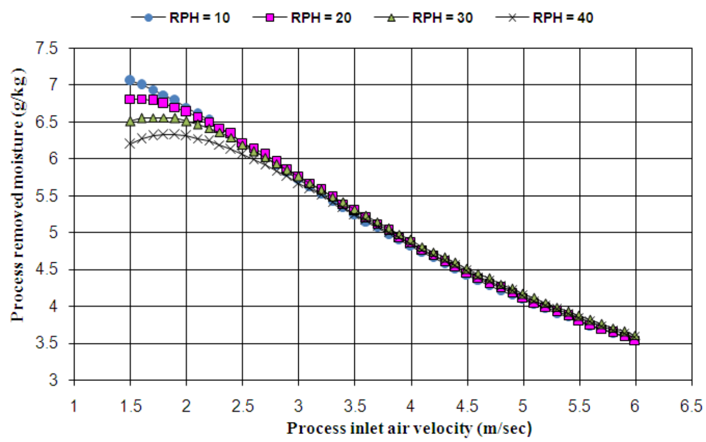

Figure 4. Changes in Process Removed Moisture with Process Inlet Air Velocity for Different Rotational Speed

Increase in Process inlet air velocity leads to reduction in process removed moisture due to lesser contact of inlet air on the desiccant surface. At low speed, desiccant wheel has better moisture removal with low process inlet air velocity. An increase in velocity of air beyond 2.5 shows no effect on process air moisture removal rate with change in Rotations of Dessicant wheel per hour.

The effect of change in process outlet air temperature has been studied for the following process inlet velocities 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6 m/s in relation with following rotational speed 10, 20, 30, 40 rph.

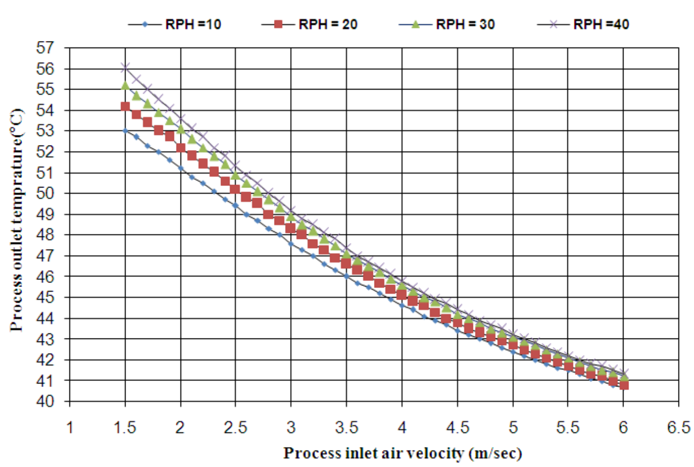

Figure 5. Changes Process Outlet Temperature with Process Inlet Air Velocity for Different Rotational Speed

Process outlet temperature reduces with increase in process inlet air velocity due to less moisture removed in the process area. The difference between the process outlet temperature at different rotational speed of desiccant wheel is more at low velocity in comparison to high velocity. However, the difference is still profound, if compared to process removed moisture. Since lower RPH removes nearly the same moisture but does so at lower process outlet temperatre, Lower RPH is preferred.

The effect of change of reactivation outlet moisture has been studied for the following process inlet velocities 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6 m/s in relation with following rotational speed 10, 20,30,40 rph.

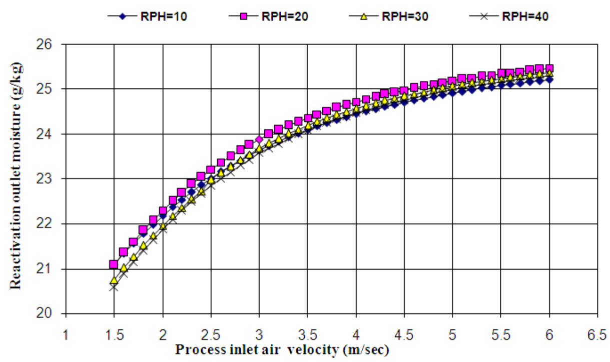

Figure 6. Changes in Reactivation Outlet Moisturer with Process Inlet Air Velocity for Different Rotational Speed

When process velocity increases, there is an increase in reactivation outlet moisture. This is due to fact that incresed velocity causes incresed flow rate of air which further increses the moisture removal from desiccant in regeneration section. The difference between the moisture removed from reactivation air for different roational speed of wheel is less, However an RPH of 20, is observed to give the best moisture removed from reactication air.

The effect of change in reactivation outlet air temperature has been studied for the following process inlet velocities 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6 m/s in relation with following rotational speed 10, 20, 30, 40 rph.

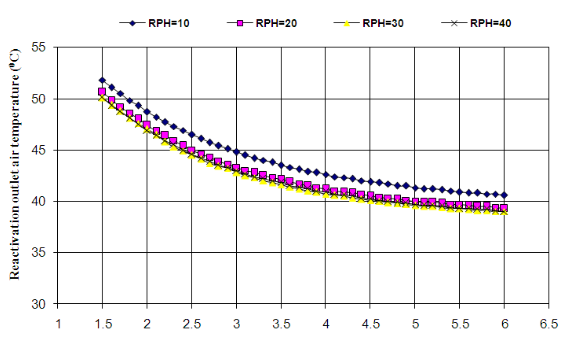

Figure 7. Changes in Reactivation Outlet Temperature with Process Inlet Air Velocity for Different Rotational Speed.

Reactivation outlet air temperature reduces with increase in process inlet air velocity. The deviation between temperature of air streams at different rotational speed is very less, wheel rotation at 20rph represents favourable results.

Case II Effects of Reactivation inlet air velocity and rotational speed:

Some parameters have been fixed in this case, like

1. Process Inlet Velocity = 2.5m/s
2. Process Inlet Temperature = 30°C
3. Process Inlet Moisture = 17g/kg
4. Reactivation inlet temperature = 30°C
5. Reactivation inlet moisture = 17g/kg
6. Process / Reactivation area ratio = 50:50

The effect of change in process removed moisture has been studied for the following reactivation inlet velocities 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6 m/s in relation with following rotational speed 10, 20,30,40 rph.

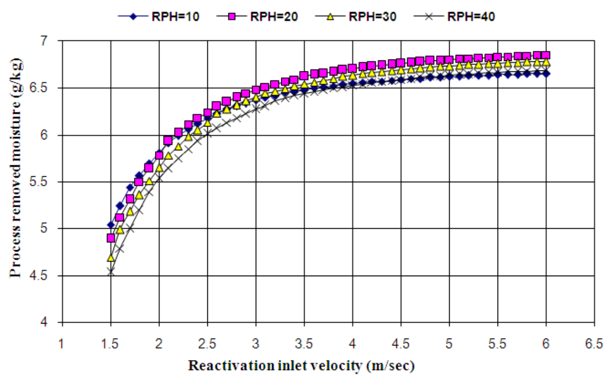

Figure 8. Changes in Process Removed Moisture with Reactivation Inlet Air Velocity for Different Rotational Speed

Increase in reactivation inlet air velocity leads to increase in process removed moisture. This is due to fact that the pores are vaccant by the hot air in reactivation area of desiccant for the proper adsorption in process area. Among different rotational speeds of desiccant wheel, 20rph shows much better moisture removal in process area for particular inlet reactivation velocities. It can be seen that in the range of 3.5m/s to 4.5m/s the change in process removed moisture is not as profound if compared to reactivation inlet velocity lesser than 3.5 and greater than 4.5.

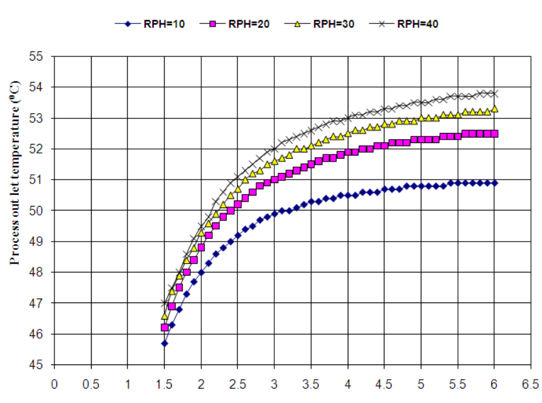

Figure 9. Changes in Process Outlet Temperature with Reactivation Inlet Air Velocity for Different Rotational Speed

Reactivation inlet velocity increases process removed moisture also increases by this process outlet temperature also increases. In RPH (10, 20) at RPH 10 minimum moisture removed and at RPH 20 max moisture removed. Process outlet temperature having low priority and we choose RPH 20 .

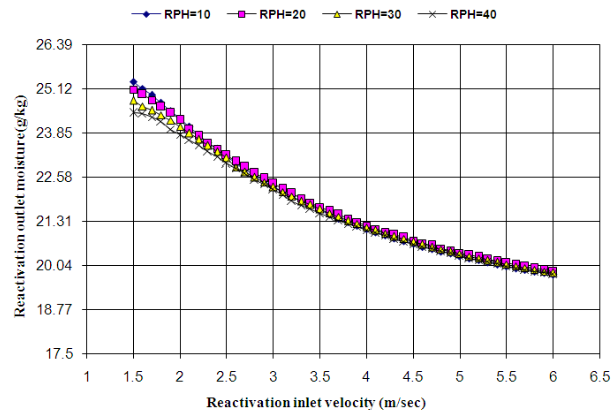

Figure 10. Changes in Reactivation Outlet Moisture with Reactivation Inlet Air Velocity for Different Rotational Speed.

Increase in reactivation inlet velocity leads to reduction in reactivation outlet moisture. For different rotational speeds, deviation in reactivation outlet moisture of air stream is almost negligible. But in consideration to previous discussed results, we prefer 20rph wheel rotation as the most favourable operating parameter.

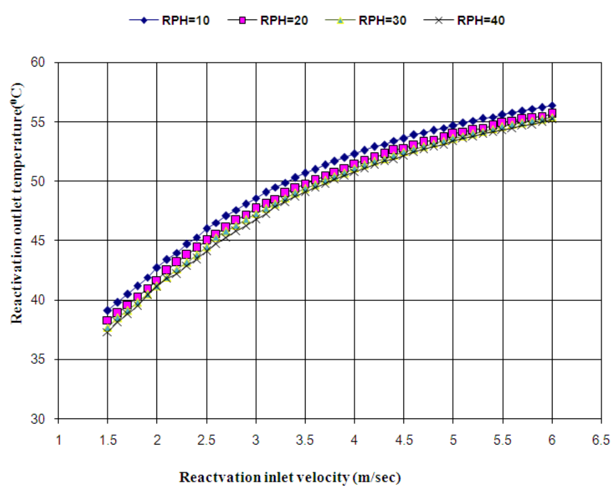

Figure 11. Changes in Reactivation Outlet Temperature with Reactivation Inlet Air Velocity for Different Rotational Speed

Reactivation outlet temperature increases with increase in reactivation inlet velocity. For different rotational speeds of desiccant wheel, reactivation outlet temperature for air streams is almost same in relation with reactivation inlet velocity. Still we consider 20 rph rotational speed of desiccant wheel to be good operating parameter

4. Conclusion

An increase in process inlet air velocity causes a reduction in process removed moisture; process outlet air temperature and reactivation outlet temperature which further shows increase in reactivation outlet moisture. The focus is on maximizing the process removed moisture and for the given desiccant wheel model, the optimum process inlet velocity is found to lie between 1.5 and 2.5 m/s.

With an increase in reactivation inlet air velocity, there is only a slight increase in process removed moisture, a sizeable rise in process outlet temperature, reactivation energy and reactivation outlet temperature. Since the increase in process removed moisture is only initial, and the moisture removed remains nearly the same for all rotational speeds after 2.5m/s.

Following recommendations have been made on the basis of obtained results:

It was observed that for low velocity of process air (1.5 m/s to 2.5 m/s), 10RPH and 20RPH are found to be optimum for operation. In case of high velocity (>2.5), little effect of RPH is observed, however the most optimum RPH is found to be 20.

For both high and low reactivation inlet velocity, 20 RPH is the most optimum rotation speed. However, the best results are observed at 3.5m/s to 4.5m/s reactivation inlet velocity.

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