The Experimentally Studying of Solid Desiccant Wheel Performance Combined with the System of Air Conditioning

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Abstract:

The aim of this study was to study the performance of the system of solid desiccant dehumidification to decrease the latent load on cooling coil for the system of air-conditioning and advance the thermal comfort, thus reduce the energy consumption. Rotary desiccant wheel contains a silica gel as a solid moisture absorbent material has been utilized in this study. The wheel was a diameter of 55 cm and a thickness of 20 cm. The wheel cross sectional area is divided into two parts in aspect ratio. The large part represent dehumidification or absorption process, in this section moisture is removed from the humid air by the silica gel. While the other part represent desorption or regeneration process in this section moisture was absorbed from the humid air by the gel of silica in the first process will be removed from it. The experimental results demonstrates that the utilizing of the desiccant wheel will reduce significantly the thermal load on the cooling coil by reducing the latent load of the passing of humid air respectively via the wheel and the cooling coil.

Keyword:- Solid Desiccant, Air Conditioning, Combined.

Nomenclature

Cap : Heat of Specific Air KJ/Kg.K.

Dcop : Performance of Dehumidification coefficient.

h : enthalpy KJ/Kg.

h_{fg} : Evaporation Enthalpy KJ/Kg

$\dot{m}$: The rate of Mass flow Kg/s.

MRC: The capacity of removing Moisture Kg/h

Q : heat load KJ/s.

T : Temperature ^{0}C.

w : The ratio of Humidity Kg/Kg $_{\text{dry air}}$.

Subscript	Description
A	air
I	inlet
O	outlet
P	Process air
R	Regeneration air
L	latent
s	sensible

1. Introduction

The main purpose of using Air Conditioning system (HVAC) is to supply thermal comfort conditions for humans. The thermal comfort conditions befalls when body temperatures are kept in a narrow range, the physiological effort of regulation is minimized and skin moisture is low. As reference by ANSI/ASHRAE Standard 55 (1992) [1-2]. Dhar and Singh [3] investigated that the hollow cylindrical bed was the practical and feasible dehumidifier for the dehumidification process. With respect to desiccant wheels. This reported by solid desiccant based hybrid air conditioning systems. Air-conditioning loads can be divided into two parts, called sensible and latent loads. Moisture presents a significant problem for the air conditioning systems and human comfort. Latent load involves removal of moisture in the air in areas of high humidity levels, therefore, dynamic dehumidifiers should be utilized. Desiccant dehumidification is suitable in dealing with latent load and improving indoor air quality by removing moisture from the humid air.

Desiccants are substances may be natural or synthetic have a high adsorption capacity with high surface area. This reduces initial cost, energy consumption the adsorbing water occur due to the difference of water vapour pressure between the humid air and the desiccant surface. Silica-gel, activated alumina, alumina gel and molecular sieve are available to utilize as a desiccant [4-5]. The thermal comfort standard ranges for humans are 20°C - 26°C and 30% - 60%, respectively. In the tropical region, the conditions at 26°C and 50% - 60% relative humidity are considered as a comfortable environment condition in Thailand climatic zones [6]. The evaluation and optimization of rotating honey-comb desiccant wheel performance using solar energy was reported by Ahmed *et al*. [7]. Nia *et al*. [8] the dehumidifiers were utilized in drying the humid air stream by forcing it through a structured packing impregnated with desiccant silica-gels to reduce the latent load of air-conditioning system and the thermal comfort improvement.

Additionally, Awad *et.*al., [9] investigated the cylindrical packed beds and the operations of adsorption and desorption of these beds .There are many types of beds such as multiple vertical beds, inclined bed and radial bed which have been utilized for dehumidification. The column type is widely utilized in the process of air dehumidification which two or more desiccant columns are structured with a set of valves to make these stationary beds work alternatively in adsorption and regeneration phase.

Taweekun et al [10] studies simulations were utilized to predict the performance of two types of dehumidifiers: cylindrical packed beds and desiccant wheels by using ANSYS and TRASYS soft-ware programs, were utilized for simulations. Moreover, experimental tests were also conducted under tropical humid climate.

2. The aim and Objective

This study aims to study the performance of the desiccant dehumidifier steel system to reduce the potential load on the cooling coil of the air conditioning system and improve thermal comfort, thus reducing energy consumption

3. **Methodology and Experiment work**

In this study, the experimental setup consisted of wheel apparatus in figure 1 and air-conditioning systems are collect at the laboratories of engineering college/university of Wasit. The indoor experiments which implemented using Wasit city climate. The experimental work deals with the investigation of the influence of process humidity ratio on the heat load of cooling coil. The experimental dehumidification system utilized the desiccant wheel to remove water vapour from the ventilation (process) air before passing into the air-conditioning system. The desiccant wheel and air-conditioning systems testing and the schematic diagram are illustrated in Figure 2 and 3 respectively.3 respectively.

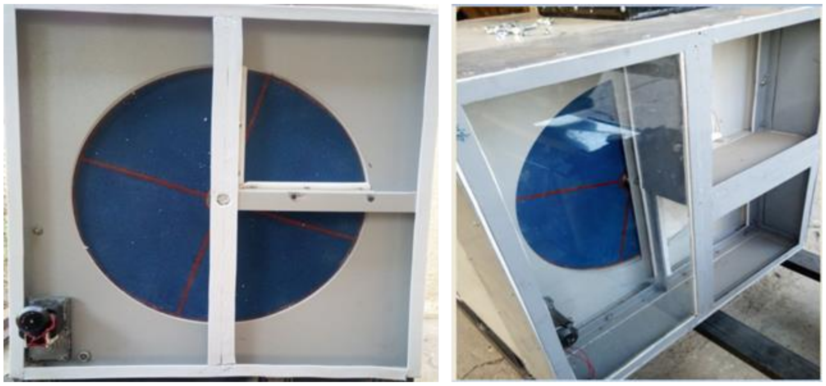

Figure 1. Wheel apparatus and air-conditioning systems

The experimental dehumidification system consisted of a rotary desiccant wheel with a diameter of 550mm and a length of 200mm containing 34.2 kg of silica gel. The factors changed in the parametric studies included the air flow rate (ṁi), inlet temperature (Ti (p, r)) of the dehumidification and regeneration process, inlet humidity ratio (wip) of process air. The air flow rate was kept around0.233and o.256kg/s by air blower with 8 vanes. The wheel speed is 30 rph by a motor driven by an inverter. The inlet temperature of the dehumidification process (Tip) and the regeneration process (Tir) were kept around 30°C to 43.4°C and 56.5°C to 70°C, respectively by a heater with temperature control. Moreover, the inlet humidity ratio of the dehumidification process (wip) and the regeneration process (wir) were kept around 0.010to 0.02 kgw/ kg dry air by using a separate dehumidifier. In addition DX cooling coil was connected with the wheel to evaluate the cooling load with and without using the desiccant wheel as demonstrated in figure 2. The air flow rate into the cooling coil was kept around0.08and o.019 kg/s with the same degrees of temperatures on desiccant wheel.

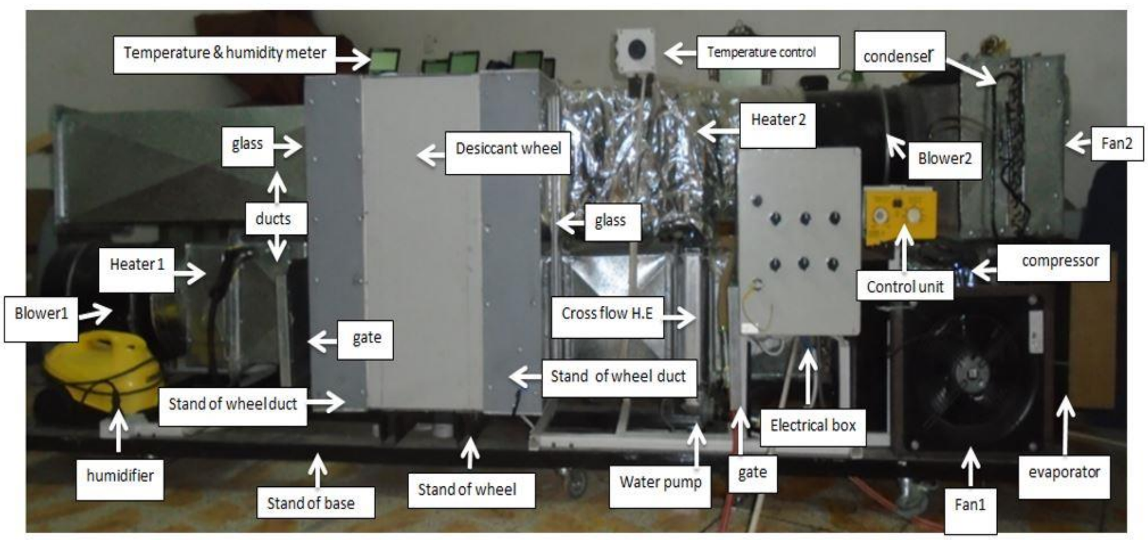

Figure 2. The desiccant Wheel apparatus and air-conditioning systems

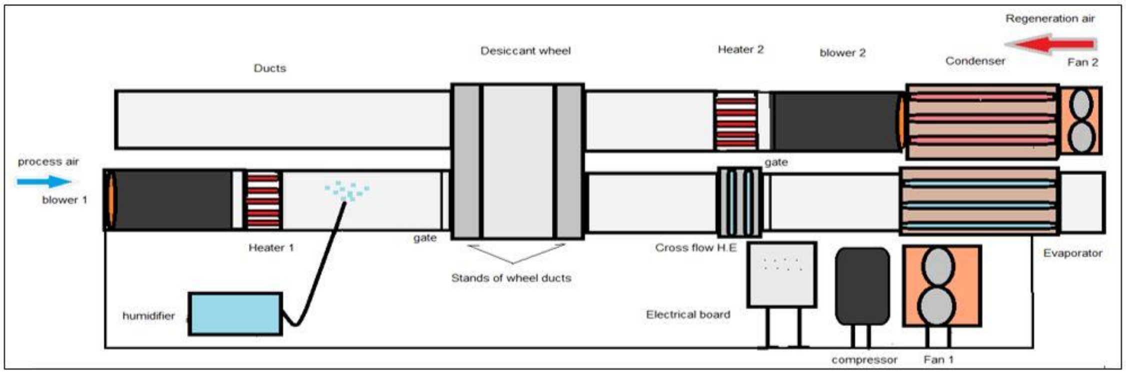

Figure 3. The schematic diagram of desiccant Wheel apparatus and air-conditioning systems

The dehumidifiers' performance was assessed depending on two various criteria. The first parameter was the capacity of moisture removing (MRC) which capacity presented as mass of moisture removed from humid air per hour (Kg/h), it can be calculated by equation (1):

$$MRC = \dot{m}_{process}(w_{ip} - w_{op}) \quad (1)$$

The second parameter was the dehumidification coefficient of performance (DCOP), which represent the ratio of the reduction of latent heat in the dehumidification process and the energy consumption during the regeneration process, it can be mathematically expressed using Equation (2)

$$DCOP = \frac{\dot{m}_{inlet\ process}(w_{ip} - w_{op})(2501 + 1.86T_{ip})}{\dot{m}_{inlet\ regeneration}(\Delta h_{regeneration})} \quad (2)$$

To calculate the heat load of cooling coil there are three loads can be evaluated: the latent heat load (Q_L), sensible heat load (Q_s) and Total heat load in cooling coil (Q_{Coil}) which can be calculated by the following equations:

$$Q_L = \dot{m}_a h_{fg}(w_{i,a} - w_{o,a}) \quad (3)$$

$$Q_s = \dot{m}_a cp_a(T_{i,a} - T_{o,a}) \quad (4)$$

$$Q_{Coil} = \dot{m}_a(h_{i,a} - h_{o,a}) \quad (5)$$

4. Result and Discussion

4.1. The influence of process air Mass Flow Rate on Desiccant Wheel Performance:

Fig. (4) demonstrates that both (DCOP) and (MRC) increases with increasing the mass flow rate of process air pass through the desiccant wheel. This occur due to the decreasing in surface vapour pressure of the desiccant due to the increase in air moisture content difference of both sides of desiccant wheel.

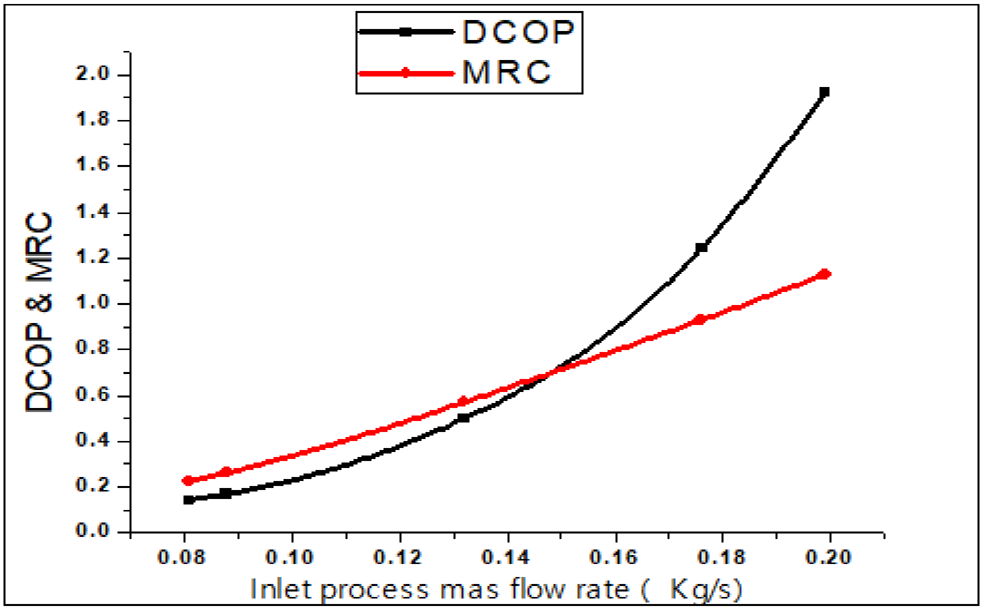

Figure (4) The process air Mass Flow Rate on Desiccant Wheel Performance

4.2. Influence of inlet process air temperature on desiccant wheel performance:

Fig. (5) demonstrates that MRC decrease with increasing air temperature. Due to the decreasing in the values of moisture content difference of the air a cross the wheel. But it is demonstrated in the figure, that there are an increase in values of DCOP due to increase the enthalpy of water vapour removed from the air in the wheel.

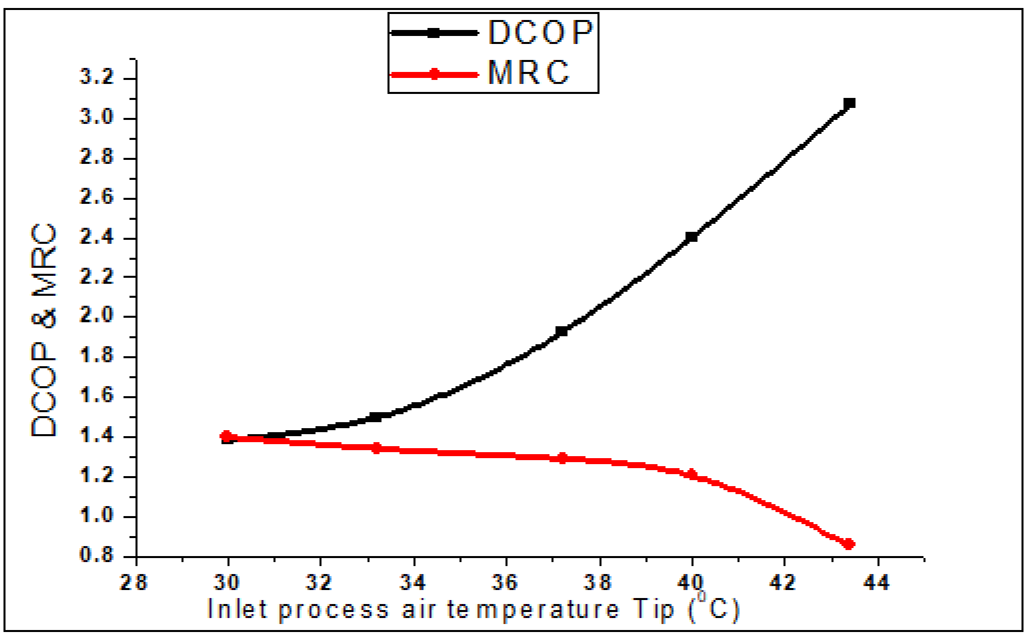

Figure (5) inlet process air temperature on desiccant wheel performance

4.3. Influence of Inlet Process Air Humidity Ratio on DW Performance

Fig. (6) indicates that the values of MRC increase with increased the moisture content of inlet process air due to the fact that increased moisture content lead to increase in dehumidification rate and thus increase in values of this parameter.

As for DCOP values, increase and then decrease due to the fact that increasing the moisture absorbed during the dehumidification process requires the consumption of a different amount of heat to release this moisture during the regenerating process.

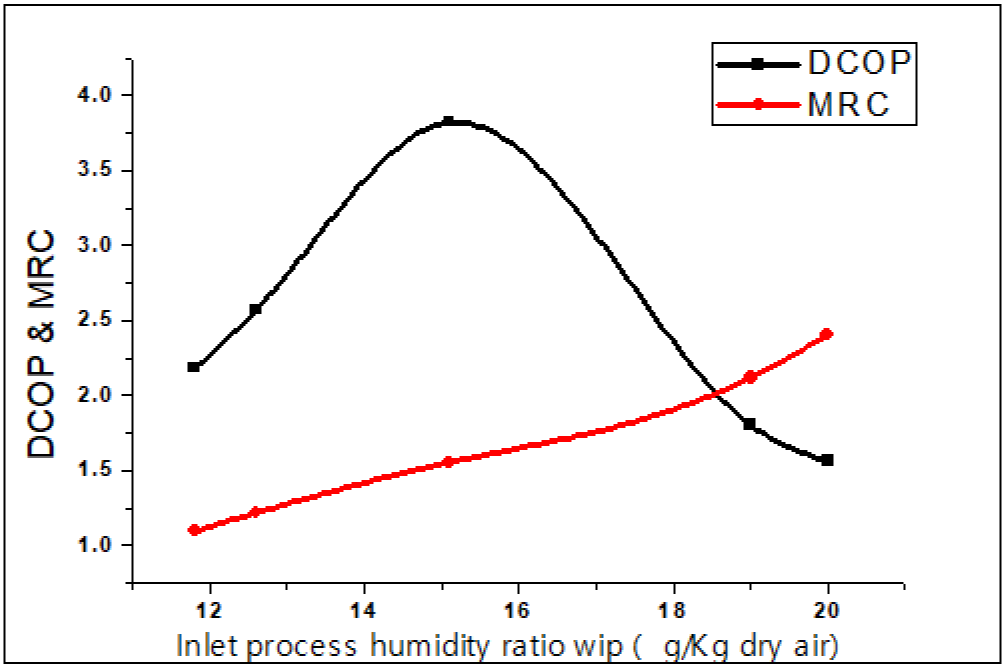

Figure (6) Inlet Process Air Humidity Ratio on DW Performance

4.4 Influence of Regeneration Air Temperature on Desiccant Wheel Performance

Fig. (7) demonstrates that the moisture removal capacity increases with the increasing of regeneration temperature. Due to the decreasing in the partial pressure of water vapour on the surface of the moisture absorbent. The reason for a decrease in values of DCOP is due to an increase in the amount of heat the air conveys to the absorbent moisture in the wheel during the regeneration process.

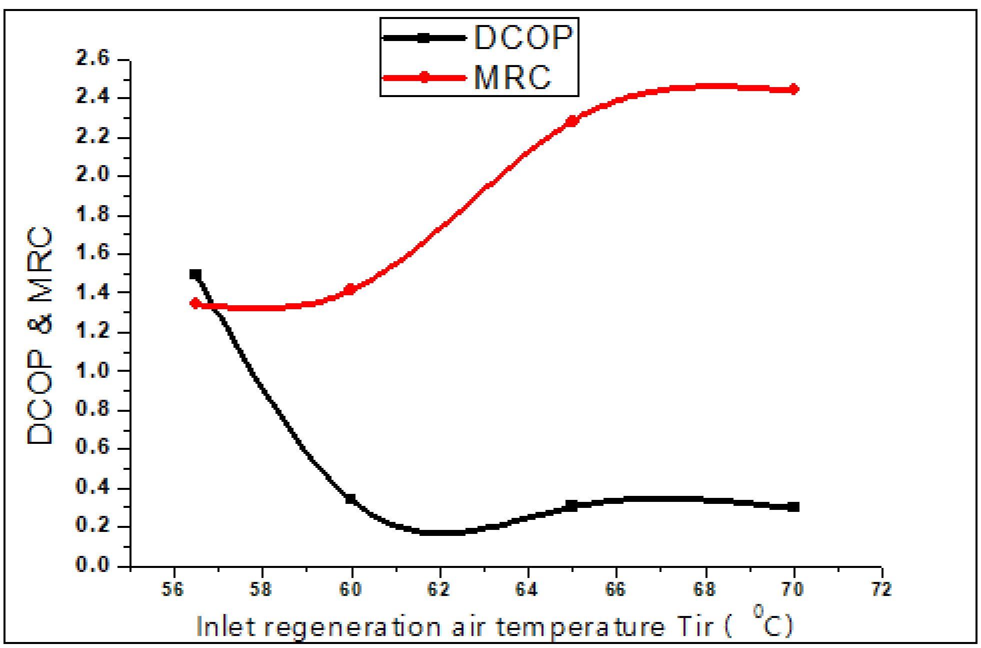

Figure (7) Regeneration Air Temperature on Desiccant Wheel Performance

4.5. Influence of Process Air Moisture Content on Thermal Load of Cooling Coil:

Fig. (8) and (9) represents the change of the thermal loads on the cooling coil as the moisture content of inlet process air changes for two cases (By-Pass state & Desiccant Wheel state) respectively. It is noted from the figures that the total thermal load on the coil increases with increasing moisture content of the process air in the two cases as a result of increased latent load due to increase the amount of moisture in the air.

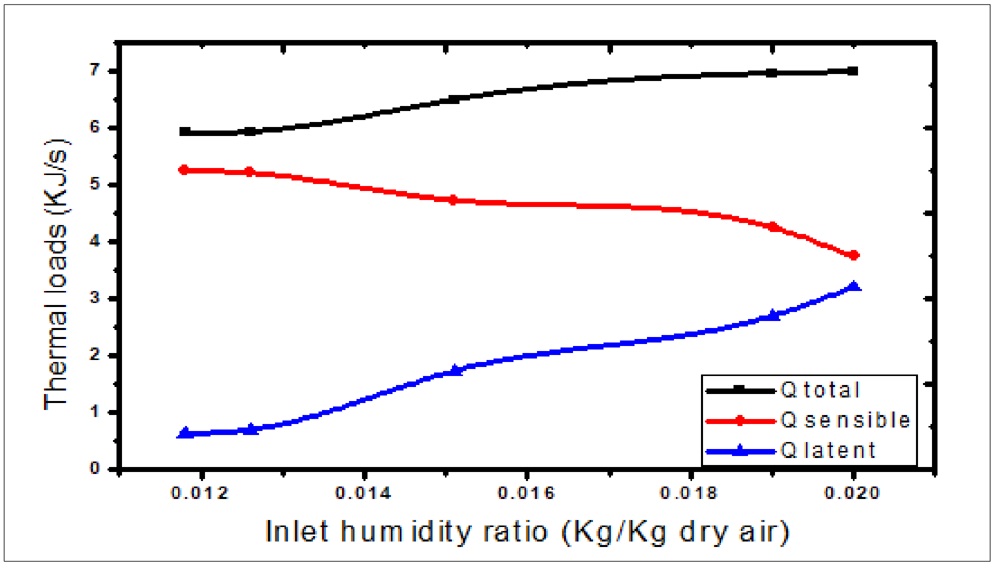

Figure (8) Process Air Moisture Content on Thermal Load of Cooling Coil By-Pass state

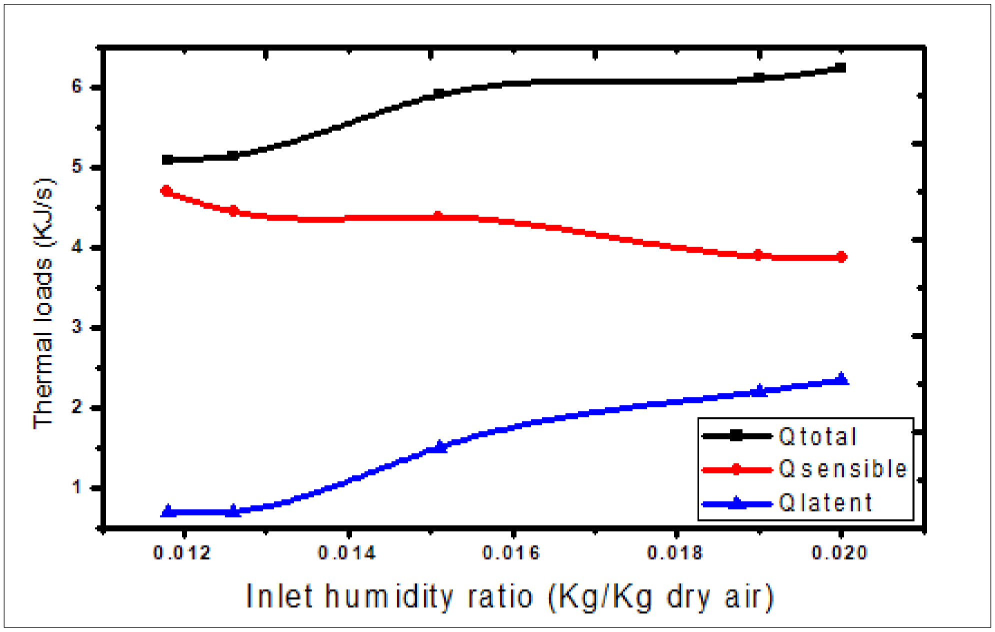

Figure (9) Process Air Moisture Content on Thermal Load of Cooling Coil Desiccant Wheel state.

Figure (10) demonstrates the comparison between the total heat loads on the cooling coil for the two states. It is noted that the value of total load on the coil at a certain value of the moisture content of the process air is lower in the case when the humid air flow through the desiccant wheel. When the process humid air passes through the desiccant wheel, the silica gel inside the wheel will absorb some of the moisture that this air carried. Thus, the latent load of this air will decrease which causing a reduction in total load of this air as it pass through the coil.

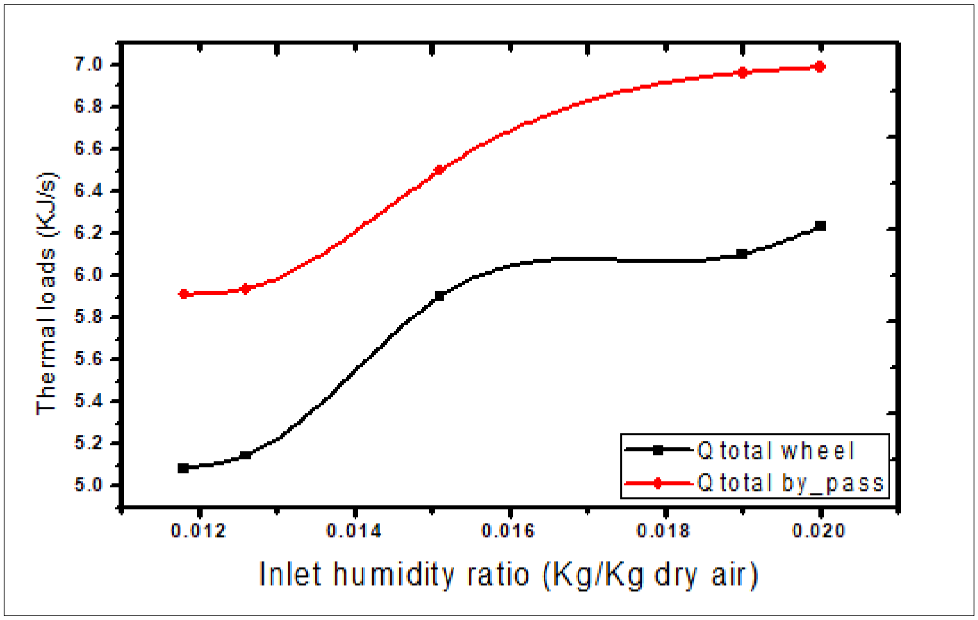

Figure (10) the comparison between the total heat loads on the cooling coil for the two states.

5. Conclusion:

Solid desiccant dehumidification system designs suitable for humid climate meant for the reduction of latent load of air-conditioning systems and improvement of the thermal comfort were proposed and the performance was analysed through experimental studies. The desiccant dehumidifier designs under investigation was the rotary desiccant wheel. Amount of desiccant in the rotary was 34 kg, and the desiccant considered was silica-gel, with average diameter of 550 mm. The main findings of the experimental results were MRC, DCOP & the total load of cooling coil the most feasible and practical conditions of the desiccant wheel utilizing in this experiment was air flow rate 0.08 to 0.25 kg/s, regenerated air temperature 56.5 to 70°C and at 0.5 rpm wheel speed; the result demonstrates that the influence of air flow rate and air temperature on DCOP were more than that of the humidity ratio. The utilization of the desiccant wheel will reduce significantly the thermal load on the cooling coil by reducing the latent load of the humid air passing respectively through the wheel and the cooling coil.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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التحقيق التجريبي لأداء عجلة المجففة الصلبة جنبا إلى جنب مع نظام تكييف الهواء

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الخلاصة

تهدف هذه الدراسة إلى دراسة أداء نظام إزالة الرطوبة المجففة الصلب لتقليل الحمل الكامن على ملف التبريد لنظام تكييف الهواء وتحسين الراحة الحرارية، وبالتالي تقليل استهلاك الطاقة. تحتوي العجلة الدوارة المجففة على هلام السيليكا كما تم استخدام مادة صلبة ماصة للرطوبة في هذه الدراسة. العجلة قطرها ٥٥٠ مم وسمكها ٢٠٠ ملم. تنقسم مساحة المقطع العرضي للعجلة إلى جزئين في نسبة العرض إلى الارتفاع. الجزء الكبير يمثل عملية إزالة الرطوبة أو الامتصاص، في هذا القسم تتم إزالة الرطوبة من الهواء الرطب بواسطة هلام السيليكا. بينما يمثل الجزء الآخر عملية الامتصاص أو التجديد في هذا القسم تم امتصاص الرطوبة من الهواء الرطب بواسطة هلام السيليكا في العملية الأولى سيتم إزالتها منه. أظهرت النتائج التجريبية أن استخدام عجلة التجفيف سيقلل بشكل كبير الحمل الحراري على ملف التبريد عن طريق تقليل الحمل الكامن للهواء الرطب الذي يمر عبر العجلة ولفائف التبريد.

الكلمات الداله:- عجلة المجففة، نظام تكييف الهواء، التحقيق التجريبي.