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Rotary desiccant wheel systems: A review

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ABSTRACT

Rotary desiccant wheel (RDW) systems work in line with the dehumidification principle. These systems use salt, such as silica gel (SG) for dehumidifying the process air (PA). Desiccant cooling is adopted as an alternative option against traditional cooling systems owing to its outstanding advantages. Regeneration is of vital importance in the overall performance assessment of RDW systems. In terms of regeneration technique, these systems can be split into two types, which are natural and electrical regeneration. Natural regeneration systems usually have solar air collectors. On the other hand, electrical regeneration systems use typical fossil fuel-powered heaters. Many design-oriented factors influence the performance of RDW systems. At the same time, operating conditions have a notable influence on system performance. The objective of this article is to furnish insights into recent research concerning RDW systems, as well as to highlight cost-effective and environmentally friendly approaches aimed at improving the performance characteristics of these systems. Coefficient of performance (COP), cost, payback period, dehumidification effectiveness, and moisture reduction rate are taken into consideration in the comparative performance assessment analyses.

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1. INTRODUCTION

Desiccants are substances with a strong attraction to moisture. Hence, desiccants can be employed as an addition to traditional systems utilising vapour compression (VC) to eliminate the load of latent heat. Desiccants excel at managing latent heat loads, effectively reducing humidity, while the evaporator in VC systems is adept at addressing sensible cooling demands efficiently decreasing air temperature. Davanagere et al. [1] outline the benefits of employing a desiccant in the subsequent points.

- It represents an eco-friendly technology that can regulate indoor building environments, functioning without the requirement for refrigerants that are detrimental to the environment.
- The level of humidity control achieved is superior compared to that accomplished by using VC systems.
- The system begins to exhibit efficiency once the latent heat load surpasses the sensible heat load.
- It possesses the ability to eliminate particulates in air pollutants.
- It utilises negligible amounts of electrical energy. Additionally, due to its regenerative nature, the system enables the usage of solar and waste energies throughout this process.
- Enhancement in the quality of indoor air is often attributable to naturally elevated ventilation.
- In certain scenarios, the energy cost for desiccant regeneration can be lower than the energy cost associated with dehumidifying air by cooling it below its dew point temperature.

Within the realm of air conditioning (AC), the process of dehumidification has gained growing significance, particularly in regions characterised by hot and humid climates, owing to its vital role in ensuring human well-being and comfort. Sterling et al. [2] conducted a study to explore the optimal range of relative humidity for promoting human health. Their findings indicate that maintaining a relative humidity of approximately 50% is influential in deterring the survival and proliferation of biological pollutants, including viruses, bacteria, mites, and fungi. Furthermore, the consumption of fossil fuels and the emission of gases in heating, ventilation and air-conditioning (HVAC)

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systems have significantly contributed to the recent increase in climate change. All these factors play a crucial role in this ongoing concern [3]. Among these factors, the traditionally used AC units have a great value, and it can be easily understood when their working principle is examined. By the working principle of conventional AC units shown in Figure 1, they cool the air at 100% relative humidity (RH), which is entirely called rotten air [4]. This rotten air can even harm human health in buildings with insufficient ventilation.

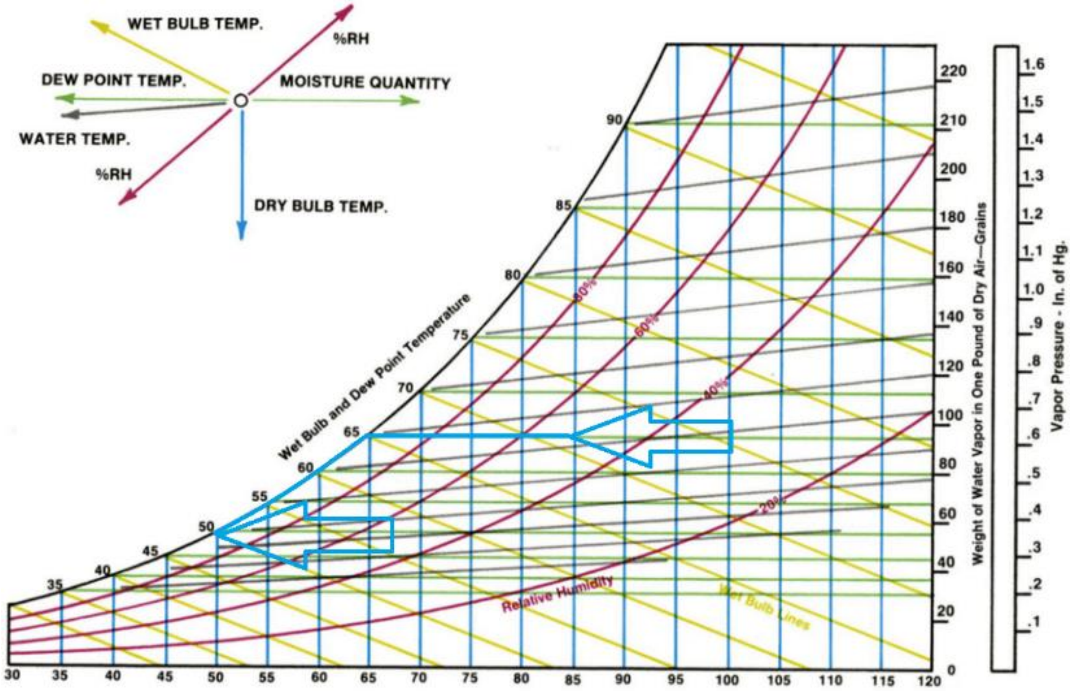

Fig. 1. Illustration depicting the operational principle of conventional AC units on a psychometric diagram.

Global warming with rising fossil fuel consumption has also enhanced with VC AC. Hence, efforts to improve existing AC systems and solid dryer-based AC as alternative AC systems have increased in system performance significantly recently [5]. Based on these investigations, it can be finalised that RDW systems represent a superior alternative to traditional air conditioners. These systems, serving as alternatives to conventional AC systems, are elucidated through the following advantages presented as bullet points [6-9].

- The system effectively manages both sensible and latent loads, making it adaptable for use in diverse climates and environmental conditions.
- Apart from employing water, which has minimal or no cost, as a refrigerant, eco-friendly and low-cost [10, 11], desiccant materials like SG and zeolite can also be utilised.
- In contrast to liquid desiccant systems, where direct interaction occurs between the liquid and air, solid desiccant systems are more compact and less prone to corrosion.
- Desiccant cooling systems might be powered by thermal energy sources of lower quality, including waste, solar, and geothermal energy. As a result, operational expenses can be notably minimised [12, 13].
- It addresses the issue of intermittent operation encountered in fixed systems utilising desiccant beds for cooling purposes.
- Solid desiccant cooling systems can manage air characterised by dew-point temperatures (e.g., -40°C) that are exceptionally low, in contrast to traditional VC systems, which can solely handle dew-point temperatures of around 4°C.

In the operational concept of RDW systems, desiccant salts primarily based on SG are commonly employed. These systems typically comprise two compartments: the process and the regenerative chambers. The process chamber draws ambient air from indoors and utilises the salts to remove moisture primarily. In the regenerative chamber, the moisture absorbed by the salts is heated and eliminated, after which it is released into the environment. This process effectively prolongs the lifespan of SG-based desiccant salts. Therefore, researchers have carried out extensive investigations across various topics within the literature concerning RDW systems. These systems are regarded as highly effective alternative solutions due to their advantageous characteristics compared to other systems. Ongoing research aims to further enhance and develop these systems, paving the way for potential advancements in the future. This article examines the working conditions, structure and design differences, rotational speeds, and solar-integrated RDW systems within the realm of desiccant-based dehumidification as well as cooling systems, comparatively, and discusses the study in the literature on the efficiency of the application. In addition, the differences in the systems as a result of these comparisons are taken into account. This article aims to furnish insights into the foundational research concerning rotary dryer wheel systems and proposes a strategy that aligns with both cost reduction and a green approach to enhance the system's performance characteristics.

2. RESEARCH ON RDW SYSTEMS

Harshe et al. [14] have confirmed that the operation of the desiccant rotary wheel as shown in Figure 2(a) can be learned with correct mathematical formulas. In Equation (1), 20 units in the *z* direction and 36 units in the θ direction are taken considering the desired calculation time and accuracy as shown in Figure 2(b).

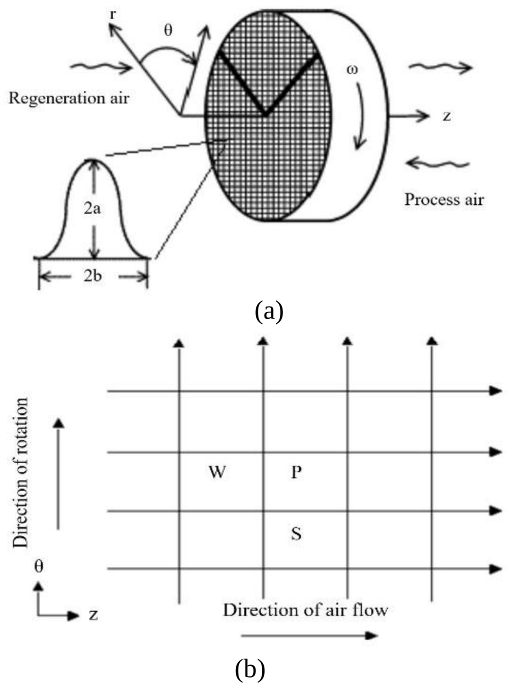

Fig. 2. (a) Representation depicting the design of an RDW, (b) Breaking down the solution space into discrete elements [14].

$$\frac{\delta W}{\delta t} + 2\pi N \frac{\delta W}{\delta \theta} = \frac{a_v k_y (Y - Y_e)}{M_d} \quad (1)$$

In Figures 3(a), and 3(b), it can be observed the estimated outcomes for a wheel speed of 20 RPM. Figure 3(a) presents key variables as the process begins, whilst Figure 3(b) displays the same variables just before the process concludes. Throughout the process phase, the moisture content inside the dryer increases at an angle, reaching zero in the purification section at the process's end. This indicates that the activation zone effectively extracts moisture content affected by humidity at the inlet, confirming the satisfactory performance of this zone. The model's predictions align with experimental observations at lower rotational speeds, but deviations are apparent at higher rates, as indicated in Figures 3(c) and 3(d) illustrating the impact of regeneration temperature (RT) on water vapour residue, revealing enhanced performance at higher temperatures. The model's predictions closely match experimental results at lower RT. The disparities between the model's estimates and empirical findings at low residue levels may stem from uncertainties in the adsorption isothermal sub-values of water vapour residues. When designing the dryer's swivel wheel, the mathematical model is employed, and numerical techniques are utilised to solve the model equations. By establishing a correlation between the Sherwood number and dryer water content, it becomes evident that the estimates align with experimental results. These predictions provide valuable insights for system operation based on preliminary observations [14].

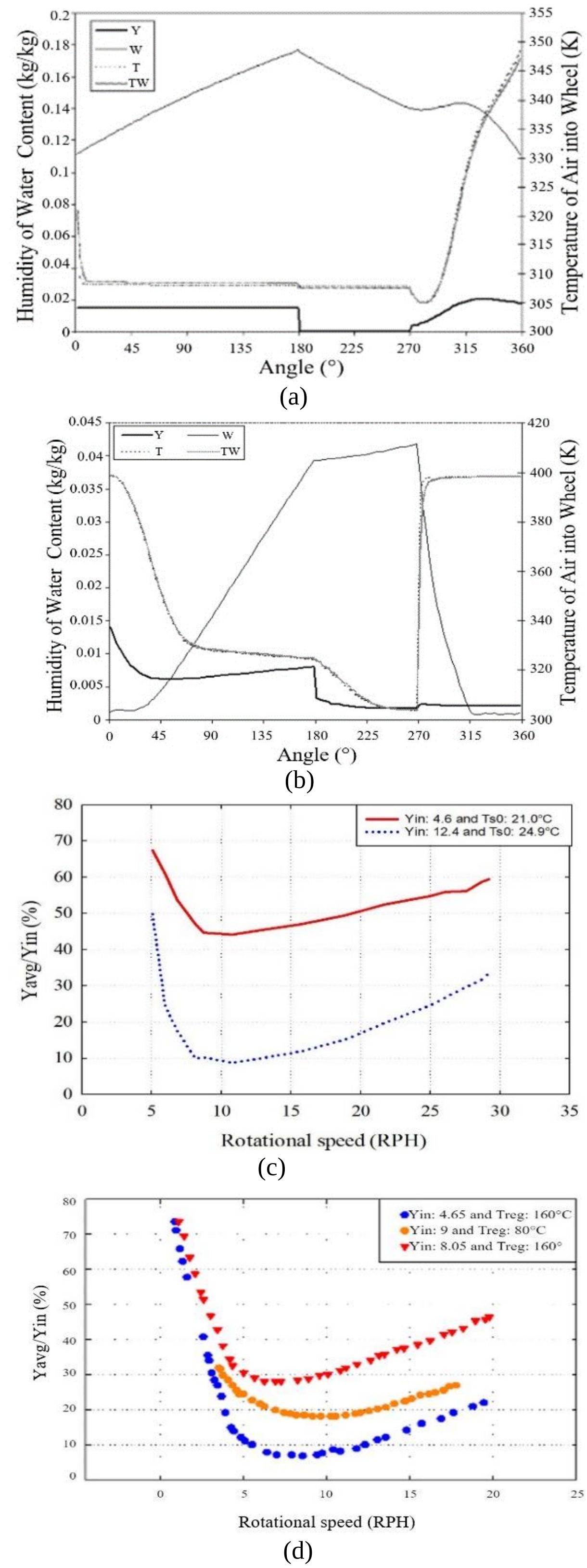

Fig. 3. (a) Anticipated changes in essential parameters at different angles, (b) Expected changes in important parameters at various angles right before the process's exit point, (c) Influence of the incoming humidity on *Yavg/Yin*, (d) Impact of the temperature utilised for RT [14].

2.1. Comparisons according to RDW systems operating conditions

In the research conducted by Panaras et al. [16], they present an experimentally verified application of a streamlined approach for modelling a desiccant wheel. This method relies on the analogy concept and incorporates the formulation, which is by Jurinak's [17] suggestion to consider the combined potentials in the system. The conditioned space in the study has a surface area of 48 m^2 as well as 150 m^3 in volume. The RDW located within this space is constructed using SG material with 630 mm in diameter and a thickness of 200 mm. Furthermore, the pre-cooling is facilitated by an evaporative cooler of the evaporative cooling pad type, featuring a useful surface area of 0.36 m^2 and a pad thickness of 0.3 m. The daily measurement conditions for various operational states of the desiccant wheel are outlined in Table 2, encompassing different airflow conditions during stable state conditions.

Regarding the operational aspects of the impeller, while the temperature levels are within the expected range, the humidity values are consistently higher than anticipated. The reason behind this disparity in humidity lies in the reduced moisture absorption capacity of the dryer during regeneration after each cycle of dehumidification. This decrease can occur due to factors such as product interaction, and it becomes particularly challenging to lower the humidity back to its initial 5% level after regeneration if it starts at 80%. Consequently, following the regeneration process, there will inevitably be a slight increase in the permanent moisture content within the desiccant, occurring within the existing natural cycle [16]. Ge et al. [18] conducted an experimental performance analysis of a two-stage rotary desiccant cooling (2-SRDC) system within buildings. The study aims to provide insights into the system's performance through practical applications, as depicted in Figure 4.

Table 2. Measuring range conditions [16].

Condition	$t_1(°C)$	$\omega_1(g/kg)$	$t_2(°C)$	$\omega_2(g/kg)$
Minimum	24	4	50	3
Maximum	40	14	80	15
Flow rate (m^3/h)	-	600	1000	1200

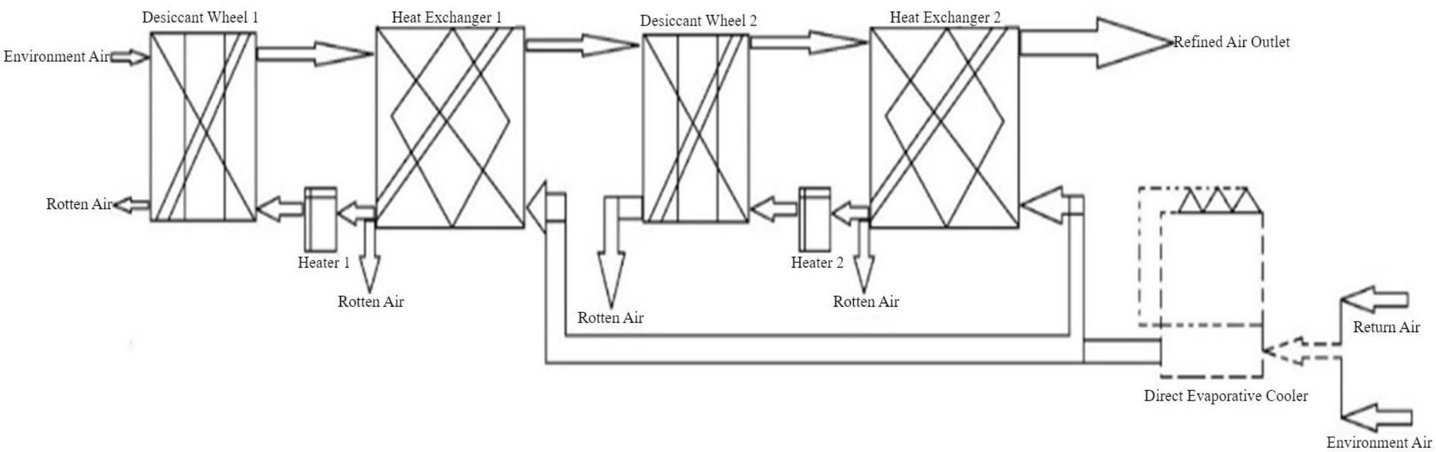

Fig. 4. Schematic illustration of an experimental study on a TSRDC system in buildings [18].

An evaporator with an efficiency of 65% is positioned at the inlet of the RA to decrease the temperature of the RA and enhance the COP. To recover the heat from the RA and minimise the thermal consumption of the system, a heat exchanger consisting of 5600 channels made of aluminium is employed. This heat exchanger has a pressure loss of under 120 Pa and operates with an efficiency of approximately 60%. The RDW is constructed using a composite desiccant ceramic surface material infused with SG and a halogen-based component. It features a honeycomb structure with flow channels that are 0.003 m in half height and width. The RDW has a size of 0.26 m in diameter and a width of 0.1 m. It operates at a rotation speed of 8 r/h, and its design focuses on achieving a low RT whilst maintaining a high dehumidification capacity. The single-stage system acquires a notably higher RT as opposed to the 2-SRDC system. The humidity and temperature values obtained at the recommended three weather conditions between 65-80°C, 65-75°C and 80-90°C are evaluated. Moreover, Table 3 presents the system's performance under a range of conditions, encompassing both mild American Air-conditioning and Refrigeration Institute (ARI) summer and humid conditions, as well as extreme weather conditions resembling those experienced in Shanghai.

Table 3. The humidity and temperature values are obtained for three weather conditions [18].

Condition	*PA Inlet Condition (Ambient Air)*		*Return Air Condition (Indoor Air)*		*RA Inlet Condition*	
Scenario	*Dry bulb (°C)*	*Humidity ratio (%)*	*Dry bulb (°C)*	*Humidity ratio (%)*	*Dry bulb (°C)*	*Humidity ratio (%)*
ARI summer	35.0	14.3	26.7	11.1	23.5	14.5
ARI humid	30.0	16.2	26.7	11.1	22.5	16.0
Shanghai (August)	35.0	23.2	27	13.5	26.5	19.5

Ge et al. [19] developed a two-stage dehumidification system with a single-rotor design. This system is comprised of four distinct segments: two regeneration stages and two process stages. This innovative configuration, depicted in Figure 5, is integrated into the newly designed dehumidification system.

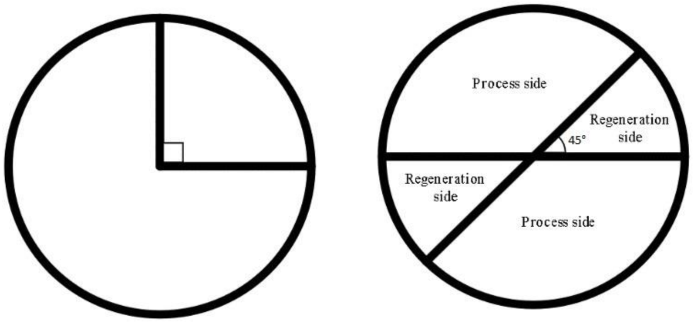

Fig. 5. Sections of conventional and engineered RDWs.

The impact of varying wheel thicknesses at different rotational speeds under ARI summer and humid conditions is examined. The values found for weather conditions are provided in Table 4. By the test result, the research findings indicated that enhancing the wheel's thickness led to enhanced performance when contrasted with alternative systems.

Table 4. Weather conditions of the study [19].

Operation Parameters	*Baseline Values*
PA inlet temperature (ARI SUMMER)	$35°C$
PA air inlet humidity ratio (ARI SUMMER)	14.3 g/kg
PA air inlet temperature (ARI HUMID)	$30°C$
PA inlet humidity ratio (ARI HUMID)	19.2 g/kg
Return air (indoor air) temperature (summer & humid)	$26.7°C$
Return air humidity ratio	11.1 g/kg
Enthalpy air flux	55.2 kJ/kg
PA flux	360 m^3/h
RA flux in the desiccant wheel (Q_9/Q_{13})	135 m^3/h
RA flux in the heat exchanger (Q_7/Q_{11})	360 m^3/h
RT (T_9/T_{13})	$50-90°C$

In addition to this, in the conducted tests, it is observed that the system employing a wheel with a thickness of 100 mm outperforms those with thicknesses of 70 mm and 40 mm. This configuration ensures a reliable air supply when RT exceed 60°C as well as 70°C during ARI summer and humid conditions, separately. Furthermore, adopting this setup allowed for achieving a high COP even with a lower RT. The two-stage dehumidification process with a single swivel wheel is approximately 4.5% more than other systems with a rotation speed of 4-8 rpm and is half the size of other systems. Ma et al. [20] initiated a study to assess the effectiveness of desiccant wheel dehumidification in generating air characterised by a diminishment of dew point temperature. The desiccant wheel is defined by a size of 0.8 m in diameter and 0.2 m in thickness. Its core structure consists of aluminium honeycomb material, and the honeycomb is covered with SG desiccant. The rotational speed of the desiccant wheel can be adjusted, falling within the spectrum of 1 to 30 r/h. The design incorporates a PA-to-RA area ratio of 3, with the PA flow rate capable of varying from 0 to 6000 m^3/h, whilst the RA flow rate can be regulated between 0 and 2000 m^3/h. Following the test results, the desiccant wheel demonstrates effective moisture removal capabilities when the system operates under conditions of 6°C and 4 g/kg, showing low humidity dehumidification conditions. It can reduce the moisture content of the PA from 6°C and 4 g/kg to less than 1 g/kg when exposed to regenerative inlet temperatures ranging from 75°C to 105°C. During this range, the relative dehumidification capacity of the desiccant wheel fluctuates between 77.4% and 85.2%, whilst the dehumidification coefficient of performance (DCOP) exhibits fluctuations within the scope of 0.45 to 0.33.

2.2. Comparison of RDW systems by structure and design differences

Hanifah et al. [21] ran a study in which they investigated an RDW system that notably lacks a honeycomb matrix structure. In this setup, the drying material selected for the process is SG. The desiccant wheel is partitioned into two distinct sections, which are an adsorption section and a regeneration section. Each of these sections comprises two segments, and they are each filled with 900 g of SG with a diameter ranging from 3 to 5 mm. Under the test results, the experimental performance of dehumidification reveals thermal, regeneration, and dehumidification efficiencies of 24%, 14%, and 11%, respectively. These values are notably lower than those reported in other studies cited in the paper, indicating a potential issue with the current design that requires improvement. Furthermore, during the experiment, the noodle product was dried for 17 hours, resulting in a reduction of its initial moisture content from 33.86% to 9.95%. Yadav and Yadav [22] proposed a wheel model designed to significantly enhance dehumidification performance. This model, known as RDW, achieves this by expanding the purging purification area. Additionally, their optimisation efforts include adjusting the fan angle within the purification area. They highlight that the dehumidification performance is superior when the RDW rotates counterclockwise. Furthermore, they identify that the highest dehumidification efficiency is achieved when the fan angle within the purification area is set at 5°. O'Connor et al. [23] have introduced an innovative RDW design tailored explicitly for inactive ventilation systems within buildings, as illustrated in Figure 6.

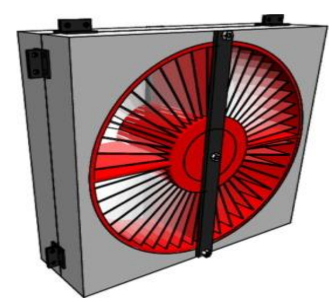

Fig. 6. Demonstration of the newly designed wheel [23].

Given the critical significance of surface area in rotary wheel dehumidifiers, the desiccant materials have been arranged within a honeycomb structure. This arrangement minimises the decrease in pressure as it passes through the rotary wheel. The planned wheel design is intended to sustain a particular pressure reduction of about 2 Pa, which is required to ensure proper ventilation. The porosity of the SG material is 66.1%, considerably less than the

90% porosity commonly found in honeycomb wheels. In a testing period lasting 600 seconds, researchers examine the dehumidification efficiency of the rotary wheel dehumidifier under dissimilar inlet air temperatures and RH conditions. To facilitate the regeneration process, source air at a temperature of 48°C and a velocity of 0.8 m/s is employed. Besides conducting experimental studies, the performance metrics of the innovative RDW design are evaluated using CFD simulations based on ANSYS. Furthermore, the performance indicators of the newly designed rotary wheel dryer are assessed, and a comparison is made between the experimental findings and the results obtained from ANSYS-based CFD simulations, as detailed in Table 5. The results obtained through CFD align closely with the empirical data. According to these findings, the dehumidification efficiency of the innovative rotary wheel ventilation system reached an impressive 65%. Remarkably, this significant reduction in moisture content is achieved with just a modest increase in air temperature of 9.6°C during the regeneration process.

Table 5. Comparison of CFD and experimental studies [23].

Types and Error		*Temperature (°C)*		*RH (%)*	
Phenomenon	*Error*	*Before wheel*	*After wheel*	*Before wheel*	*After wheel*
Adsorption	CFD	20	27.14	90.7	33.14
	Experiment	20.11	27.46	91.28	27.46
	Error (%)	0.55	1.17	0.64	-20.68
Desorption	CFD	48	45.54	7.32	11.45
	Experiment	49.68	45.29	6.60	10.23
	Error (%)	3.38	-0.55	-10.91	-11.93

Jia et al. [24] have developed a composite dryer wheel, illustrated in Figure 7, to enhance the performance of the RDW cooling system. The composite desiccant material is composed of two layers: a host matrix featuring open pores, primarily made of SG, and the inclusion of a hygroscopic substance, lithium chloride, infused into these pores. The composite desiccant has a pore surface area of 194 m^2/g and a pore diameter of 3.98 nm.

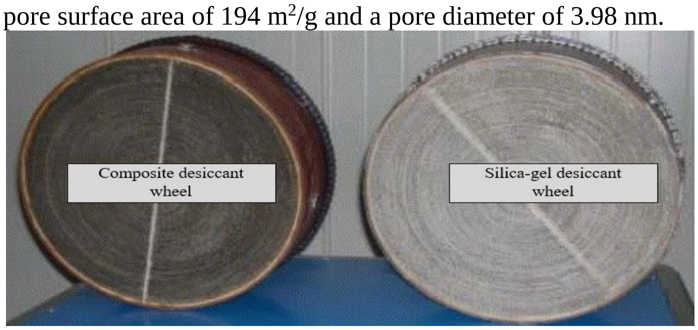

Fig. 7. Pictures of the developed composite and SG-based RDW [24].

The newly designed dryer wheel can reduce water molecules further. It has removed about 25% more moisture from the air compared to SG. Additionally, results from simulations utilising a validated model demonstrate that the DCOP regarding the contemporary wheel is notably better when compared to the traditional wheel, as shown in Figure 8.

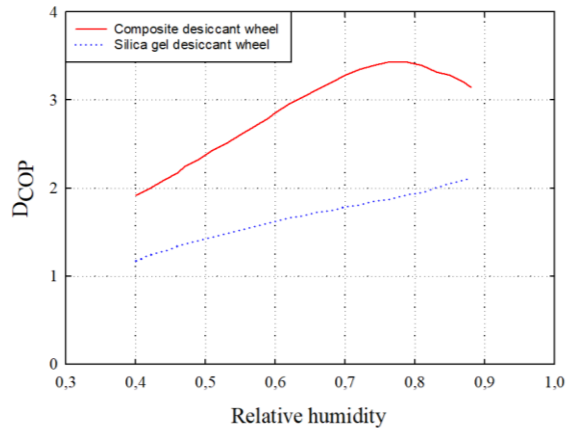

Fig. 8. Comparison of a composite wheel with the traditional wheel in terms of DCOP in 16 rph rotation speed, 100°C RT and 21°C inlet temperature [24].

Moreover, it appears that there could be an optimal wheel thickness, potentially ranging from 80 to 100 mm, that maximises the amount of dehumidification achieved. The overall system COP can reach 1.28, which is approximately 35% more advanced than the system utilising SG. This performance improvement allows the supplied air to be adjusted to around 20°C with a relative humidity of 67%, making it suitable for AC applications. Zhang et al. [25] conducted a comparison study to assess the hygroscopic properties of three materials: SG, calcium chloride ($CaCl_2$), and a compound desiccant consisting of SG and $CaCl_2$ (SG-$CaCl_2$). The hygroscopic characteristics of each wheel configuration are evaluated under weather conditions of 25°C and 70% RH. The wheel diameters and thicknesses are identical, having a measure of 40 cm in diameter and 20 cm in thickness. In a comparative experimental test study involving stable and unstable states, the parameters for the air supply are as follows: PA flow is 790 m^3/h, temperature ranges from 27 to 35°C, and RH ranges from 40% to 63%. At a flow rate of 263 m^3/h, the temperature fluctuates between 70°C and 120°C at different RTs. The study's findings reveal that composite dryers achieve equilibrium more rapidly compared to SG dryers, as shown in Figure 9. Their superior water absorption capability makes them suitable for drying wheel applications.

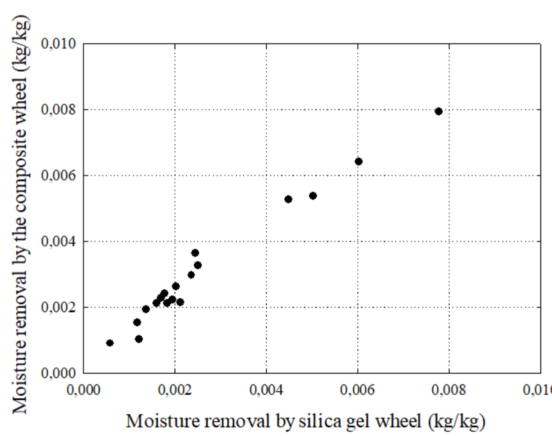

Fig. 9. Comparison of instant moisture removal in air conditions of 60-120°C RT, 27.5-35.0°C inlet air temperature and 39-63.8% inlet humidity [25].

2.3. Pre-cooling and comparisons by rotational speed

Su et al. [26] have created a dehumidification system that incorporates a recirculated regenerative, and precooling RDW. The RDW possess a diameter of 260 mm, in addition, the processing area of the drying wheel is three times larger than the regeneration area. While the proposed system uses conventional cooling conditions, the PA temperature, the RH of the PA, the flow rate of the PA, the temperature of the RA and the pre-cooling temperature are approximately 35°C, 75%, 225 m^3/h, 135°C, 22°C, respectively. According to the results, as the RH of the PA in the developed system increases from 60% to 90%, there is a 7.8% mitigation in the dehumidification capacity. Conversely, when the PA temperature is increased by 4°C, there is a 1.3% increment in the dehumidification capacity. The enhanced dehumidification system, which combines the advanced pre-cooling and recirculating regenerative rotary dryer, removes approximately 30% more moisture than traditional systems. Interestingly, as the RA flow rate varies between about 10% to 18%, the sensible heat rate decreases with increasing RA flow rate. In addition, the dehumidification performance coefficient fluctuates between 0.36 and 4.32, depending on the moderate heat ratio, which ranges from 0.23 to 4.62. Angrisani et al. [27] have tested the effects of rotational speed on the RDW. As a result of these tests, it is observed that the adsorption rate of the drying wheel gradually increases when the PA input temperature is low. The environmental conditions during these tests are a temperature of 32°C and a humidity level of 15 grams of water vapour per kilogram of air (g/kg). The ideal rotational speed to maintain high dehumidification rates depends on specific operating conditions. Here are the speed ranges corresponding to various conditions:

- When the inlet process humidity increases from 8 to 11 g/kg, the ideal speed varies between 7 to 10 rpm.
- For a rise in RT from 45°C to 65°C, the recommended speed range is 6 to 10 rpm.
- When the ratio between regeneration and PA flow rates rises from 0.5 to 1.1, the optimal speed range is 5 to 9 rpm.
- However, when the inlet process temperature enhances from 25°C to 34°C, the ideal speed diminishes from 8 rpm to 6 rpm.

The highest dehumidification efficiency is achieved at a rotational speed of 0.5 to 0.6 when the inlet process has low humidity and temperature, whilst RT and flow rate are high. The optimum rotation speed, concerning the DCOP, remains consistent regardless of operating conditions. High DCOP is attained with RT, flow rate, and high inlet process humidity and temperature. Furthermore, the sensible energy proportion increases with low RT and flow rate, coupled with high inlet process humidity and temperature, in comparison to the rotational speed of the dryer wheel. In other words, while the sensible energy proportion and DCOP increase in a direct relationship, they are inversely related to the dehumidification rate. Chen et al. [28] aim to investigate the distinctions between systems with and without pre-cooling. Their research endeavours to pioneer the energy-efficient design of pre-cooling systems integrated into RDWSs, with a specific emphasis on assessing their performance in high-temperature and high-humidity conditions. The system primarily comprises four key components: a front-surface air cooler, a back-surface air cooler, a fan, and a desiccant wheel. In this study, SG serves as the drying material, and the channel shape adopts a honeycomb structure with a rotational speed typically set at 12 rph. Accordingly, the presence of a front cooler in the system results in higher dehumidification efficiency and enthalpy efficiency compared to the system without one. If the humidity ratio, relative humidity, and PA inlet temperature increase, both dehumidification efficiency and enthalpy efficiency also rise, regardless of whether precooling is employed or not. In a study conducted by Gadalla and Saghafifar [29], they propose the implementation of air precooling in two-stage solid desiccant AC systems using Maisotsenko coolers as a means to enhance the COP. According to the results presented, the COP_{avg} of the system during the hours from 10:00 AM to 2:00 PM for the months spanning from June to October is approximately 1.77. Also, the system's average rate of heat input required for operation is calculated to be 100.3 kW, and the average building cooling load is 46.2 kW. This yields an overall system COP_{avg} of 0.46. However, it is worth noting that the COP_{avg} of the system during the period from 8:00 AM to 5:00 PM, which is considered a more reliable measure of system performance, is calculated to be 0.72.

2.4. Solar Energy integrated RDW

Ahmed, Kattab, and Fouad [30] devise a solar heater regeneration process for an RDW system, which is depicted in Figure 10(a). The schematic representation of the operational principle can be seen in Figure 10(b).

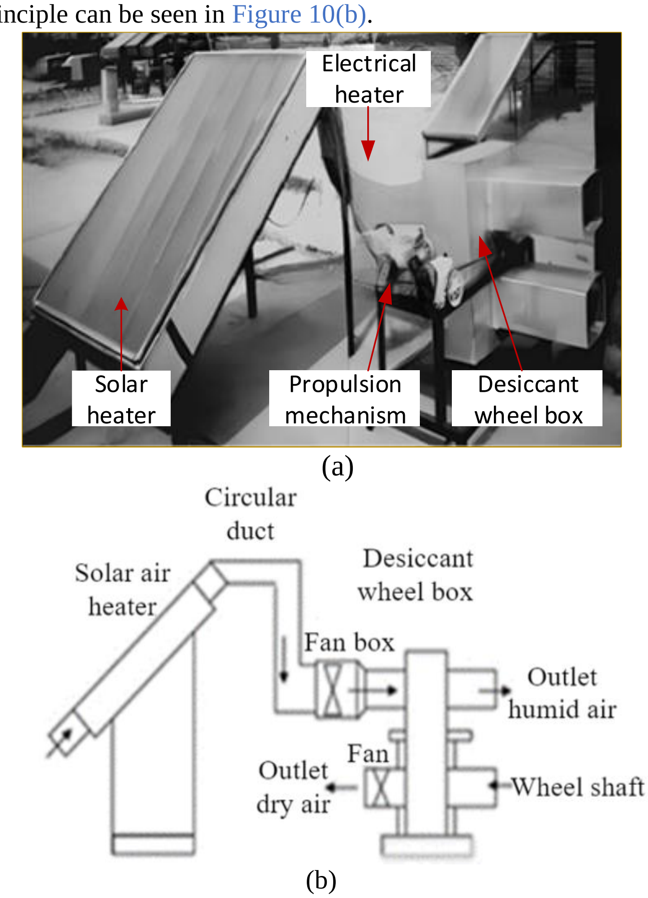

Fig. 10. (a) The designed system and (b) the schematic representation of the designed system [30].

The system primarily comprises a 2 m^2 solar collector, a rotating dryer wheel constructed from galvanised iron weighing 30 kg within a measure of 0.7 m in diameter and 0.2 m in thickness, split evenly into two segments for regeneration, maintaining temperatures between 60-90°C. The thickness of the tire ranges from 0.26 to 18 m. The significant airflow rate is determined to be within the range of 1-5 kg/min, operating at temperatures between 60-90°C and rotational speeds between 15-60 rpm. It is reasonable to assume that the wheel can be configured to achieve an average regeneration efficiency of 0.8 and 0.3 at regenerating temperatures of 60-90°C, separately. Additionally, the optimal pore spacing varies between 0.4 and 0.7, depending on the RT and airflow conditions. The perforated plate solar heater, covering an area of 2 m^2, efficiently transfers approximately 72.8% of the total required regeneration energy when operating with an airflow rate of 1.9 kg/min at an RT of 60°C. Nonetheless, this efficiency experiences a notable decline, averaging only 13.7%, whilst the airflow rate is elevated to 9.4 kg/min, and the RT is raised to 90°C.

Liu et al. [31] introduce a modern hybrid AC system named the Solar-Powered RDW AC system, which incorporates solar thermal collectors, photovoltaic power generation, VC cooling technology, and a two-stage rotary desiccant wheel system. Its primary objective is to enhance indoor comfort within buildings located in regions characterised by conditions that are exceedingly humid and hot weather. Once the testing phase concludes, the findings indicate that with each 10 ℃ rise in RT, the dehumidification capacity and cooling capacity exhibit an increment ranging from 0.9 g/kg to 2.7 g/kg and 0.4 kW to 1.9 kW, one by one. Moreover, for each 1 g/kg uptick in outdoor air moisture content, there is a corresponding increase in the overall required installation area, which is from 2.2% to 2.3%. The Solar-Powered RDW AC system demonstrates commendable operational performance. Consequently, in hot and humid conditions, this system functions effectively and serves as a valuable reference for future applications.

Kabeel and Abdelgaied [32] are currently engaged in a research project aimed at examining how the incorporation of an RDW within a solar dryer unit affects its thermal performance. In this investigation, the combined system consists of an RDW, a drying unit, and a solar-powered air collector, with SG serving as the drying material. Based on the findings of their study, the temperature of the drying air within the integrated system rises from 65°C to 82°C, accompanied by a decrease in humidity from 15 g/kg to 8.8 g/kg compared to the standalone solar dryer system. These outcomes indicate that the integration of the RDW with the solar drying unit resulted in an average 153% boost in the system's useful heat gain when compared to using the solar drying unit alone.

3. CONCLUSION

RDW represent systems that combine desiccant, dehumidification, and evaporative cooling technologies. They offer separate control over humidity and temperature, do not use harmful CFCs, and have gained popularity due to their low energy consumption. RDWs have the potential to replace traditional VC air conditioners as technology in this field advances. Compared to conventional VC air conditioners, RDWs take precedence in key areas such as energy efficiency, health, comfort, and eco-friendliness, leading to a growing trend in their adoption. Ongoing research and development efforts focus on enhancing system performance through the use of new materials, technologies, and configurations, as well as addressing factors like cost reduction, weight reduction, and aesthetics.

This article compiles current comparative studies on working conditions, structural and design variations, pre-cooling, rotation speed, and solar energy integration in RDW systems, drawing from existing literature. It aims to investigate how various design and construction-related factors impact RDW performance. Furthermore, this article seeks to promote basic research on rotary desiccant wheel systems. It suggests an approach prioritising cost savings and environmentally sustainable practices to improve the system's performance features.

- The most ideal wheel thickness is measured as 80-100mm.
- At high rotation speeds, PA temperatures are lower.
- At high RT temperatures, the moisture absorption rate increases further with RDW integration.
- Composite wheels reach 1.28 with a COP increase of up to 35% compared to conventional SG-based wheels.
- Depending on the wheel design of RDWSs, an increase of up to 65% in moisture absorption can be observed [22].
- Wheels designed with SG-$CaCl_2$ compound can provide approximately 15% more moisture removal in unconditional time than traditional SG-based wheels.

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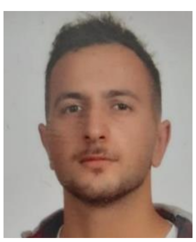

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