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Design and Development of Desiccant Air Dryer

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Abstract: *Compressed air systems are widely used in industrial applications. In such systems, the presence of moisture can significantly impact the performance of the equipment and the quality of the product. The current study outlines the design and development of an compact desiccant air dryer that facilitates the removal of moisture from compressed air effectively. The proposed system is based on the principle of absorption. The system comprises two towers that are filled with activated alumina. The proposed system facilitates the continuous supply of dry air by providing the facility for the regeneration of the towers. The control mechanism of the proposed system comprises a 5/2 solenoid valve. The experimental results obtained indicate that the proposed system facilitates the removal of up to 95% moisture with a low pressure drop of about 0.5 bar. The proposed system is found to be cost-effective and easy to fabricate. The proposed system can be used in small-scale industrial applications. The experimental results obtained indicate that the proposed system is an effective and reliable solution for the drying of compressed air*

Keywords: Desiccant Air Dryer, Adsorption, Moisture Removal, Activated Alumina, Twin Tower System, Compressed Air

I. INTRODUCTION

Compressed air is considered to be one of the widely used utilities in modern industrial applications due to its flexibility, safety, and ease of transmission. However, it is worth noting that compressed air is always accompanied by some amount of moisture in the form of water vapor. During the process of compressing the compressed air, this water vapor gets mixed with it. If this moisture is allowed to persist in compressed air, it may cause some serious problems during its operation. These problems include corrosion of pipelines, blocking of valves, malfunctioning of pneumatic devices, and degradation of product quality. The presence of moisture in compressed air also reduces the efficiency and lifespan of industrial equipment. In applications such as those in the manufacturing of electronic devices, pharmaceutical products, and food processing, even small quantities of moisture may cause product defects. Therefore, it is highly recommended to remove moisture from compressed air in order to ensure its efficient operation and product quality. For drying compressed air, several dryers are used. These include refrigerated dryers, membrane dryers, and desiccant dryers. In moderate conditions, refrigerated dryers are used for drying compressed air. However, these dryers are considered to be less efficient in drying compressed air to low dew point temperatures. On the other hand, desiccant dryers are highly efficient in drying compressed air. Desiccant dryers are capable of drying compressed air to low dew point temperatures. Desiccant air dryers utilize the adsorption process, where the moist air present in the compressed air is adsorbed by the desiccant.

The desiccant may be activated alumina, silica gel, or molecular sieves. Activated alumina is most commonly used as a desiccant. The desiccant air dryers are designed as twin towers, where one tower is used for drying and the other for regeneration. The desiccant gets exhausted after a certain time and then needs to be replaced. This research work focuses on designing and developing a small-scale, efficient, and economical twin tower desiccant air dryer system. The proposed system is designed and developed for efficient drying of compressed air. The proposed system consists of two vertical cylinders, activated alumina, pneumatic pipelines, pneumatic connectors, a solenoid valve of size 5/2, a

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pressure gauge, and a timer-based control circuit. The solenoid valve is a very important component of the proposed system, as it helps in the automatic switching of the adsorption and regeneration processes. This study aims to design and develop a small-scale, efficient, and economical twin tower desiccant air dryer system. The proposed system can be designed and developed by utilizing the available resources and manufacturing techniques. The performance of the proposed system can be evaluated based on the efficiency of the system and pressure drop.

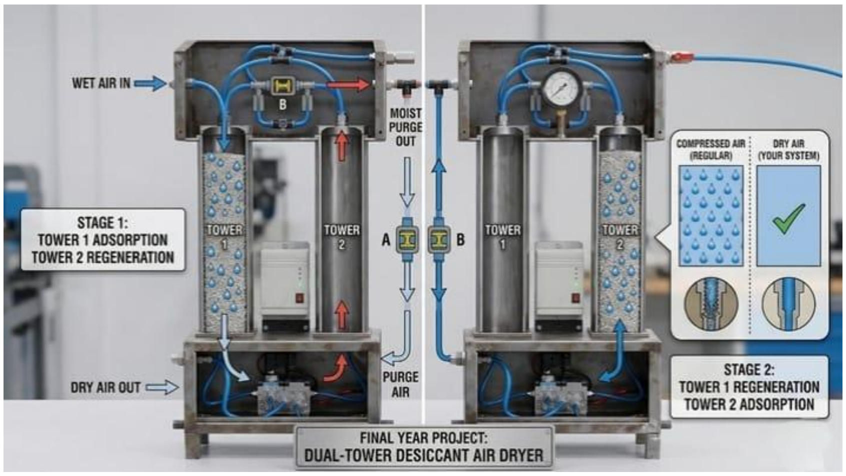

Fig. 1. Desiccant Air Dryer

II. LITERATURE REVIEW

Sr. No.	Author(s) & Year	Title of Paper	Key Work Done	Identified Gap	Improvement in Present Work
1	Ramli M., Ibrahim N., Rahman A. (2021)	Review of Desiccant Materials for Air Drying Applications	Compared different desiccant materials and their adsorption capacity	No practical system design	Implemented activated alumina in real system
2	Jain S., Bansal P. (2015)	Performance Analysis of Packed Bed Desiccant System	Studied heat & mass transfer in desiccant bed	No automatic operation	Added twin tower with automatic switching
3	Kim J., Lee H. (2018)	Adsorption Characteristics of Activated Alumina	Analyzed adsorption and regeneration properties	Only material study	Integrated into working prototype
4	Patel R., Mehta S. (2019)	Design of Heatless Desiccant Air Dryer	Developed twin tower system with purge air	Complex and costly system	Developed simple and cost-effective model
5	Sharma P., Kumar R., Singh D. (2019)	Performance Evaluation of Twin Tower Dryer	Studied efficiency under different conditions	No compact design	Developed compact system
6	Kumar A., Singh B. (2020)	Design of Desiccant Air Drying System	Studied components and system design	Lack of automation	Implemented timer-based control
7	Ahmed M., Ali K. (2021)	Energy Efficiency in Desiccant Systems	Studied regeneration	High energy usage	Used simple heatless

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			techniques		regeneration
8	Zhang Y., Wang L. (2017)	Solid Desiccant Dehumidification System	Analyzed adsorption performance	No practical model	Developed working prototype

III. MATERIALS

A. Activated Alumina (Desiccant Material)

The activated alumina desiccant material is used in the developed air dryer system due to its excellent properties. Activated alumina is used as the main desiccant in the developed desiccant air dryer system. It is composed of aluminum oxide, also known as alumina. Activated alumina is used due to its excellent properties. It is highly porous in nature and has a large surface area. These properties of activated alumina are used to adsorb moisture from compressed air. Activated alumina is highly porous in nature. It is composed of alumina. Activated alumina is used due to its excellent properties. Activated alumina is highly porous in nature. It is composed of alumina. Activated alumina is used due to its excellent properties. Activated alumina is highly porous in nature. It is composed of alumina. One of the main advantages of using activated alumina is its excellent mechanical properties. Activated alumina is highly porous in nature. It is composed of alumina. Activated alumina is used due to its excellent properties. Activated alumina is highly porous in nature. It is composed of alumina. Activated alumina is used due to its excellent properties. Activated alumina is highly porous in nature. It is composed of alumina. Activated alumina is used due to its excellent properties. Activated alumina is highly porous in nature. It is composed of alumina. Activated alumina is used due to its excellent properties. Activated alumina is highly porous in nature. It is composed of alumina. Activated alumina is used due to its excellent properties. Activated alumina is highly porous in nature. It is composed of alumina. Activated alumina is used due to its excellent properties. Activated alumina is highly porous in nature. It is composed of alumina. Activated alumina is used due to its excellent properties. Activated alumina is highly porous in nature.

Fig. 2 Activated Alumina

B. Twin Tower (Desiccant Cylinders)

The twin tower is the main core of the desiccant air dryers and is essential in ensuring efficient and uninterrupted dryness of compressed air. The system consists of two identical cylindrical towers filled with desiccant material, which work alternately in dry and regeneration modes. The cylinders are made of mild steel, which is highly suitable because of its strength and durability in pressurized environments. The vertical position of the cylinders ensures efficient distribution of compressed air and maximizes contact with the desiccant material, hence improving the adsorption capacity of the system During operation, one of the cylinders is in the dry mode, where compressed air is passed through the desiccant material and the moisture is adsorbed. At the same time, the other cylinder is in regeneration

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mode, where the adsorbed moisture is released by passing purge air through the material. After a given time interval, the flow is alternated between the cylinders using a control valve system.

Fig. 3 Twin Tower (Desiccant Cylinders)

C. Solenoid Valve (5/2 Type)

The solenoid valve is one of the most important control devices in the desiccant air dryer system. The device helps control the compressed air flowing into the two towers of the desiccant air dryer. The device has five ports and two positions. The five ports and two positions enable the compressed air to be switched to either of the two towers containing the cylinders. The switching of the compressed air is important in the drying and regeneration process of the air. The device uses the principle of electromagnetism. The device has a coil that receives an electrical signal. The signal generates a magnetic field that helps switch the compressed air flowing into the device. The compressed air is switched due to the spool that moves when the magnetic field is generated. The spool moves back to the original position when the signal is withdrawn. The original position of the spool changes the direction in which the compressed air flows The solenoid valve is connected to the timer control unit. The timer control unit automatically switches the compressed air flowing into the two towers containing the desiccant. The compressed air flowing into the towers is used in the drying process. The compressed air flowing into the second tower is used in the regeneration process.

Fig. 4 Solenoid Valve (5/2 Type)

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D. Outer Body Construction of Desiccant Air Dryer : The outer body of the desiccant air dryer system is designed to provide structural support, proper alignment of components, and protection to the internal parts of the system. The entire structure of the desiccant air dryer system is composed of three main parts: upper body, lower body, and twin cylindrical towers. All of these parts are constructed of mild steel. The upper body of the desiccant air dryer system is composed of mild steel sheets. It is placed at the top of the system. It is used to house the connections of airflow, piping arrangements, and other controlling devices. There are openings in the top box of the desiccant air dryer system for inlet and outlet connections of airflow, valves, and other devices. The top box of the desiccant air dryer system is rigid in nature. This is done to provide proper alignment of the upper ends of the twin towers. The lower body of the desiccant air dryer system is used as the base of the entire setup. It is composed of mild steel sheets.

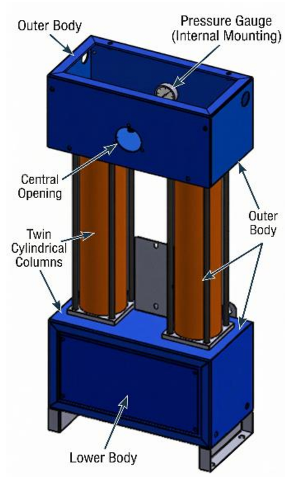

Fig. 5: Outer Body

The entire setup of the desiccant air dryer system is supported by the bottom box. All of the components of the desiccant air dryer system, such as the cylindrical towers, are supported by it. It is also used to provide space to accommodate other devices, such as the solenoid valve and pneumatic devices. It is also used to provide protection to the entire setup from any damage. In addition to this, legs are also used to provide clearance. The twin cylinders are vertically placed between the upper and lower bodies. These are made of mild steel, which is used for the desiccant chambers. These chambers are filled with activated alumina. Sealing is done at both ends of these chambers to avoid any leakage. Also, these are vertically placed to allow efficient interaction between compressed air and desiccant. In addition, support rods are used, which are columns placed between the upper and lower bodies. These columns are used to ensure the structural integrity of the system. These columns ensure that the twin cylinders are fixed during operation. All these parts are welded and fixed to form a rigid and compact structure. Mild steel is used, which offers excellent strength and durability. It can withstand any mechanical stress. The construction of the outer body is such that it is stable, compact, and well-aligned. This is an essential feature of ensuring efficient working and longer lifespan of the desiccant air dryer.

IV. PERFORMANCE RESULTS OF DESICCANT AIR DRYER

Sr. No.	Parameter	Inlet Value	Outlet Value	Unit	Remarks
1	Moisture Content	75–80%	~5–20%	%	95% moisture removed
2	Pressure	8	7.5	bar	Slight pressure drop
3	Pressure Drop	—	0.5	bar	Within acceptable limit
4	Desiccant Efficiency	—	80%	%	Activated alumina performance

Table. 6 : Performance Results of Desiccant Air Dryer

The performance of the developed desiccant air dryer system was evaluated in terms of moisture removal efficiency and pressure. From the observed results, it is evident that the moisture content in the compressed air at the inlet was in the range of 75–80%, which was reduced significantly at the outlet, ranging from 5–20%. This shows that almost 95% of the moisture was removed effectively by the developed system, thereby indicating effective adsorption of moisture by activated alumina desiccant. The inlet pressure of the system was maintained at 8 bar, whereas the outlet pressure was recorded at 7.5 bar. From this, it is evident that there is a pressure drop of 0.5 bar in the system, which is acceptable for any pneumatic system. This shows that there is smooth airflow in the system with low pressure drop, indicating that there is no significant air resistance in the system. Moreover, the desiccant used in the system, namely activated alumina, was also effective in terms of efficiency, which is around 80%, thereby indicating that it is suitable for moisture removal purposes. Moreover, since there were two towers in the system, it was ensured that there was continuous operation in which one tower was used for drying purposes, whereas the other tower was used for regeneration purposes. Thus, it is evident that the developed system is effective in terms of efficiency with high moisture removal capabilities.

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