Suitability of using Silica Gel in Powder Form as an Adsorbent in the Drying Process

Romana Dobakova[1], Filip Duda[2*], Ivan Mihalik[3], Tomas Brestovic[4]

[1]Department of Power Engineering, Faculty of Mechanical Engineering, Technical University of Kosice, Slovakia
*Corresponding Author

Received: 24 September 2022/ Revised: 06 October 2022/ Accepted: 14 October 2022/ Published: 31-10-2022

Abstract— *Gases used in industry must meet the required parameters such as the content of gas impurities, moisture content and mechanical impurities, which have a significant impact on its subsequent use. Various industrial drying methods are used to remove moisture. Among the most used drying methods are methods based on subcooling the gas below the condensation temperature, adsorption drying methods or special methods. The article primarily deals with the drying of gases in a fluid layer of ground silica gel. It describes the issue of the suitability of silica gel as an adsorbent in any form of its structure, the advantages and disadvantages of its use.*

Keywords— silica gel, adsorption, drying.

I. INTRODUCTION

The drying process is a complicated physical process, in which the effect of heat reduces the liquid content in the substance, without changing its chemical composition.

The essence of drying is the migration of moisture in the opposite direction to the sorption process. During the general drying process, moisture moves from the porous core of the material to the surface layers and into the surrounding environment, whereupon the moisture meets the drying medium, which carries it away.

To determine the most optimal drying conditions, it is necessary to know the physical laws that affect drying in the individual phases of the entire process, the input parameters and the required performances.

II. SILICA GEL AS ADSORBENT

The principle of adsorption is the ability of some porous solid substances to bind gas particles or liquid substances on their surface. Trapped substances are released by desorption and the adsorbent can return to the process. The adsorbed amount depends not only on the nature of the adsorbing gas, but also on the nature of the solid substance, on the size of the surface, on the partial pressure of the adsorbing component in the gas phase, and on the temperature. During adsorption, it is important that the adsorbent has as large an active surface as possible.

Known adsorbents include silica gel. It is a granular, porous form of silica, produced synthetically from sodium silicate and sulfuric acid in the form of hard irregular grains or regular balls. The porous structure of interconnected cavities provides a very high surface area (up to 800 $m^2 \cdot g^{-1}$), which allows water vapor to be easily adsorbed. Thanks to this feature, it can be used for example when drying gases. Ordinary silica gel binds an amount of water corresponding to approximately 20% of its weight. Even when saturated with water vapor, silica gel still has the appearance of a dry product, and its shape remains unchanged. After being saturated with water, it can be regenerated again by heating to the appropriate temperature (approx. 150 °C). Aluminium oxide is added to increase its water resistance.

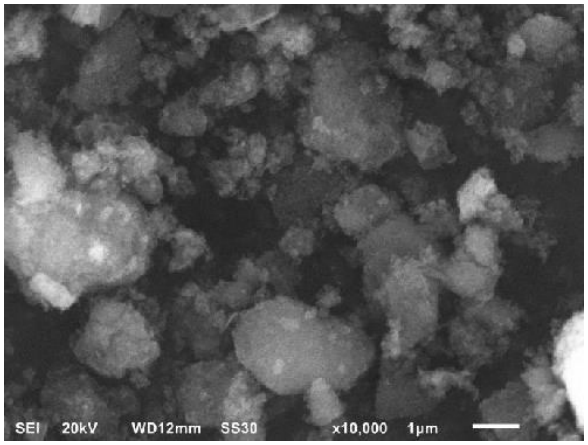


FIGURE 1: Structure of silica gel [6]

Silica gel is non-toxic, non-flammable and chemically highly inert. Sometimes it comes with a moisture indicator admixture that will change its colour whenever it is wet.

a) Type N – normal grains b) Type WS – water resistant grains c) Type Orange gel – indicator grains

FIGURE 2: Types of silica gel

III. DESCRIPTION OF THE MEASUREMENT PROCESS AND DESIGN OF THE EXPERIMENTAL EQUIPMENT

For the purposes of the experiment, spherical silica gel was ground into a fine powder with the help of a crushing mill, while the grain size of the particles was in the range of 0.004 - 0.08 mm (Fig. 3). The structure of the sample was observed using a BRESSER microscope (Fig. 4). Hydrogen was used as the gas that caused the levitation of silica gel particles and the subsequent formation of a fluid layer. This gas was simultaneously subjected to experimental drying.

FIGURE 3: Ground sample of silica gel

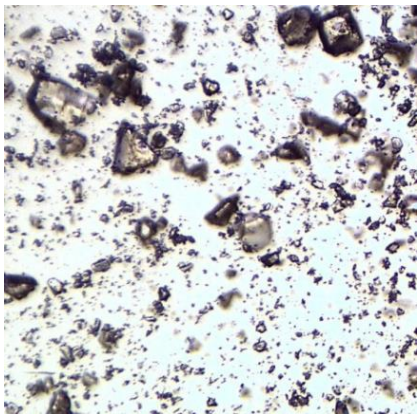
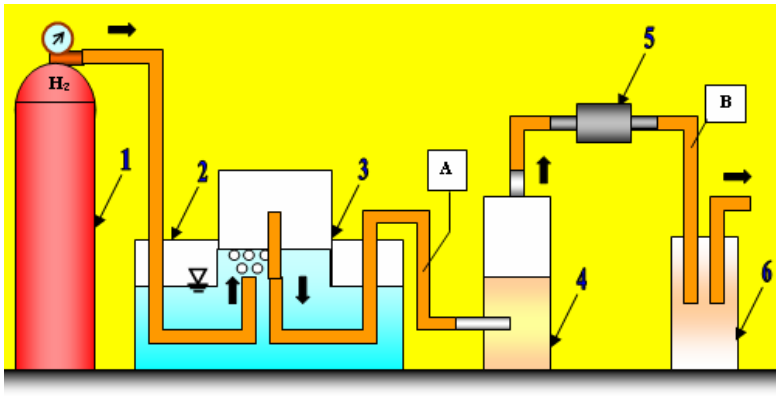


FIGURE 4: The structure of silica gel under a microscope

The model of the designed device for determining the efficiency of silica gel drying is shown in fig. 5. When measuring the required quantities, it was based on two measurement points - point A and B.



1 – pressure vessel, 2 – outer container, 3 – measuring cylinder, 4 – container with silica gel, 5 – filter, 6 – drain container SiO_2

FIGURE 5: Model of experimental equipment

The used hydrogen subjected to drying was stored in a pressure vessel 3.0. The pressure vessel has a gas purity of 99.999% and residual impurities are 0.001% (water vapor, oxygen, nitrogen, CO, CO_2, hydrocarbons).

Dry hydrogen gas was discharged from the pressure vessel into a vessel with water, where it was subsequently moistened using a levelling device (outer vessel and measuring cylinder). By bubbling hydrogen through the water, it was moistened. Subsequently, the humidified gas proceeded through the part where the sensor recording the gas humidity was placed, into a container with silica gel placed in a cylinder-shaped vessel with a total height of 0.02 m, made of PVC. The diameter of the vessel was 0.046 m.

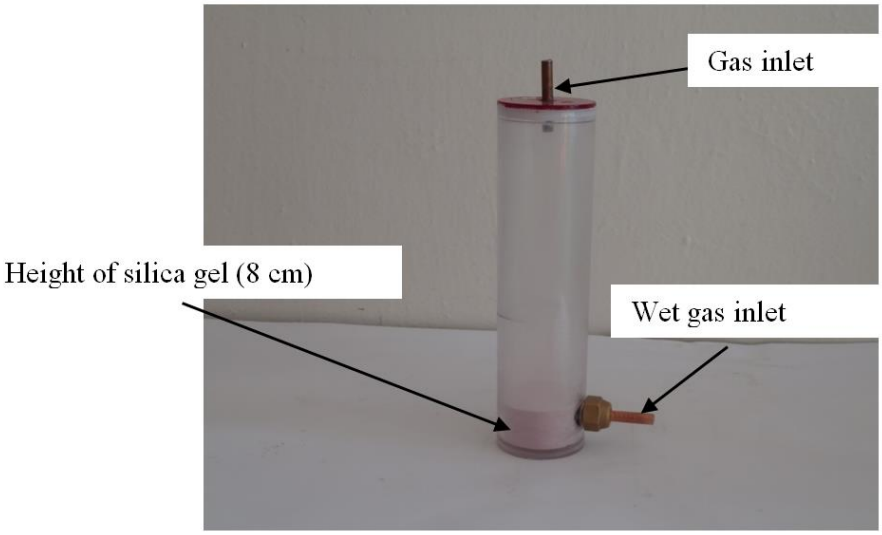


FIGURE 6: Vessel with silica gel

After entering the container, the hydrogen formed a fluid layer of silica gel, and at the same time it dried. After passing through the container with silica gel, the hydrogen passed through the filter, which had the task of capturing silica gel particles that were carried by the gas stream, to the part where the sensor recording the humidity of the gas was placed.

IV. EVALUATION OF EXPERIMENTAL MEASUREMENT RESULTS

During the measurement, the values of the relative humidity of hydrogen and the temperature during its flow through the constructed experimental device were recorded. To determine these quantities, we used a measuring device from the manufacturer Ahlborn - ALMEMO 2390-5 and a relative humidity and air temperature sensor FHA646. The results were subsequently processed using the AMR-Control software on a PC.

The measurement at point A was made in front of a cylinder filled with silica gel. The time interval was 10 seconds, and the measured values are shown in fig. 7.

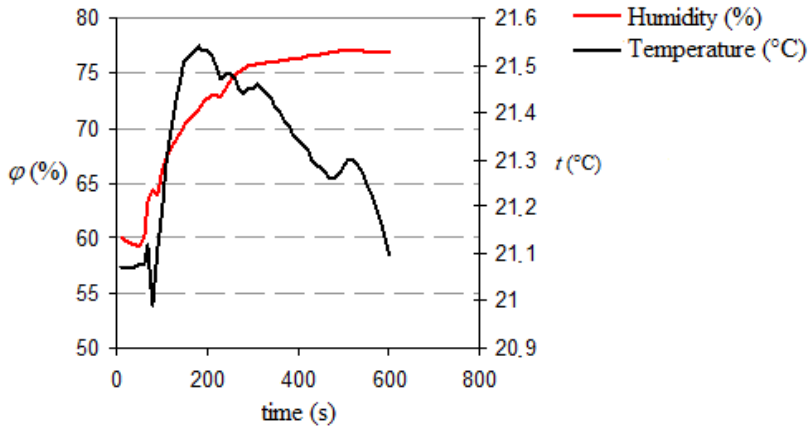


FIGURE 7: Dependence of relative humidity and temperature at measuring point A

The highest temperature value during the measurement was 21.54 °C and humidity 77%.

The measurement at point B was made behind the filter. The time interval was 10 seconds, and the measured values are shown in fig. 8.

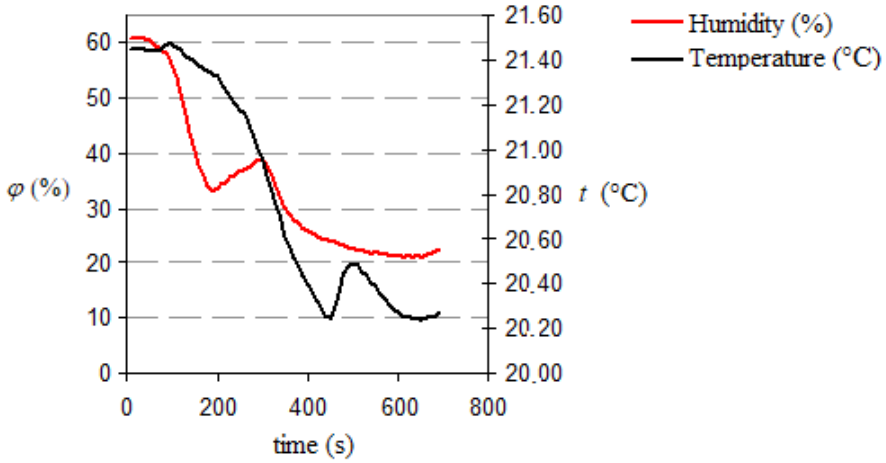


FIGURE 8: Dependence of relative humidity and temperature at measuring point B

The minimum temperature value was 20.4 °C and humidity 21.1% and the maximum measured temperature was 21.47 °C and humidity 60.8%.

To check and verify the appropriateness of using the gas drying method in a fluid layer of silica gel, the measurement was also carried out with classic non-ground silica gel (ball shape). The measurement was carried out on a constructed experimental device without the inclusion of a filter.

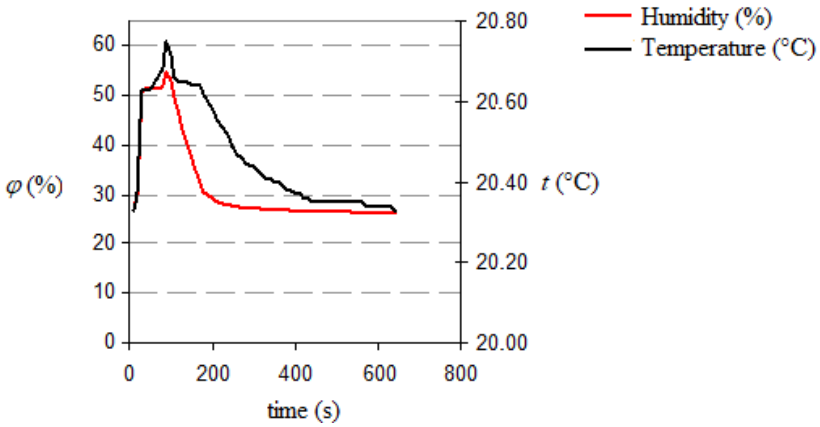


FIGURE 9: Dependence of relative humidity and temperature of unground silica gel at measuring point B

According to the measured values, a relative humidity value of 21.1% was achieved in connection with a filter device, with the method using unground silica gel the value was 26.3%, meaning 5.2% lower.

V. CONCLUSION

The use of ground silica gel as an adsorbent has both advantages and disadvantages compared to classic silica gel. From an economic point of view, the drying method with the classic structure of silica gel is more advantageous, since the initial costs of changing its structure (grinding in a crushing mill) are eliminated, as well as the need to use a high-efficiency filter device. Another disadvantage of using ground silica gel is its lower weight, which makes it easier to drift. There is an increase in the height of the fluid layer, which reduces the density of the particles and the gas flows more easily around the dispersed particles. As a result of this phenomenon, their direct contact does not occur, which can be explained by the relatively high range of minimum and maximum measured humidity.

Since it was found by measurement that the removal of moisture from the gas using the method with ground silica gel and the classic structure represents a difference of only 5.2%, the drying method with classic silica gel is preferable, taking into account both economic and health aspects in the operation process. Ground silica gel carried by the air stream also has a significant impact on the life of filters, which tends to clog and reduce gas flow. Particles that are not caught by the filter can clog other parts of the device, as well as measuring instruments, which can subsequently be damaged and the given output parameters of the measured quantities can be distorted.

ACKNOWLEDGEMENTS

This paper was written with the financial support from the VEGA granting agency within the project solutions No. 1/0626/20 and No. 1/0532/22 from the KEGA granting agency within the project solutions No. 012TUKE-4/2022 and with financial support from the granting agency APVV within the Project Solution No. APVV-15-0202, APVV-21-0274 and APVV-20-0205.

REFERENCES

[1] Yan, K. L. and Wang, Q.: Adsorption characteristics of the silica gels as adsorbent for gasoline vapors removal. IOP Conf. Series: Earth and Environmental Science, 153 (2018), 022010.

[2] Grande, C. A. et. al.: Silica Gel as a Selective Adsorbent for Biogas Drying and Upgrading. Ind. Eng. Chem. Res, 59 (2020), p. 10142−10149.

[3] Mourik, J.: Experiences with Silica Gel as Adsorbent. American Industrial Hygiene Association Journal, 26 (5) (2007), p. 498 – 509.

[4] Scherer, G. W.: Effect of drying on properties of silica gel. Journal of Non-Crystalline Solids, 215 (2-3) (1997), p. 155 -168.

[5] Mujumdar, A.S.: Principles, Classification, and Selection of Dryers. Handbook of Industrial Drying. CRC, (2006). p. p. 1279.

[6] Song, Z., Zhao, H.: Preparation and Characterization of Mullite-Silica Aerogel Composite Material. Open Journal of Organic Polymer Materials, 8 (4) 2018, p. 43 – 52.