EXPERIMENTAL STUDY OF DYNAMIC ADSORPTION IN PACKED BED

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Abstract. *The packed beds are widely used industrially by the adsorption of water vapor, the separation of some organic solvents and toxic gases, so there is one type of adsorbent specific for each purpose. For example, activated carbon adsorption is commonly used in oils and organic solvents, since the silica gel and molecular sieves are used in the adsorption of water vapor present in moist air. These adsorption systems can be applied in various industrial drying processes, in dehumidification of air in air-conditioning, in the plastics industry, in controlled humidity chambers for drying agricultural products. One of the advantages of using compressed beds is the low cost and financial performance, in addition to its high regeneration capacity at low temperatures. Because of all these advantages, the present study objective to verify experimentally the dynamics of adsorption in packed beds, in order to investigate the behavior of adsorbed mass profiles for condition provided. The experimental apparatus was mounted on the Solar Energy Laboratory. The fluid adsorbate used in this study was the moist air and the adsorbent used in the filling of the column was silica gel, particle size 4 mm, which has an auto power adsorption. The air was compressed by a radial compressor, draining by a flow meter, then passing by a fixed bed adsorptive, with a diameter of 40 mm and 600 mm in length filled with silica gel. The result shows the maximum amount of water that the bed can adsorbed to a given condition over time. Noting an increase in the amount of water adsorbed by the bed with increasing flow.*

Keywords*: Packed bed, dehumidification and adsorption.*

1. INTRODUCTION

The dehumidification of air through a fixed bed is an important industrial operation and can be applied in the drying of agricultural, pharmaceuticals and food products (avoiding the absorption of moisture in hygroscopic products), in air-conditioning (replacing the conventional system vapor compression system by adsorptive) and in the plastics industry.

The adsorption beds are composed primarily of a hygroscopic material, and the choice of material depends on the type of adsorbed used, because each pair adsorbent / adsorbed has a particular behavior. Silica gel (SiO_2) is the adsorbed used more in the process of dehumidification, because of its high capacity to adsorb water vapor present in humid air. This high adsorption capacity is because of their microporous structure of internal, which has cavities with very high internal surface area (up to 800 m^2/g), adsorbing about 40 % of its weight in water (Ruthven, 1984).

The process of dehumidification of air occurs when the pressure of water vapor present inside the particle pore silica gel is less than the pressure of water vapor near the surface of the grain, doing as the water molecules diffuse inside the particles of silica gel and the higher the humidity the greater the mass of water adsorbed by the silica gel particle. In this process, there is no chemical reaction involved and even when saturated, the grain of silica gel still has a dry appearance and unchanged (Besant, 2005). One of the advantages of using compressed beds is the low operating cost, do not pollute the environment and can be regenerated using low temperatures supplied by solar collectors.

The study involving the use of adsorption beds in processes of dehumidification of air is increasing for some time. In 1994, San and Jiang tested and modeled analytically the transient response of a system with two beds packed with particles of silica gel used as a dehumidifier. Park and Knaebel in 1995, studied the dynamics of adsorption of water vapor in a fixed bed of silica gel, assessing the moisture content in the air moist in an adsorptive bed. Inaba and Horibe in 2004, studied the adsorption in a rectangular bed filled with silica gel, when exposed to a flow of moist air. In 2008, Awad investigated experimentally and numerically the dehumidification of compressed beds when exposed to a radial air flow. Kabeel in 2009 conducted a numerical and experimental study on packed beds to evaluate their performance in adsorption and desorption processes.

This paper aims to describe, study experimentally the dynamics of adsorption in packed beds, in order to investigate the behavior of adsorbed mass profiles for each condition provided at the entrance of the adsorptive process used in dehumidification of air.

1.1 Adsorptive cycle

Adsorptive cycle is complete, the desiccant passes through three stages, adsorption, regeneration and cooling, as can be seen in Figure 1. In the first stage of the graph (A) the pressure of steam on the surface of the desiccant is low because it is cold and dry. As the water vapor present in moist air penetrates the surface of the adsorbent, causes a heating (heat of adsorption released) and an increase in vapor pressure at the desiccant surface, passing the first stage for the second (B). At this stage, it runs a balance between the vapor pressures of the air and on the surface of the adsorbent, there is no longer the pressure difference between steam in the air and desiccant surface, preventing the desiccant to collect more humidity. When do you balance the pressures it is necessary to expose the silica in a flow of hot air. This flow will make the vapor pressure at the surface of the desiccant increase relative to the pressure that is around the same, causing the migration of moisture occurs from the surface out of the desiccant balancing the pressure difference exists. In the third stage (C), the desiccant is dry, but due to elevated temperature and pressure, and is not yet possible to adsorb moisture. To restore the low vapor pressure desiccant is cooled, returning to starting point (point A) in diagram and completing the cycle, thus, collect moisture again (Rady, 2009).

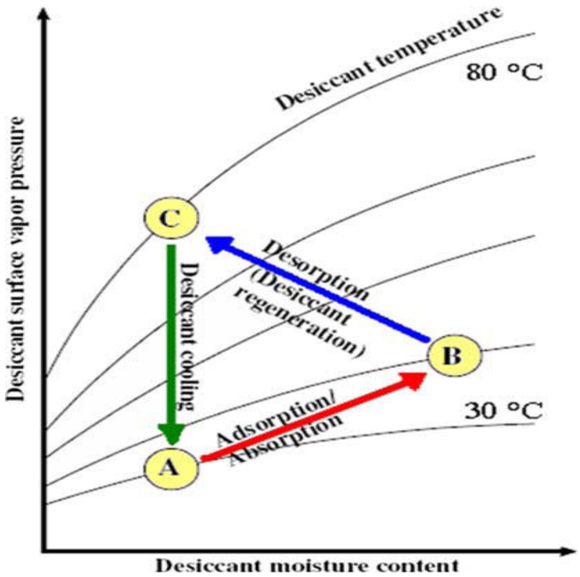

Figura 1: Representation of desiccant cycle processes (Rady, 2009).

2. MATERIALS AND METHODS

The experimental apparatus was assembled and instrumented in the Solar Energy Laboratory (LES). The fluid flow was used in the water vapor present in the environment. The adsorptive bed was used approximately 650g of silica gel with a particle size of 4 mm. This adsorptive material before being placed in the interior of the bed, was placed to dry in oven at 100 ºC for approximately 24 hours. Figure 3 illustrates in detail the fitting of the experimental apparatus. The perform the fluid flow, we used a radial compressor (1) with power of 0.5 HP, after the passage of fluid through the radial compressor, it was determined the flow through a flow meter (2) Scientific brand Pliers model M-100SPM-D/10M. The variation in flow was obtained through a frequency converter connected to the ventilator. After the flow meter, the flow of moist air headed for the fixed bed adsorptive (3), where he began the process of dehumidifying the air. To capture the temperature inside the bed were used three type sensors PT-100. These sensors were connected to the module data acquisition (4) Hottinger Baldwin Messtechnik brand (HBM) model SPIDER 8. The signals were detected by sensors and converted by the modules on your computer. A Micro-differential digital manometer (5) of the brand and model Instrutherm MPD - 79 was attached to the bed to determine the adsorptive loss of charge, information obtained by the gauge (5) and the flow meter (2), which were also stored the computer. To measure the mass of silica gel and the mass of water vapor adsorbed, we used a Precision Electronic Scale - Model Belmark K30. Were placed two thermo-hygrometers, one at the entrance of the bed (6) and another within a drying chamber (7) both for the purpose of determining the temperature and humidity before and after adsorptive bed.

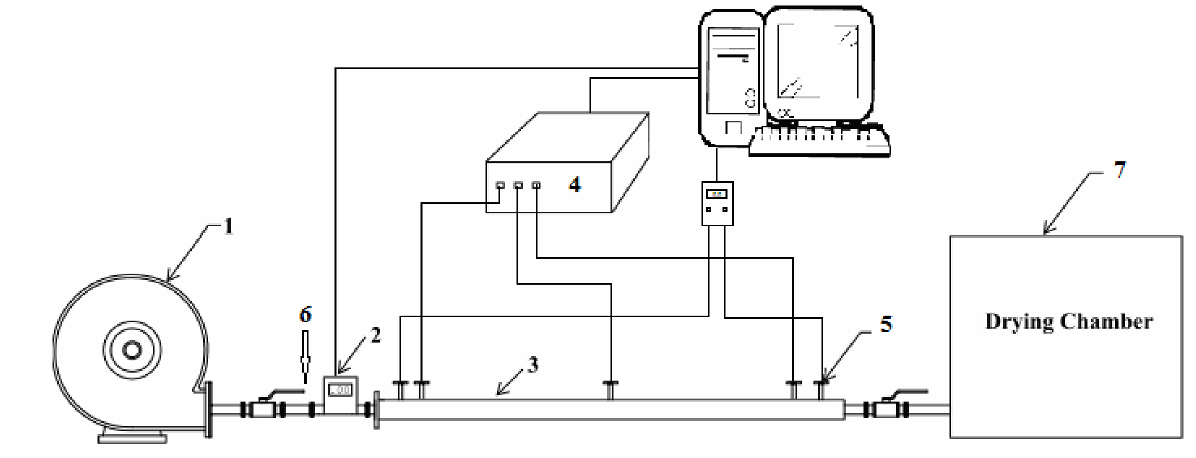

Figure 3: Experimental setup

3. EXPERIMENTAL RESULTS

The adsorbed mass profiles presented in Figure 4 show the maximum quantity of water that can adsorb the bed for a certain condition of humidity and temperature (UR= 77% and T=27°C), respectively. We used three air flow rates, 0.78, 1.20 and 1.80 m^3/h, respectively. According to the profiles presented in this figure, we observed an increase in adsorbed mass over time for all three conditions of air flow imposed. It was also found that seven hours of experiment in the column had not yet reached saturation, might be determined but will be shown a maximum of approximately 12, 13, 14 g water/kg silica gel, for the three conditions of air, respectively.

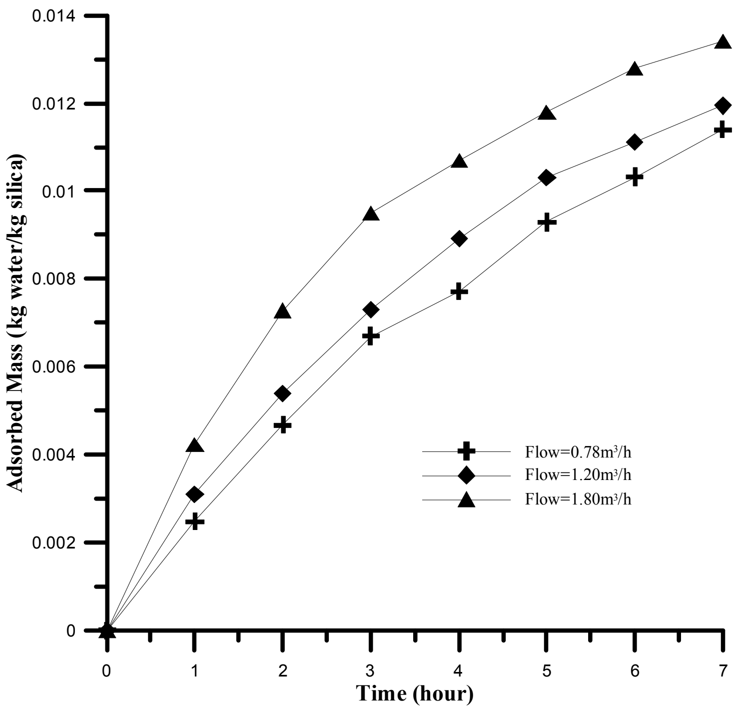

Figure 4: Perfil de massa adsorvida em função do tempo.

Aiming to check the moisture content and temperature inside the drying chamber were plotted profiles of temperature and humidity inside the drying chamber. The conditions imposed at the entrance of the adsorptive bed, were of 0.01807 kg/kg and 31.1 °C. The profiles of humidity and temperature presented in Figure 5 show a rapid reduction of moisture in the first 30 min, reaching approximately 0.002 kg/kg, this occurs due to retention of water vapor in the air by silica gel, which initially is quite drought. After this period you may notice an increase in moisture of the bed over time, which is due to the evolutionary process of retention of water vapor caused by saturation of the column, allowing the passage of more humid air over time. In the temperature profile was observed an increase in the first two hours of experiment. This increase is a consequence of the adsorptive phenomenon which causes heat generation inside the grains of silica. This heat is entrained by the flow of air supplied by fan and measure the grains are close to saturation, the heat generated in the process decreased, and at some point, the heat generated equals that dissipated by convection and the air reaches its maximum temperature, around 39 °C, after this point the beans begin to cool until they reach the inlet temperature in the bed. This cooling is caused by saturation of the grains inside the adsorptive bed.

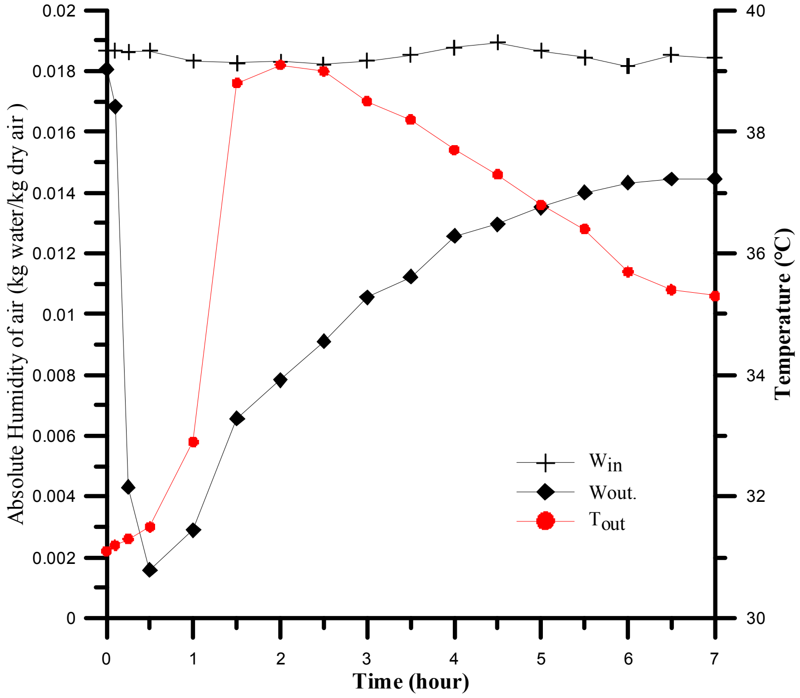

Figure 5: Perfil absolute humidity and temperature in the drying chamber.

4. CONCLUSION

Considering the results obtained experimentally, we can conclude that there was an increase in adsorbed mass profiles for the three conditions of air flow (0.78, 1.20 and 1.80 m^3/h), and that in seven hours of the experiment the column does not had reached saturation, which is very good. It was also concluded that the drying chamber undergoes rapid dehumidification of air in the first 30 minutes, reaching 0002 kg/kg and after suffering an increase in humidity around 0.014 kg/kg. Referring to the temperature profile, we can conclude that there is an increase on the first two hours of trial and reaching a peak of 39 °C and after that peak, there is a decrease in temperature reaching 35 °C.

5. REFERENCES

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