AN EXPERIMENTAL STUDY OF SORPTION KINETICS ON ADSORPTIVE COLUMN

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Abstract. This work presents the experimental results of water adsorption kinetics obtained on two adsorption columns filled out with silica gel. The purpose of the study is to set adsorption into two different column configurations: one of them through radial flow, and the other through axial flow. It was set up an experimental bench made up of two adsorption columns, measuring one meter long and with a diameter of 0,4 m, and connected to one another by means of valves and a water evaporator. For the study of radial adsorption, a concentric, screen-made tube to carry the water axially was placed longitudinally along one of the columns in such a way that makes adsorption occur in a radial direction towards the silica gel. The thermo-grams obtained by means of thermocouples, placed inside the column, and also from the adsorbed mass variation in relation to time, allowed us to characterize and compare the kinetics of these two geometric configurations. The obtained results are important for the optimization of adsorptive collectors used in solar cooling making possible a much larger amount of adsorbed water and much better refrigerating power.

Keywords: *Adsorption, Cooling, Silica gel.*

1. INTRODUCTION

The use of solar energy accompanied man since the beginning of humanity, according to Faidemraich and Lyra (1995), in the third century B.C. parabolic mirrors were built and in the second century before Christ, Diócles described a treatise on systems of parabolic mirrors, called "on mirrors to ignite." Faraday, in 1848, was one of the first to describe the principles of adsorption of vapor by a solid adsorbent. However, the history of the solar cooling time of 1878 when the French mathematician Augustin Mouchot demonstrated its calculations on solar cooling with absorption cooling machine, designed by Edmond Carré, to produce ice, which was presented at the World Congress in Paris (TCHERNEV, 1979).

The applications of solar energy in systems that require heat for its operation, has gained achievements that contributed to increasing the efficiency of these systems. For an adsorption refrigeration system by using solar energy as a heat source to promote the regeneration of the adsorbent, there are two ways to get the second effect refrigerator Meunier (1994), one uses flat collectors and inexpensive, has an intermittent cycle, employs exclusively in direct solar energy and is technically very simple, but presents the disadvantage of having low efficiency when compared to cooling systems for mechanical compression. The other way USA solar collectors with parabolic dishes for concentration of energy, which heat a thermal fluid, and this fluid is used as a source of energy in an adsorption system that presents C.O.P. greater than one, according to experiments performed by Douss and Meunier (1989). In an adsorption refrigeration system by using the collector to capture solar energy that the adsorbent is conditioned in its interior to provide a configuration that facilitates the process of desorption and adsorption, and thus, this work aims to compare the adsorptive capacity between tubular columns with two different configurations, i.e., a radial flow through the other flow.

2. THEORETICAL RATIONALE

2.1. ADSORPTION

Adsorption is a phenomenon that consists in the condensation of particles, whether molecules or ions particles, the surface of separation between some solid and gas or liquid that are in contact. Adsorption manifests itself in remarkable measure substances in particular, called adsorbents such as activated charcoal, activated clay, alumina, bauxite activated with silica gel, among others, which are finely divided and treated in order to make a huge area for its mass (m2 / g). In the adsorption process occurs the preferential separation of a substance, liquid or gas, through the surface of a solid. The solid receives the name of adsorbent, while liquid or gas that is adsorbed is named adsorbato. Adsorption is different from absorption, because it uses two liquids as well as sorption, with the possible formation of a third substance, while the adsorption presents a solid and a liquid or gas as well.

The adsorption can occur either by physical mechanisms such as by chemical (FOUST, 1980). The physical adsorption occurs when intermolecular forces of attraction between molecules of the fluid and the solid surface are greater than the forces of attraction between individual molecules of the fluid. The molecules of the fluid adhere to the surface of the solid and the balance is established between the adsorbed fluid and the rest remained in the liquid phase. The adsorption heat is small and has the same order of magnitude of the condensation heats.

In chemical adsorption, there is the involvement of chemical interactions between the adsorbed fluid and the adsorbent solid, which is the transfer of electrons, equivalent to the formation of chemical bonds between the surface of the solid and adsorbato. Porous substances are divided into microporous, macro and mesoporous depending on the size of their pores. Davies and Legros (1986) mentioned that, according to the IUPAC convention, the substances are microporous with pore diameter up to 4 nm, while the substances are mesopores with pore diameter between 4 and 100 nm, whereas above these values, the substance is considered macroporous.

2.1.1 TYPES ADSORBENTS

The adsorbents used may be divided, according to their affinity for polar compounds in hydrophilic or hydrophobic. According to Srivastava and Eames (1998), the hydrophilic adsorbents have greater affinity for polar substances, like water, while the hydrophobic adsorbents show higher affinity for gases and oily compounds. The more hydrophilic adsorbents used in heat pumps and refrigeration systems are silica gel and zeolite and the most used hydrophobic adsorbent is activated carbon. In this work the adsorbent employed was silica gel and water was the adsorbato.

3. DEVELOPMENT

3.1 TUBULAR PLAN COLLECTOR

The tubular plan collector is formed by series of tubes that displays a concentric screen inside, allowing the adsorption in porous bed radially, facilitating the adsorbato dissemination throughout the adsorptive column. Using experimental results it was possible to verify the effects on adsorption capacity caused by the withdrawal of the screen, changing the flow of adsorbato from radial to axial. The evaluation of the columns was made by measurements of concentrations of the bed and adsorbato analysis of thermograms generated by thermocouples placed along the column. Figure 1 shows the tubular reactor with a concentric screen (left side), which allows that the adsorbent is conditioned between the screen and the inner wall of the tube, and on the right side the column without the concentric screen allows that the entire bed is filled with the adsorbent.

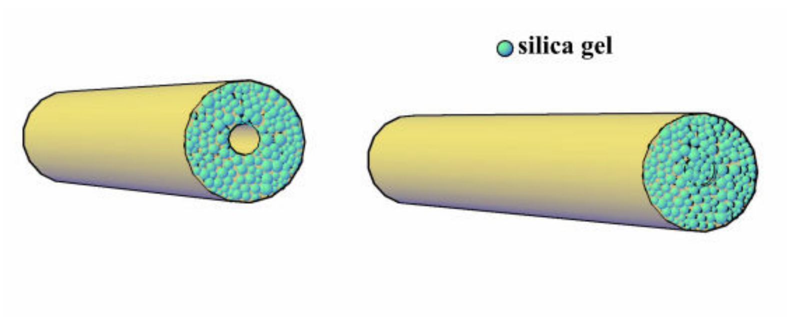

Figure 1 - adsorptive columns studied.

3.2 EXPERIMENTS

Two reactors were constructed of copper with 1 meter long and 0.04 m of external diameter and one with a concentric screen of 0.01 m in diameter. The adsorbato used was distilled water and the adsorbent silica gel. Each reactor contains in its interior, five temperature sensors, with the aim to verify whether the phenomenon occurs throughout the bed adsorptive porous, because this process occurs with the release of energy (exothermic), the sensor type PT-100 are well distributed, 5 sensor to 5 cm from the entrance of adsorbato, the 4, 3 and 2 to 22.5 cm distance between them and the 1st sensor at 5 cm away from the other end as Figure 2.

When the silica gel lost its adsorption capacity , i.e., it was saturated, it was withdrawn from the reactor and placed inside an oven at 120 º C for a minimum period of 24 h, after regeneration it was replaced inside the reactor, immediately. After this, it was expected that it becomes cool until reach room temperature, at this moment the mass of the set reactor and adsorbato was measured. The reactor is coupled to an evaporator to keep water at a constant temperature to be adsorbed by the passage of a thermal fluid through a heat coil which is inside of it, because, during the period that water is being adsorbed by the porous bed occurs a decrease of temperature into evaporator and hence the pressure reduction, thus impairing the adsorptive process.

A vacuum pump removed any air within porous bed. At the end of this process the bed is with a pressure of 0.1 kPa, while in the cylinder, coupled to the reactor, pressure is constant, corresponding adsorbato saturation pressure, in the case, the water saturation pressure at 30 º C which is 4.29 kPa. In this stage, the valve is open, allowing the passage of adsorbato for the porous bed, the temperatures indicated by the sensors were recorded through the catman 4.5, which converts the signals transmitted by modules that are connected to a computer which recorded temperatures every 2 s. The reactor mass was measured using a digital scale with a capacity of 30 kg, the mass was recorded every hour over a period of 6 hours, thus checking the mass of adsorbato in both reactors. Experiments were carried out with adsorption time of 90 min, 180 min and 8 hours when the concentration of adsorbato within porous bed was always checked out.

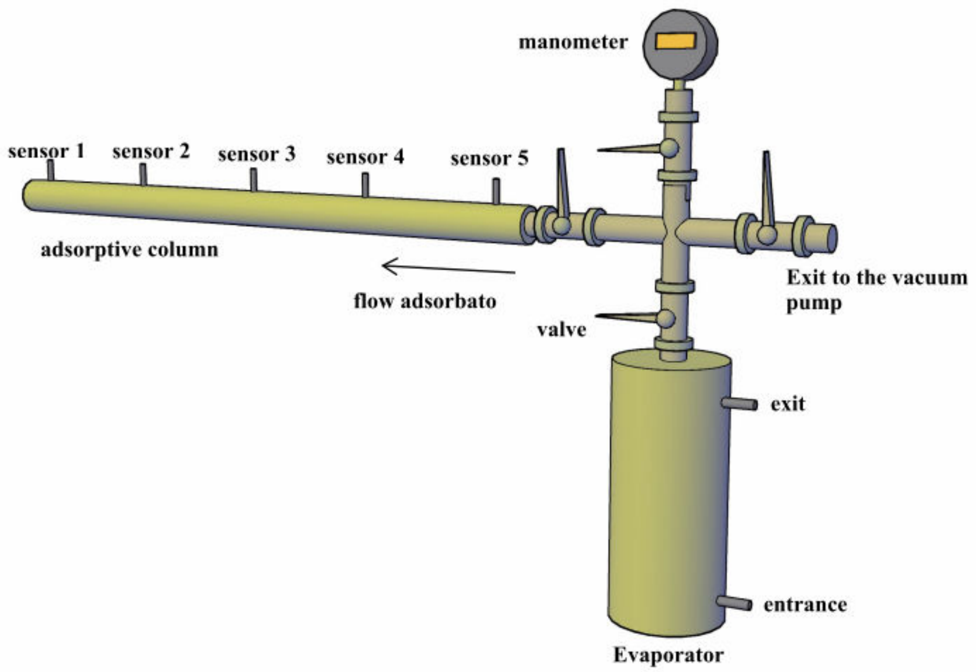

Figure 2 - Schematic of the tubular reactor prototype

4. RESULTS AND DISCUSSIONS

The obtained results show that throughout the bed of porous silica gel the adsorptive phenomenon occurred in both columns, because, as we observed in thermograms below, there was recording of temperature rise in all five sensors. However, we can realize that the sensor in the opposite side of the entrance of the adsorbato always recorded the lowest temperature showing that the columns exist in both resistance to the flow of adsorbato because the temperature of adsorbato grows as flows through the column, reaching the end of the bed at a temperature higher than at the entry, thus hindering its adsorption by the adsorbent. Furthermore, the sensor which is the entry of the column demonstrated temperature smaller than the three middle sensors (sensor 2, sensor 3, sendor 4) due to this sensor receives the adsorbato at a cooler temperature.

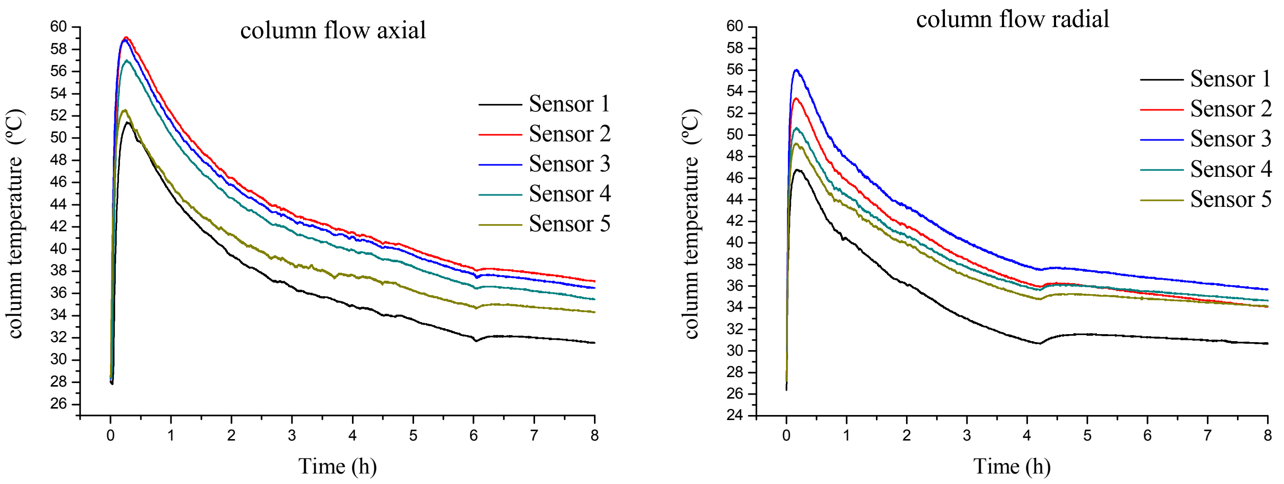

Figure 3a - Curves of temperature distribution on adsorption columns (8 hours).

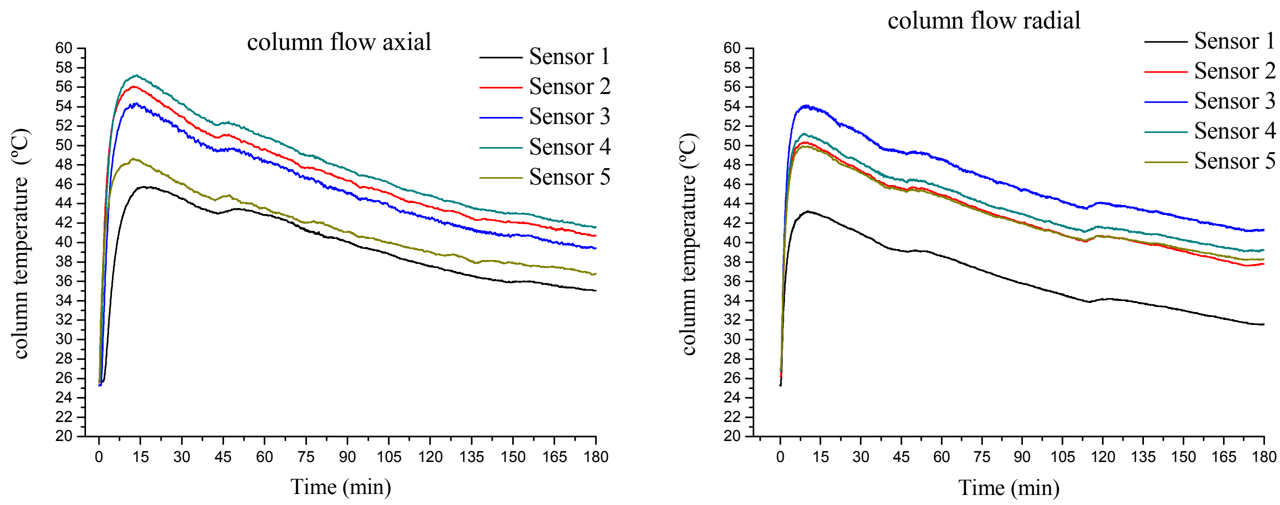

Figure 3b - curves of temperature distribution in columns of adsorption (180 min.).

Figure 4 shows a clear difference between the time that the water vapor leads to spread it throughout the column, which, in the column with radial flow is registered in an elevation of temperature sensors, virtually at the same time, column with flow after approximately 4 min is recorded a temperature increasing in the last sensor, indicating the arrival of the water vapor.

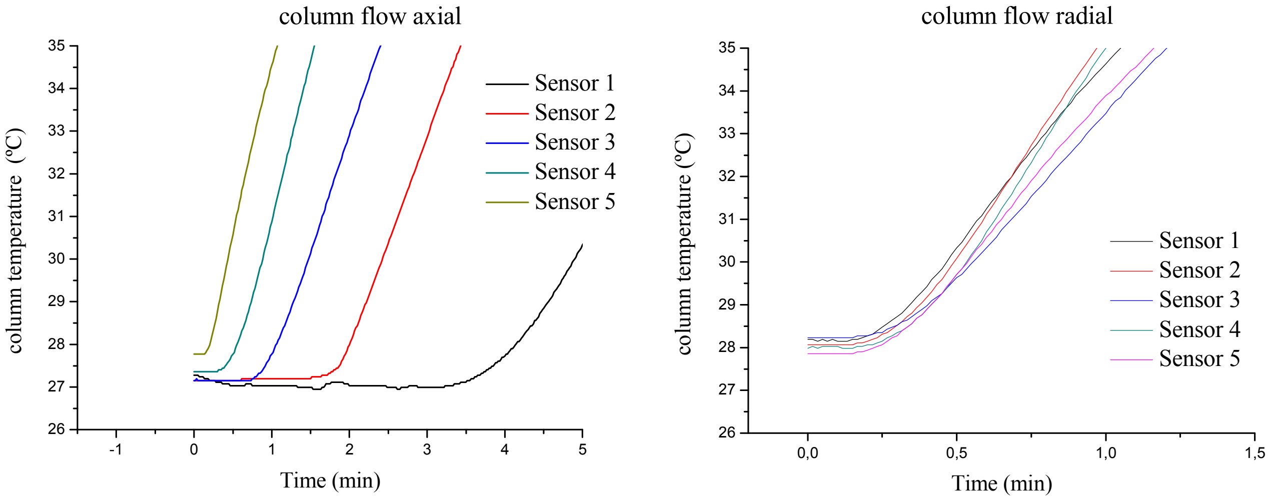

Figure 4 - Time to start the record of the temperature sensors.

The Fig. 5 presents the variation of the water concentration in the porous bed for a period of 6 hours. Realize that the column that shows the radial flow adsorption adsorbs faster than the column with axial flow, despite the occurrence of adsorptive process throughout the two columns, we noticed that the concentration was always higher during the measurements performed in this period, indicating that the column with radial flow is saturated more quickly.

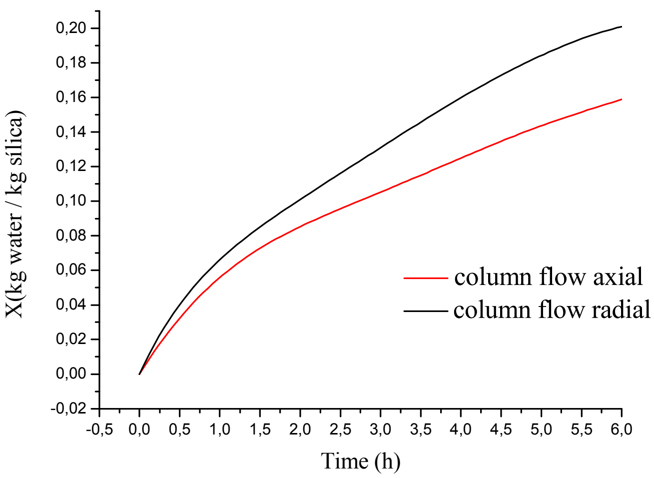

Figure 5 - Variation of the adsorptive adsorbato mass in columns.

5. CONCLUSION

Experimental tests were performed with adsorptive columns which have different adsorption flow, one radial and axial another, therefore comparing the adsorptive capacity of both. The results showed that in both analyzed configurations the adsorptive process occurred throughout the entire column of 1 meter, since it was observed elevation of temperatures in the five sensors, indicating that the adsorbato was adsorbed. It was found that in the column with axial flow the adsorbato takes more time to diffuse into the porous bed, around 4 min more than the column with radial flow. The concentration of water vapor adsorbed by the column with tubular radial flow was higher in all measures undertaken over a period of 6 h, as could be seen in Figure 5, indicating that the column is saturated more quickly. Then, we can conclude which is very important the existence of a concentric screen, because with it there was a better adsorbed diffusivity within the porous bed and a adsorbent saturation time smaller when compared with the other adsorptive column.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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