A cheap, fast and simple way to measure sorption isotherms of granular materials

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TECHNICAL NOTE

A CHEAP, FAST AND SIMPLE WAY TO MEASURE SORPTION ISOTHERMS OF GRANULAR MATERIALS

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ABSTRACT

A set-up and a method are described with which sorption isotherms of granular materials can be measured. The set-up uses a recirculating air flow through a fluidized bed of granular materials. The measuring procedure starts with drying the granular material completely. A known amount of water is added to the fluidized bed. At equilibrium between the amount of water in the granular material and the circulating air the air humidity is measured. The method is demonstrated using silica gel.

1. Introduction

A solid granular material can contain a certain amount of water. The air in which this solid material is placed can also contain an amount of water. The equilibrium relation between the amount of water in the solid and the air is called the sorption isotherm. In general this sorption isotherm depends on the temperature.

Sorption isotherms are used in drying processes. Often it gives the boundary condition of a drying sample. When the air humidity with which the solid material dries is known then the sorption isotherm gives the water concentration in the solid material at the air-solid interface, on the condition that the drying resistance in the air phase may be neglected, which is very often the case.

Sorption isotherms can be measured with high precision instruments. Such instruments are rather expensive. Other disadvantages are that they are sensitive and that often only a very small sample can be used. For instance an apparatus is described by Dengler and Krückels (1970).

This article describes an alternative technique for measuring sorption isotherms which does not have the disadvantages mentioned above. This technique can be used very well for granular materials.

The aim of this article is to introduce this technique and to show how it behaves in the case when the solid material is silica gel. The sorption isotherm of silica gel is measured. The emphasis lies on using the technique and not on silica gel.

In section 2 the experimental set-up will be introduced and the measuring procedure follows in section 3. Next in section 4 the results of silica gel will be presented and finally the conclusions are given in section 5.

2. Experimental set-up

The experimental set-up is given in figure 1. The granular material of which the sorption isotherm has to be measured is in the form of a fluidized bed put on top of a porous plate. The diameter of the bed is approximately 15 cm. Through the plate and the bed goes an air flow generated by a pump. The

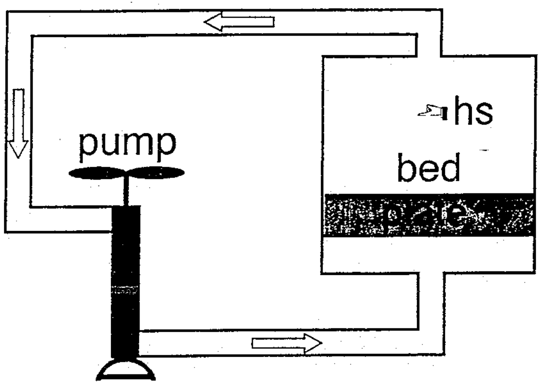

Figure 1. Set-up to measure sorption isotherms of a granular material.

air flow is a closed loop. Above the bed the air humidity can be measured with a humidity sensor (hs).

3. Measuring procedure

The method for measuring sorption isotherms is demonstrated using silica gel with a particle diameter of approximately 150 μm. The fluidized bed contained typically 0.15 kg of silica gel. To obtain completely dry silica gel the gel was put in an oven and heated up to 150°C. Next the pressure above the gel was reduced to typically 10^4 Pa. This process was repeated until no more bubbles were seen to escape from the gel. After cooling down the dry gel, it was put on the porous plate and the air flow was used to create a fluidized bed. Finally a known amount of water was added to the gel. This was done in the form of drops with a known quantity. After equilibrium between solid and vapour is reached, the humidity in the vapour was measured with a simple humidity sensor.

4. Results

Three series of experiments were performed. The first serie started with completely dry silica gel. In the second and the third serie an accurate known

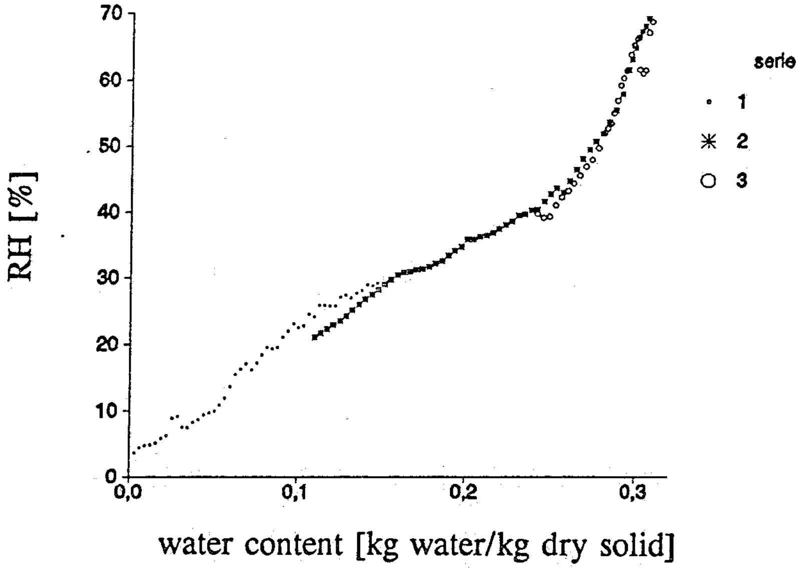

Figure 2. Sorption isotherm of silica gel. For three series of experiments the relative air humidity (RH in %) is given as a function of the water content of the solid phase.

amount of water was added to the gel before the addition in the form of drops started. This was done to get an idea of eventual systematic errors in the addition of drops or to trace a significant leakage of water. In figure 2 the resulting relative air humidity (percent) is plotted as a function of the water content of the solid phase (kg water/kg dry solid). In the computation of the water content of the solid phase the water content of the air was neglected. The volume of the vapour phase was of the order of 10^{-3} m^3. The experiment was only done for humidities below 70 percent because for higher humidities it took long to reach equilibrium. The temperature was approximately 20°C.

5. Conclusion

A very simple set-up and measuring procedure has been given to obtain sorption isotherms of granular materials. The method has been demonstrated using silica gel. It was not the goal to obtain very accurate data on silica gel.

The advantages of this method are that it is cheap, simple, fast and that the sorption isotherm can be obtained using a large quantity of solid material. It is not necessary that the solid material is fluidized. Also a packed bed could be used.

A disadvantage of this method is that it cannot distinguish between an absorption and a desorption isotherm. Materials where this difference is essential should not be used this way. Another disadvantage is that the material must be dried completely before the sorption isotherm can be measured.

The set-up can be improved on certain points. The water was added in the form of drops. It is nicer to spray the water over the bed. The equilibrium is then reached much faster. The set-up can be extended with a thermostat through which the airflow can be brought on a fixed temperature rather easily.

Reference

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