MODELING THERMAL ENERGY STORAGE BY ADSORPTION

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ABSTRACT

In this paper, thermal energy storage by using adsorption of moisture from air for application of space heating is discussed. We were able to achieve energy storage capacities of 200-250 kWh/m^3 in a lab scale applications. Mechanistic modelling of the process has been developed. This energy storage technology can be used for solar thermal systems, as well as for systems that have low quality excess thermal energy. Although the results obtained so far are applied to space heating, this technology can also be used for space cooling. Recent results obtained for experiments carried out under different operating conditions are discussed in this paper, together with the results obtained for the verification of the mathematical model.

Mechanistic modelling of thermal energy storage by using adsorption of water vapor from ambient air has been carried out by using Wolfram *Mathematica®* in this article. A hybrid adsorbent that contains activated alumina and zeolite was used for this application. The modeling included a mass balance in the column, an adsorbed water accumulation balance in the pellet, an energy balance in the column, as well as an energy balance around the column wall to account for heat losses. Developed model was verified with experimental results by comparing the breakthrough curves and the change of temperature at the end of the column as a function of time at different volumetric flow rates for a small column. Due to the assumption of negligible pellet resistance for adsorption, there was a bit of a difference between the model and the experimental data.

INTRODUCTION

The main objective of this article was to model the exothermic adsorption of water vapor from air for thermal energy storage applications, in Wolfram *Mathematica®* programming environment in order to estimate the concentration and temperature breakthrough curves at different flow rates. This modeling is done by using the properties of the adsorbent, and physical properties of gas stream (air) with changing temperature and humidity.

MATERIALS AND METHODS

Adsorption column was filled with the hybrid adsorbent made out of activated alumina and zeolite materials. Experimental procedure was mainly composed of adsorption and regeneration steps.

During the adsorption process, entering air was humidified up to 97% relative humidity with the use of a bubbler. The humid air then passed through the adsorption column where water vapor was adsorbed in the column. The exothermic adsorption process heated up the air carrying the moisture. After the removal of moisture, dry and warm air (which can reach up to 80^{o}C) exits the adsorption column. This warm air can be used for space or water tank heating. Humidity of the exiting air leaving the column increased gradually with time after the saturation of the adsorbent [1, 2].

During the regeneration, air was heated with an in-line heater to 250^{o}C, which is the regeneration temperature. In literature, this temperature is found to be the most efficient regeneration temperature to obtain a higher energy density [3]. This heated air then passed through the adsorption column to regenerate the adsorbent in the column by releasing the water from the pores of the adsorbent.

MODEL DESCRIPTION OF THE ADSORPTION PROCESS

Developed mechanistic model considered the mass balance in the column, dsorbed water balance in the pellets of the adsorbent, energy balance in the column, as well as the energy balance around the column wall. Following assumptions were made for modeling the adsorption process:

1) Gas is ideal,
2) Pressure drop in the column is negligible,
3) No change in concentration and temperature in the column radially,
4) Mass and heat transfer resistances in the pellet are negligible.

RESULTS AND DISCUSSION

Method of lines technique in Wolfram *Mathematica®* was used to solve the combined mass and energy balances numerically. Results obtained from the model were compared to the experimental results at different flow rates for the hybrid adsorbent for the verification of the model.

The results showed that, although there were some differences between the model predictions and the experimental results, the model predicted the breakthrough time quite well at the optimum volumetric flow rates where the energy density was maximized. The differences were observed at the end of the breakthrough curves, where the experimental results for concentration and temperature breakthrough curves showed tailing due to diffusion resistance in the pellets of the adsorbent, whereas the model showed as an S-curve for these breakthrough curves. This was expected, since the model did not take into account the diffusion resistances in the pellet. Maximum temperature observed at the outlet of the column was 85^{o}C.

CONCLUSIONS AND RECOMMENDATIONS

The differences between the model and the experimental results are due to the fact that the resistance to mass transfer in the pellets of the adsorbent was assumed to be negligible in the model, whereas the experimental results showed that this resistance can not be neglected. Therefore, these differences can be eliminated by performing an additional mass balance around the pellets that considers the rate of water diffusion into the pores.

REFERENCES

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