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THERMALLY-DRIVEN HYDROGEN COMPRESSION BASED ON ADSORPTION ONTO ACTIVATED CARBONS

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Introduction

Carbon materials have received a noteworthy attention as gas storage materials due to their highly developed textural properties as well as very high surface areas, thus ensuring a complete reversible hydrogen uptake and release¹. A thermally-driven hydrogen compression can be realized by using a solid bed consisting of carbon materials with high surface area and high adsorption potential, such as activated carbons (ACs), and by lowering/ increasing the system temperature. Such a compressor ensures several advantages, like absence of moving parts, no vibration, no noise and simple design.

Hydrogen adsorption on two different ACs have been investigated. With the help of numerical simulations, the performances of a such thermally-driven compressor have been also analysed.

Materials and Methods

The investigated ACs were the MAXSORB® MSC-30 and MSP-20 from Kansai Coke and Chemicals, Japan. The textural characterization of the ACs was performed using the automatic adsorption apparatus ASAP 2020 from Micromeritics®. The BET areas, S_{BET} , were obtained by using the BET equation in the range of relative pressures 0.01-0.03. The pore size distributions were obtained by using the non-local density function theory (NLDFT) from the software SAIEUS®. The skeletal densities of the investigated ACs were obtained by helium picnometry using an AccuPyc II 1340 apparatus from Micromeritics®.

Hydrogen adsorption measurements were carried out in the range of temperatures 77-273 K and up to 15 MPa by using the volumetric high-pressure device HPVA II from Micromeritics-Particulate Systems. The control of temperature was realized by a single-stage closed cycle cryogenic refrigerator ensuring a precise control of temperature with a margin of error ± 0.005 K and able to work between 25 and 350 K.

The numerical simulations were performed by using the software MATLAB®.

Results and Discussion

The measured textural properties of the two investigated ACs are reported in Table 1. Overall, MSC-30 exhibits better developed textural properties than MSP-20.

Table 1. Textural properties of MSC-30 and MSP-20

Name	S_{BET} m ² /g	Pore Volume cm ³ /g	Skeletal Density g/cm ³
MSC-30	3305	1.61	2.5062
MSP-20	2363	0.95	2.3937

The higher SBET of MSC-30, as well as the higher pore volume, led to enhanced hydrogen uptakes. Hence, at 77 K and 4 MPa, MSC-30 reached the highest excess hydrogen capacity of 29.8 mmol/g, i.e. 5.8 wt.%. On the other hand, at the same temperature and pressure conditions, a hydrogen uptake of 23.8 mmol/g (4.8 wt.%) was obtained with MSP-20.

Thus, a zero-dimensional model was developed to simulate the performances of an adsorption compressor consisting in a reservoir having a volume of 1 L and filled up with 500 g of MSC-30.

The modified Dubinin-Astakhov equation was used for relating the amount of adsorbed hydrogen with the temperature and pressure². Hydrogen adsorption is considered to take place at 77 K, whereas the desorption occurring at room temperature. Hydrogen is fed into the reservoir at a pressure of 4 MPa. All thermal exchanges with the external environment were considered to occur by convection. Figure 1 shows the working principles of such a compressor. After adsorption takes place at 77 K and 4 MPa, the system is heated up to 298 K. Hence, hydrogen is desorbed, ensuring the pressure reaching a value as high as 70 MPa. When the delivery set pressure is achieved, a discharge valve is open automatically allowing an outward flux of compressed hydrogen.

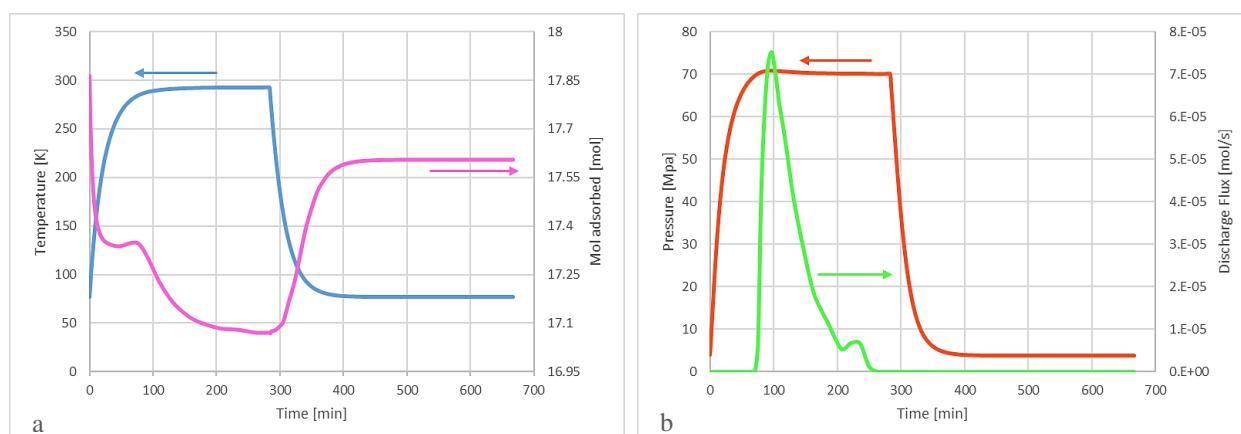


Figure 1. Performance of an adsorption compressor. a) Time trend of Temperature and Moles of hydrogen adsorbed on the AC. b) Time trend of Pressure and Compressed Hydrogen Discharge Flux

The compressor works cyclically, thus when there is no more compressed hydrogen from the reservoir, the system is cooled down to start a new compression step.

Conclusions

An innovative hydrogen compressor based on hydrogen adsorption/desorption on ACs can be realized by simply lowering/increasing the system temperature, being a promising alternative to the worldwide used mechanical compressors. Such a system is potentially able to reach a discharge pressure of 70 MPa, nowadays required for the development of hydrogen vehicles and hydrogen refuelling stations, as well as for stationary facilities of small/medium size.

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