Modelling and analysis of a complete adsorption heat pump system

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Adsorption heat pumps (AHPs) can play a significant role in the future energy transition policies. However, the technology still needs to be matured and further research is still necessary. In this work, the detailed model of a complete AHP system suitable for domestic water heating is presented, aiming to fulfil the literature gap for models that can simulate the dynamics of these complete heating systems while maintaining a high level of modeling detail for the adsorbent bed. The model integrates all the main components of the AHP system, namely the evaporator, the condenser, the heater, the water reservoir and the adsorber. The adsorber is modeled by a 2D distributed parameter model with dynamic boundary conditions since the evaporator and condenser's temperatures vary within a cycle as well as from cycle to cycle. The novel model obtains the detailed temperature, pressure, and uptake fields in the adsorbent bed when integrated in a complete AHP system.

Real scale AHP systems cannot be accurately modelled by lumped-parameter models due to the heterogeneities on the temperature, pressure, and uptake in the adsorbent bed. The time evolution of the system's variables over five simulated cycles is obtained, as well as the coefficient of performance (COP) and specific heating power (SHP) of the whole system. For working conditions suitable for domestic water heating the system's COP is 1.35 and the SHP is 79.3 W.kg $1.s^{-1}$. The proposed model can be used in the future for detailed parametric analysis, aiming to find the optimal performances of similar AHP systems, leading to faster improved prototyping and AHP systems' development. Furthermore, the novel model is a valuable tool to evaluate the performance of new adsorbent materials operating in real systems, as well as to test control techniques and integration of AHP systems with other heating devices and technologies. It is also possible to use the proposed model for adsorption cooling applications.

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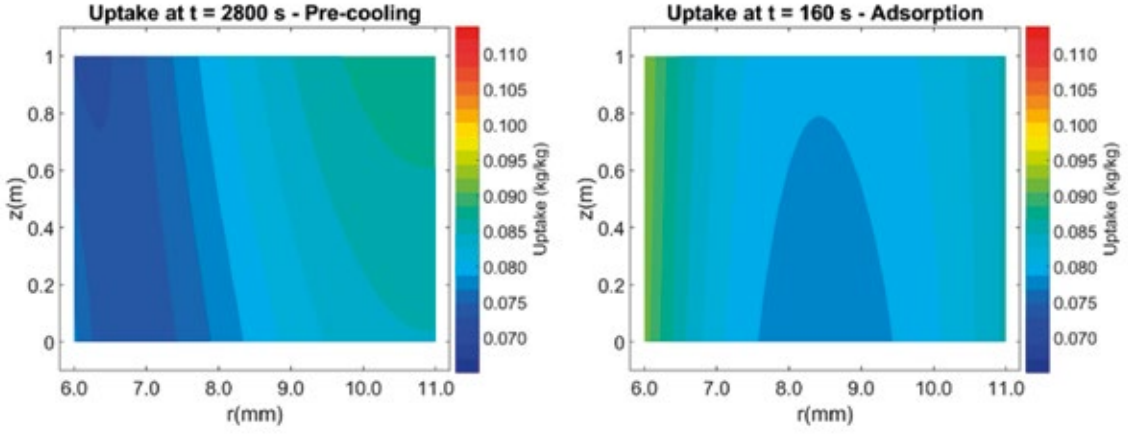

FIGURE 1
Uptake distributions in the adsorbent bed at selected instants during pre-cooling and adsorption phases.