

French Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes one of the PhD subjects proposed by the French Polytech network. The network is composed of engineering schools/universities. The document also provides information about the supervisor.

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PhD information	
Title	Development and analysis of an innovative heat storage system, using open falling bed adsorption reactor
Main topics regards to CSC list (3 topics at maximum)	V.4 New high performance energy saving technology

Required skills in science and engineering	good knowledge in chemical engineering, heat transfer, energetics
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Subject description (two pages maximum including biblio)

Establishing more sustainable energy infrastructure requires the integration of renewable energy sources, such as solar thermal collectors, for heating needs coverage. However, the intermittent nature of solar resource can introduce operational fluctuations and supply-demand mismatches. Integrating thermal energy storage systems (TES) bridges the temporal gaps and stabilizes the heating networks. TES technologies are grouped into sensible, latent, and thermochemical storage methods.

Thermochemical TES provides the highest energy density. Furthermore, as the storage material is stored at ambient temperature, it avoids sensible heat losses to the surroundings, enabling long-duration storage with minimal losses, which is advantageous for extended up to seasonal storage (Wen et al., 2025). The principle of this technology is the sorption phenomenon between a sorbent (generally in the solid phase) and a vapour (that can be water vapour from the surrounding air). During the exothermal bounding of the vapour to the sorbent, sorption heat is rejected to the surrounding and can be used for different purpose (from low-temperature building heating to high temperature industrial needs), and as the phenomenon is reversible, the input of external heat to the sorbent can then regenerate the storage material through endothermal desorption.

Thermochemical TES systems have already been widely analysed. However, most efforts focused on sorption materials, or at the system level on fixed-bed (Mazet et al., 2024) or closed-cycle (Humbert et al., 2022) systems. Open-cycle moving-bed design offers an alternative suited to high-power, flexible thermal storage that can function in a continuous manner (Farcot et al, 2018). In this case, both the solid sorbent and the humid air flow cross-flow in a reactor, continuously providing the bed with fresh sorbent and water vapour. In this configuration - where sorbent particles go down vertically thanks to gravity against a horizontal flow of humid air - heat and mass transfers are enhanced and the adjustment of the air and/or the solid flowrate allows adjusting the reactor power.

Despite their potential, the moving-bed reactors remain underexplored. Previous studies have examined various configurations: Korba et al. (2024) and Wen et al. (2025) studied counter-current reactors across different temperature ranges through numerical modelling, while Kerskes et al. (2012) described the system but did not present moving-bed experimental results and only proposed fixed-bed configuration. The aim of this thesis is thus to focus on this type of technology, that still presents major challenges, especially from an experimental point of view. Indeed, previous studies have shown concerns concerning the sorbent flowability (Farcot et al, 2019), including the formation of sorbent agglomerates within the reactor, leading to significant reductions in reactor performance. Furthermore, depending on the sorbent's particle size distribution, air flow pressure drops can become so high that it is energetically very costly to circulate air through the reactor bed. The aging of the sorbent during cycling as well as transport between the reactor and the storage tank, together with the management of this tank, must be studied. Consequently, work has to be put on the study of additives to the pure sorbents :

these additives should improve flowability of the solid and help the heat and mass transfers phenomena in the bed without impeding the heat storage capacity of the overall system. A prototype of sorption storage system is available at the LOCIE laboratory. This thesis will take advantage of this prototype, to perform experiments at the system level on different composites (sorbent + additive) compositions and proportions, to find the best trade-off. In parallel to this experimental work, existing numerical models on sorbent beds will be adapted to be able to perform analysis of the bed behaviour in other conditions, as well as analysing the implementation of the system in real application frameworks.

Thus, based on our expertise and previous results and tools as described above, the objective of this thesis is to develop an innovative open circulating-bed thermochemical storage system, by studying the following aspects, which have not been addressed to date:

- Behavior of the sorbents with and without additives that could help the flowability (behavior upon the addition of an anti-caking agent) through experimental characterization, a trade-off between flowability and heat storage capacity will have to be investigated.
- Dynamic behavior of the system (reactor, storage, and auxiliary equipment) as a function of energy resources and demand (through experimental and numerical studies);
- Analysis of the system in terms of energy density, auxiliary power consumption, embodied energy, cost, and sizing (through numerical study);
- control of the system (experimental and numerical study);
- Integration and technical-economic optimization of the overall energy storage cycle in different case studies.

References:

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- Humbert G., Y. Ding and A. Sciacovelli, "Combined enhancement of thermal and chemical performance of closed thermochemical energy storage system by optimized tree-like heat exchanger structures," *Applied Energy*, vol. 311, p. 118633, 2022.
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- Wen F., C. Wang, H. Yang, L. Tong, S. Yin, L. Wang and Y. Ding, "Numerical investigation of heat release performance in a moving-bed reactor for low-to-medium temperature thermochemical energy storage," *Journal of Energy Storage*, vol. 125, p. 116951, 2025.