

Multi-objective optimization of a metal hydride reactor coupled with phase change materials for fast hydrogen sorption time

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In recent years, the interest in H₂ as a fuel has risen dramatically. However, its storage remains the main challenge due to its lightweight. Solid-state H₂ storage inside metal hydrides has been the forefront option due to its high hydrogen storage capacity and safety[1]. However, H₂ storage in metal hydrides (MH) comes with a hefty price for heat management. As a result, for mobile applications, many works are devoted to designing efficient heat exchangers to decrease the hydrogen storage/restore time. Recently, much attention has been turned to innovative passive heat management using phase change materials (PCM)[2]. The results of previous works showed that the hydrogen charging/discharging time from metal hydride reactors (MHR)-PCM systems are still higher than 5 min, target set by the US department of energy (DOE) for mobile applications. Therefore, such MHR-PCM systems fit beautifully in stationary applications where the H₂ charging time is not critical.

In this study, we analyze the performance of MHR-PCM systems using a two-dimensional numerical model. Figure 1 schematically depicts an MHR-PCM for stationary applications. This work aims to investigate the effects of the thermophysical properties of PCM on the H charging and discharging time. Furthermore, the impact of the heat transfer enhancement by inserting extended surfaces such as fins on the system's performance is also analyzed.

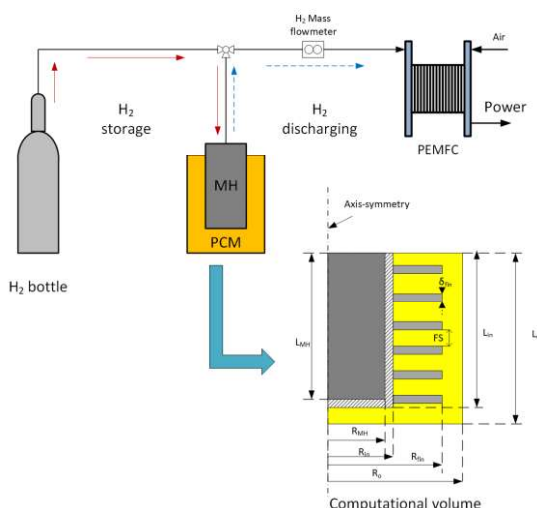


Figure 1: MHR-PCM systems for stationary applications. The well-known LaNi₅ based hydride materials are selected in this work due to their fast kinetics and their readily available

thermophysical properties. On the other hand, paraffin-based PCMs are chosen for their highly versatile properties to thermal energy storage applications. Since temperature gradients drive the metal hydride performance, the difference between the MH operating temperature and the heat transfer media should be high. Therefore, the choice of the melting point of PCM should depend on the absorption/desorption temperatures intimately linked to the H₂ ab/desorption pressures through the Van't Hoff equation. The simulations are conducted with absorption and desorption pressures of 10 and 1.5 bar, respectively. The melting point is allowed to vary between 25 and 50 °C.

Figure 2 portrays the H₂ charging/discharging time variation with the PCM's melting/freezing point. As can be seen from the figure, the H charging time t_c and H discharging time t_d have opposite trends. The increasing of the melting point favors the decreasing of t_d , while increases t_c . However, there is an optimum PCM melting point where the overall process time, $t_c + t_d$ is minimum.

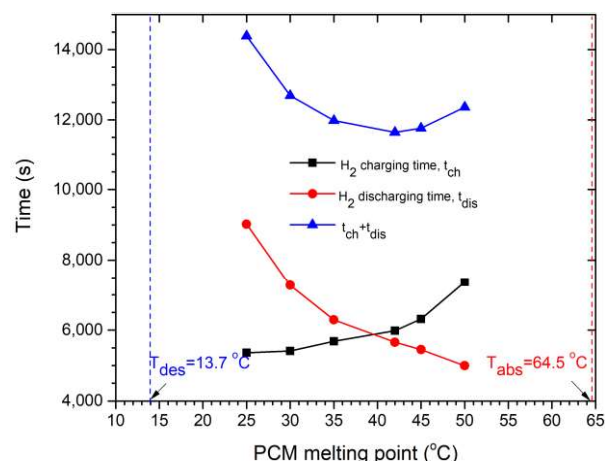


Figure 2: The change of H₂ charging/discharging time with the PCM melting point

This work aims to conduct a multi-objective optimization by simultaneously minimizing t_c and t_d with the properties of PCMs as decision variables.

References

- [1] Züttel A. Materials for hydrogen storage. Materials Today 2003; 6: 24-33.
- [2] Garrier S, et al. A new MgH₂ tank concept using a phase-change material to store the heat of reaction. Int. J hydrogen energy 2013; 38: 9766-9771.



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