Triply Periodic Minimal Surface Heat Exchanger as Metal Hydride Based Hydrogen Storage Reactor

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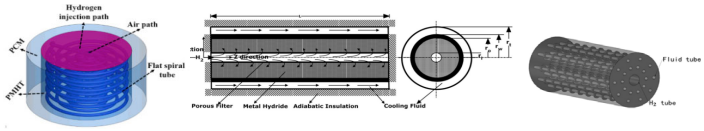
Sustainable energy production growth has become significant in recent years and a well-developed support technology will be in high demand soon. Energy production from sustainable sources usually has a common problem, which is the excess energy that generated need to be stored to accommodate the limitation of its fluctuation production characteristic. One promising way is to use the excess energy to generate hydrogen, but current hydrogen storage technology still left unanswered solution on safe, efficient, and high mobility storage solution.

Metal Hydride with Triply Periodic Minimal Surface (TPMS)

Metal hydride can store hydrogen simultaneously while releasing heat in the process, and hydrogen is released after heat is delivered to the compound vice versa.

$$Me + \frac{x}{2}H_2 \leftrightarrow MeH_x$$

This hydrogen storage solution storage has been investigated and found attractive with its properties of safety aspect as non-toxic and high energy density based on volumetric value. It offers ambient temperature, low pressure, and high volumetric hydrogen density. The biggest concern of Metal Hydride utilization is due to low gravimetric hydrogen density, Metal Hydride utilization for hydrogen storage on mobility sector is limited.

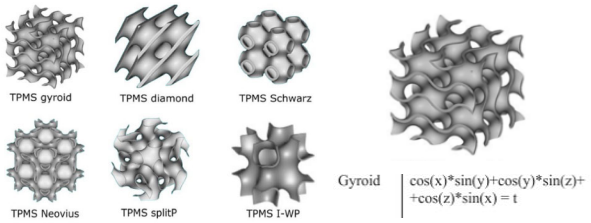


Attempts on improving storage performance

[3] Patil, S. D., & Ram Gopal, M. (2013). Analysis of a metal hydride reactor for hydrogen storage. In International Journal of Hydrogen Energy (Vol. 38, Issue 2, pp. 942–951). https://doi.org/10.1016/j.ijhydene.2012.10.031
[4] Ma, J., Wang, Y., Shi, S., Yang, F., Bao, Z., & Zhang, Z. (2014). Optimization of heat transfer device and analysis of heat & mass transfer on the finned multi-tubular metal hydride tank. In International Journal of Hydrogen Energy (Vol. 39, Issue 25, pp. 13583–13595).
[5] Ardahaie, S. Saedi, M. J. Hosseini, M. Eisapour, A. H. Eisapour, and A. A. Ranjbar. 2021. "A Novel Porous Metal Hydride Tank for Hydrogen Energy Storage and Consumption Assisted by PCM Jackets and Spiral Tubes." Journal of Cleaner Production 311.

Previous research has discovered that improving heat transfer ability on the reactor could increase the metal hydride reaction kinetics rate.

In the other hand, a triply periodic minimal surface (TPMS) is one form of complex geometries in cellular structure that is created based on mathematically-constrained cell shape patterned asymmetrically in 3D space. It has been investigated and found as one of the better structure to both withstand load and heat transfer if we compared to another lattice structure.



A scenario of a high strength structure and compact hydrogen storage that could charge and discharge hydrogen at a competitive speed with manageable pressure and temperature working condition then developed combining the previous mentioned technology. The ability to withstand load from TPMS structure will be utilized to overcome the limitation of low gravimetric density of metal hydride

Expected Results and Future Prospects

Numerical analysis has been conducted with promising result on usability and even better performance than previous study on common pipe in pipe approach design. This open the possibility to further explore the application of TPMS MH reactor on mobility usage like car frame, airplane shell, rocket tank and many other possible application.