Perforation Effect on a Rectangular Metal Hydride Tank for Hydriding and Dehydriding Process

Evangelos Gkanas[1], Sofoklis Makridis[1], Efstathios Kikkinides[2], Athanasios Stubos[3]

[1]Department of Mechanical Engineering, University of Western Macedonia, Kozani, Greece; Environmental Laboratory, Institute of Nuclear Technology and Radiation Protection, NCSR 'Demokritos', Agia Paraskevi, Athens, Greece

[2]Department of Mechanical Engineering, University of Western Macedonia, Kozani, Greece

[3]Environmental Laboratory, Institute of Nuclear Technology and Radiation Protection, NCSR 'Demokritos', Agia Paraskevi, Athens, Greece

Abstract

Hydrogen storage in a metal hydride bed, uses an intermetallic alloy that can absorb efficiently high amounts of hydrogen by chemical bonding resulting to metal hydrides. This alloy is capable of absorbing and desorbing hydrogen while maintaining its own structure. The temperature and supplied pressure can be easily controlled during the cycling process of hydrogenation and dehydrogenation. The knowledge of heat and mass transfer in a metal - hydrogen reactor during absorption-desorption, is very important for the proper design of relevant hydrogen storage units. The heat, mass and momentum transfer in a metal-hydride reactor is mathematically described by energy, mass and momentum balance equations. These equations are solved to simulate the performance of the metal hydride reactor, which is very important for the proper design and operation of the unit. The solution of these differential equations was performed using the COMSOL multiphysics software. The aim of such simulations is to understand how different reactor configurations and operating characteristics affect the absorption-desorption process. In the present study we considered two different reactor configurations: The first bed reactor (BED-1), as shown in Figure 1, is a rectangular metal hydride bed containing powdered LaNi5, while the second bed reactor (BED-2), as shown in Figure 2, has holes perpendicular to its large surface. These holes were organized in the geometry in order to simulate the flux of ambient air through the reactor, which subsequently affects the heat transfer and indirectly the mass transfer of hydrogen atoms through the metal. During absorption, the reaction in BED-2 appears to be more violent but with a slower response compared to the reaction in BED-1. The maximum temperature in BED-2 is 30.5 degC after 230-240 s while for BED-1 the respective temperature is 27.8 degC after 180-190 s. Furthermore, the maximum hydrogen concentration increases significantly to 3.5 mol/m^3 for BED-2 compared to 2.5 mol/m^3 for BED-1. In the desorption procedure, the pressure and the hydrogen concentration in the BED-2 decrease sharply while in BED-1 the pressure slightly increases and the hydrogen concentration decreases more smoothly. To conclude, the presence of holes on a metal hydride tank can significantly affect the metal to hydrogen reaction during both absorption and desorption.

Reference

1. U.Mayer, M.Groll ¨Heat and mass transfer in metal hydride reaction beds: experimental and theoretical results¨ Journal of less-common metals 131 (1987).
2. P.Marty, J-F. Fourmigue, P.De Rango, ¨Numerical simulation of heat and mass transfer during the absorption of hydrogen in a magnesium hydride¨ Energy conversion and management 47 (2006).
3. P. Muthukumar, S. Venkata Ramana, ¨Study of heat and mass transfer in MmNi4.6Al0.4 during desorption of hydrogen¨, International Journal of Hydrogen Energy¨, 35, 10811-10818, (2010).
4. Mahmut D. Mat, Yuksel Kaplan, ¨Numerical study of hydrogen absorption in a Lm-Ni5 hydride reactor¨, International Journal of Hydrogen Energy, 26, 957-963, (2001).

Figures used in the abstract

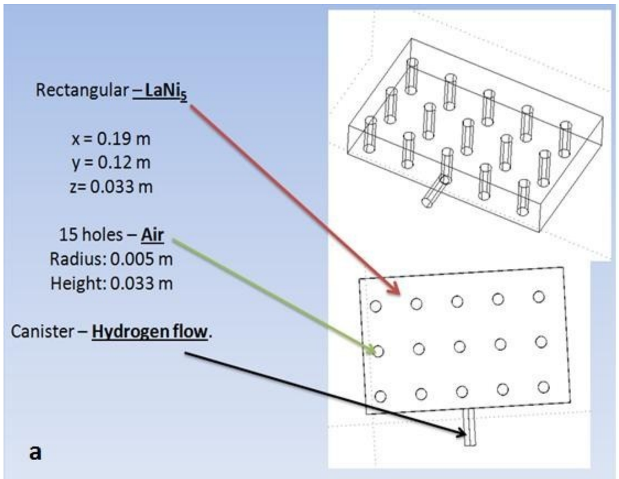

Figure 1: Geometry of the hydride bed without holes.

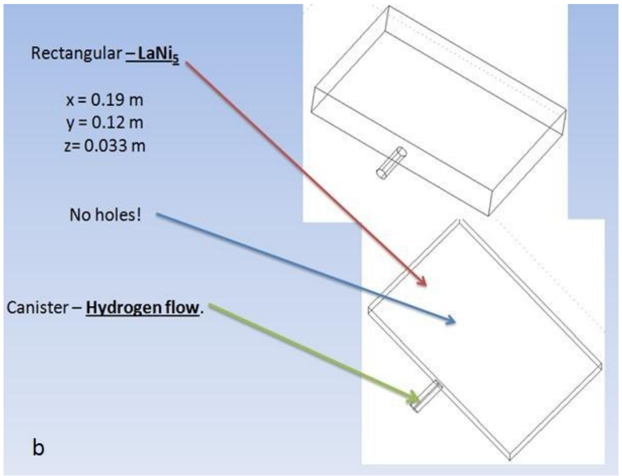

Figure 2: Geometry of the hydride bed with holes.

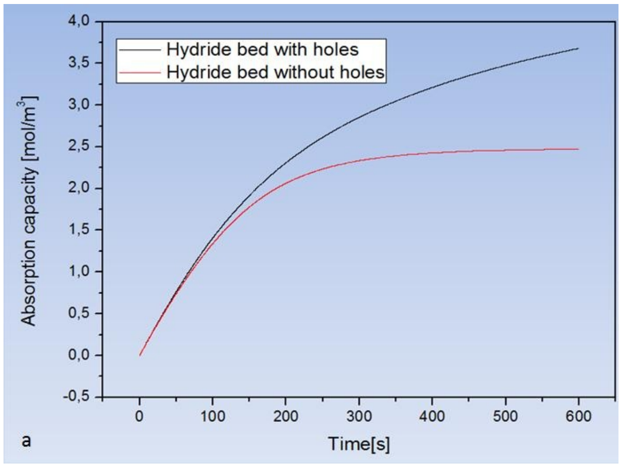

Figure 3: Absorption response for the two different reactor configurations.

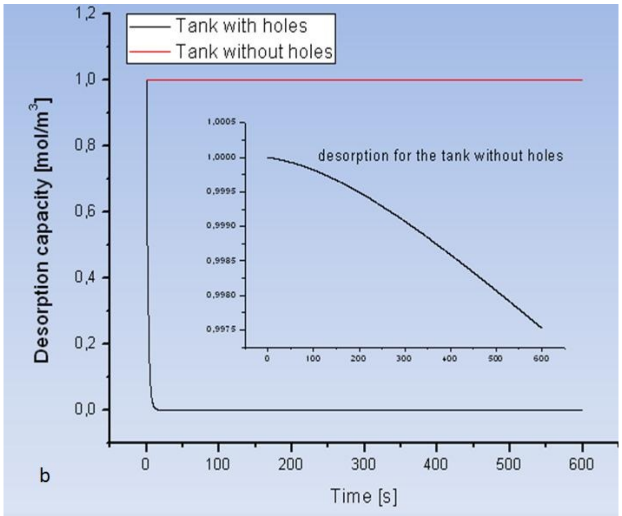

Figure 4: Desorption response for the two different reactor configurations.