Absorption of Hydrogen in the HBond©9000 Metal Hydride Tank

Lukáš Tóth
Department of Power Engineering, Faculty of Mechanical Engineering,
Technical University of Košice,
042 00 Košice, Slovak Republic

Tomáš Brestovič
Department of Power Engineering, Faculty of Mechanical Engineering,
Technical University of Košice,
042 00 Košice, Slovak Republic

Natália Jasminská
Department of Power Engineering, Faculty of Mechanical Engineering,
Technical University of Košice,
042 00 Košice, Slovak Republic

Abstract

The present article describes the measurements of hydrogen absorbed into an intermetallic alloy. The process of hydrogen absorption into a metal hydride tank is accompanied with generating heat that must be removed during the process. If the tank is not cooled, the gas pressure rapidly increases and even with a small amount of the stored hydrogen the pressure exceeds the permissible value. By contrast, during hydrogen desorption it is required to supply the same amount of specific heat to avoid a significant decrease in pressure which would result in a decrease in hydrogen release kinetics.

Keywords: hydrogen storage; intermetallic alloy; metal hydride; hydride tank;

1. Introduction

Hydrogen storage represents a key problem and an elementary obstacle with regard to its massive practical applications. One of the prospective possibilities is hydrogen accumulation in MH materials.

Such accumulation is appropriate mainly in stationary applications and power engineering that facilitate hydrogen absorption into the intermetallic space of the metal lattice. It is the safest method of storage, as compared to conventional methods.

The measurements of hydrogen storage capacities for individual alloys provide the knowledge of the specific amount of the stored gas; however, the determination of characteristics in real-life storing of hydrogen provides an overall view of thermal fields, energy flows and other relevant parameters of the used equipments that are interconnected.

2. HBond©9000 Metal Hydride Tank

From the structural point of view, the tank is a double-shell vessel. The internal part consists of seven symmetrically arranged cylindrical tubes (Ø 50 x 2 mm) containing metal hydride (Fig. 1 and 2) that are placed in a storage vessel (Ø 168.3 x 2 mm) with an option of liquid cooling during absorption (or heating during desorption).

The tank is made of stainless steel. The total length of the tank, including the internal tubes and without the inlet valve is 1,612 mm. The tubes are welded at both ends and form a compact unit. The tank contains 56 kg of $La_{0,85}Ce_{0,15}Ni_5$ alloy into which hydrogen is absorbed.

The capacity of a single tank is as much as 9,000 Nl (9 Nm^3), representing only 0.80892 kg of hydrogen at a very low hydrogen density. The percentage by weight of the stored hydrogen for this alloy is 1.43 % (measured by the volumetric method). The required hydrogen purity at the inlet into the MH tank is 99.9 vol. %. The metal hydride alloy was tested at the Technical University in Helsinski where it was observed that the absorption capacity did not degrade even after 1,000 cycles of absorption/desorption.

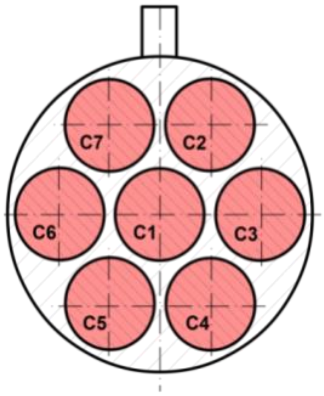

Figure 1. Horizontal cross-sections of the MH tank.

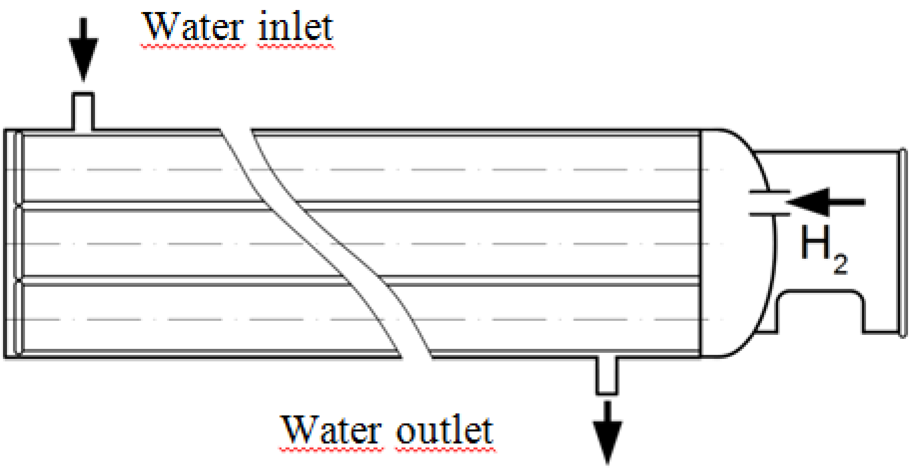

Figure 2.Longitudinal cross-section of the MH tank.

Cooling water is supplied and discharged at the terminal sections of the tank in the radial direction (Fig. 2).

The tank is thermally insulated along its entire surface, with the heat transfer coefficient of 1.8 $W \cdot m^{-2} \cdot K^{-1}$. Radiation is negligible due to low emissivity of the insulation surface.

2.1 Accumulation of Hydrogen in the HBond©9000 Metal Hydride Tank

Accumulation of hydrogen in the metal hydride tank was tested during two measurements. In the hydrogen storage process, the pressure in the tank must not exceed the value of 1.5 MPa and the temperature of 25 °C (determined by the tank manufacturer). As the measurements indicated, these conditions were not adhered to.

As the metal hydride tank was gradually filled up with hydrogen, the pressure in the tank was rising up to the value of 1.6 MPa and the resulting amount of the stored hydrogen after the first measurement was 2.048 Nm^3 (Fig. 3).

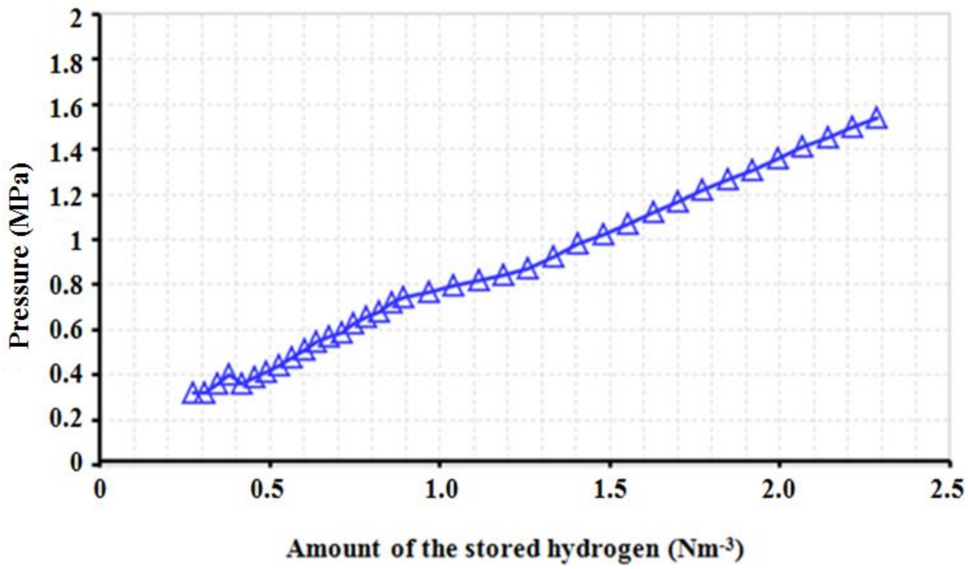

Figure 3. Relationship between the amount of the stored hydrogen and the pressure in the tank - without cooling.

The measurements of the temperature of the metal hydride tank were carried out using the FLUKE Ti10 thermal imaging camera and the ALMEMO 2390-8 contact thermometer. During the measurements, the observed temperature of the metal hydride tank was 36 °C while the max. permissible temperature of the tank is 25 °C (Fig. 4).

Figure 4. Measurement of the temperature of the metal hydride tank.

With regard to the fact that at the first measurement the surface temperature of the tank exceeded the maximum permissible temperature, the second measurement was carried out while cooling the tank using a water cooler with the electrical input power of 600 W.

As a result of water cooling, the temperature was reduced down to 19 °C. Water cooling was activated in 15-minute intervals (Fig. 5).

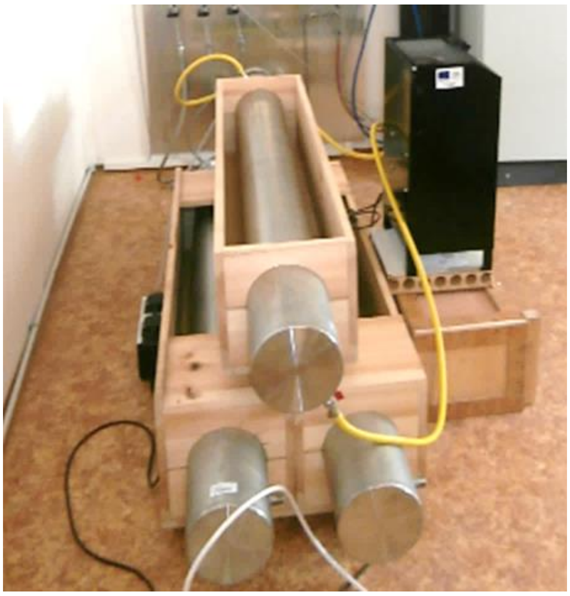

Figure 5. Cooling the metal hydride tank with a water cooler.

In the beginning of the second measurement, there was a decrease in the pressure down to 0.67 MPa. This was caused by a decrease in the temperature inside the tank, i.e. by partial absorption. Subsequently, during further filling of the tank the pressure in the tank was rising again, primarily as a result of a gradual increase in the volume of the stored hydrogen, as well as a temperature increase.

Due to a lower temperature in the tank, the achieved pressures were lower than 1.5 MPa (despite a larger amount of hydrogen in hydrides).

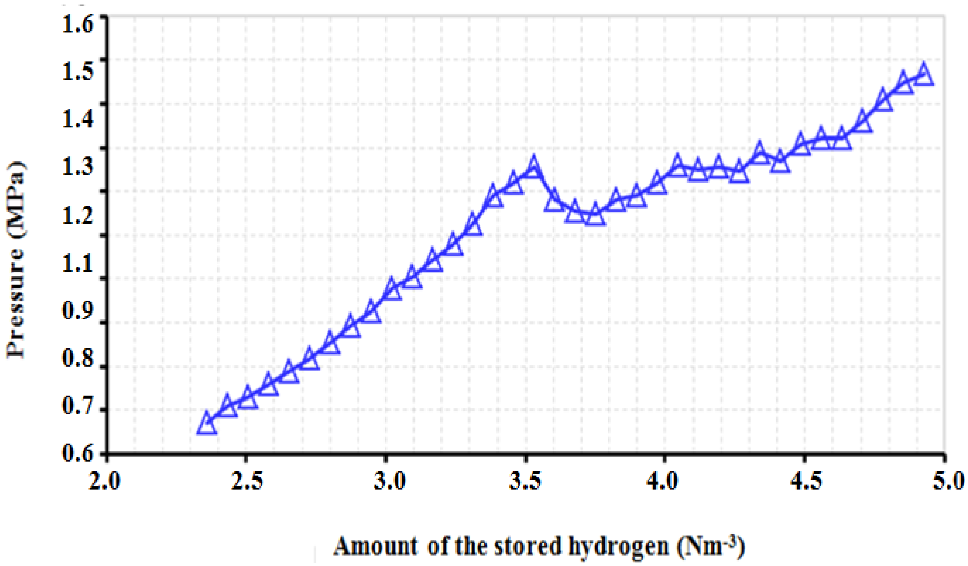

Figure 6. Relationship between the amount of the stored hydrogen and the pressure in the tank - with cooling.

3. Conclusion

The experimental measurements indicated that in order to eliminate fluctuations in pressure and ensure a stable pressure it is necessary to maintain a stable and optimal temperature of the metal hydride tank. Achieving the necessary temperature requires the use of an appropriate type of a cooling device or a cooling set, thus stabilising the pressure and increasing the efficiency of the tank filling procedure.

As the absorption temperature must not exceed 25 °C and hydrogen production is at the highest level in summer months it is necessary to engage compressor-based cooling or any other form of cooling, for example the one based on the Peltier Module principle.

4. Acknowledgement

This paper was written with the financial support of the granting agency APPV within the project solution No. APVV-15-0202, of the granting agency VEGA within the project solution No. 1/0752/16 and of the granting agency KEGA within the project solution No. 005TUKE-4/2016.

5. References

E. Anil Kumar, M.P. Maiya, S.S. Murthy,"Influence of transient operating conditions on pressure-concentration isotherms and storage characteristics of hydriding alloys". In: International Journal of Hydrogen Energy, (2007); s. 32. 2382-2389. ISSN 0360-3199.

T. Brestovič, N. Jasminská, M. Čarnogurská, M. Lázár,"Measurement and Simulation of Transient Phenomena in Metal Hydride Bed". In: Applied Mechanics and Materials. Vol. 816 (2015), s. 204-212. ISSN 1662-7482. ISSN 1662-7482.

K.H.J. Buschow, H.H. Van Mal, “Phase relations and hydrogen absorption in the lanthanum-nickel system”. In: J. Less-Common Met. 29 (1973), s. 203. ISSN 0022-5088.

B.H. Kang, C.W. Park, C.S. Lee,“Dynamic behaviour of heat and hydrogen transfer in a metal hydride cooling system”. In: Int J Hydrogen Energy. 21 (1996); s. 769-774. ISSN 0360-3199.

B. D. Macdonald, A.M. Rowe, “Impacts of external heat transfer enhancements of metal hydride storage tanks”. International Journal of Hydrogen Energy. 31 (2006), s. 1721-1731. ISSN 0360-3199.

H.H. Van Mal, K.H.J. Buschow, K. A.R. Miedema,“Hydrogen Absorption in LaNi5 and Related Compounds - Experimental Observations and Their Explanation”. In: Journal of the Less- Common Metals. 35(1) (1974), s. 65-76. ISSN 0022-5088.