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Experimental Measurement and Simulation of the Filling of the Metal Hydride Tank by the Hydrogen

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Abstract— *The article is focused on absorption and desorption of hydrogen into metal hydride. It describes underway the actions in the metal hydride tank during of filling this tank. In the first part of the article is described the main segments of the metal hydride tank and its basic technical parameters and the properties of the metal hydride, which tank is filled. It describes the experimental measurement during the filling the tank of hydrogen. During the filling tank with hydrogen is a temperature of the tank very important. The quantity the hydrogen storage and desorption of hydrogen from tank depends on the temperature of the tank. Due to, it is important to determine the characteristic of the tank, mainly the dependence the pressure and temperature. In the article is described of the simulation of filling this tank in the simulation program ANSYS CFX. For the simulation of heating of the tank were used boundary conditions as data from the experimental measurement. With the help this simulation, the evolution of the temperature during the filling of the metal hydride tank during its filling was displayed.*

Keywords— *Hydrogen storage, metal hydride tank, absorption, desorption;*

I. Introduction

The hydrogen is an ideal energy carrier because of the fact that during the combustion is not by polluting the atmosphere. It is the purest energy source if it is made from renewable sources. It is assumed the hydrogen will be considered one of the main sources of energy for the future not only for transport application but also for stationary energy source. Hydrogen is one of the simplest and most common elements. The molecules are smaller than the molecules of other gases and thus easily passing through the porous walls and a small storage tank leaks. Its storage is possible in three forms as the gas in pressure tanks, as the liquid in cryogenic tanks or as solid in hydride alloy.

II. Absorption and Desorption of Hydrogen to the Metal Hydride

X For absorption of hydrogen is used polyaniline. The reason of use of polymer is that the polymer is contents lot of atoms of hydrogen which should be stored. Polyaniline is suitable for hydrogen storage because its production is cheap and easy. The change its physical structure to the nanospheres and nanowires allows increase of its surface area. Through this is achieving bigger amount potential binding sites for hydrogen. The properties of hydrogen absorption are improved by adding the pozitive ions, for example the lithium. Lithium causes the increase of strength interaction. Polymer with lithium shows increase ionic conductivity (2.10^{-4} cm^{-1}) at room temperature. Also, the studies revealed other important properties of lithium. Chemisorption and physisorption are shown on the figure 1 [1-3].

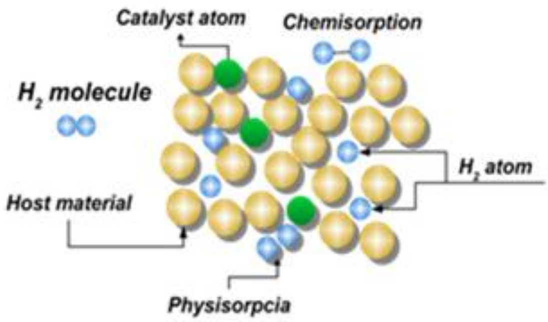

Fig. 1. Chemisorption and physisorption in catalytic materials.

The hydrogen gas molecule can be captured to material through three main mechanisms. The easiest form is weak binding with host material by physisorption of molecule. This binding arises if the temperature, in which it occurs to reaction, is enough low. In general, a temperature of about 77 K is required. The molecule of hydrogen can on separate to atoms in presence of catalysts as Ti, Fe, Ni, Pd. The hydrogen atoms are then linked by diffusion through porous host material [4-7].

III. Metal hydride tank HBond-9000

The metal hydride tank (see Figure 1) was made by company LabTech in Sofia, Bulgaria. The alloy has been tested to the highest institute of Helsinki University of Technology. The alloy has no degradation of hydrogen storage after 1000 cycles. The minimum purity of the hydrogen input into the metal hydride reservoir is 99.9 vol. %. This corresponds to a dew point -40 °C at atmospheric pressure.

Fig. 2. Metal hydride tank HBond-9000.

During filling, the metal hydride does not emit impurities

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therefore the purity of hydrogen on the output is to same and sometimes the better as on the input. The tank is fitted with all the tools and the valves necessary for its operation. In the tank is possible to install next additional devices, for example the controller to ensure control of the storage unit. Through this controller and on the base of standard protocols of transfer of dates is possible to get necessary information. Other informations about tank are specified in the tab. 1.

TABLE I. Properties of tank.

Technical specification of tank	Parameters
Capacity of storage	Min. 27 $Nm^3(H_2)$
Max filling pressure	15 bar
Filling temperature	≤ 25 °C
Rate of hydrogen during the filling	Min 13.5 $Nm^3(H_2)$
Purity of hydrogen on the inlet to the tank	≥ 99.9 hm%
Contents of oxygen in the inlet to the tank	≤ 10 ppm
Dew point H_2 on the inlet and atmosphere pressure	≤ - 40 °C
Rate of hydrogen desorption	9 $Nm^3.h^{-1}(H_2)$
Max rate of hydrogen desorption	13.5 $Nm^3.h^{-1}$ h (H_2)
Pressure of hydrogen	Min. 2 bar g
Water temperature for cooling	Min 20 °C
Cyclic stability (absorption, desorption)	1000 cycles during 10 years
Installation	Covered
Minimum temperature of surroundings	-20 °C
Other technical specification of tank	
Type of alloy	$LaNi_5$ – 140 kg
Consumption of cooling water resp. coolant (20 °C)	0.1 $m^3.hod^{-1}$
Volume flow of coolant	56.10^{-6} $m^3.s^{-1}$

IV. Simulation of Filling Metal Hydride Tank

The geometry of tank was constructed according to figure 3. The mesh was created using the "SWEEP" function, which means the mesh is stretched in layers. In the simulation program were set boundary conditions as type of flow of cooling water, heat transfer, temperature of inlet and outlet water and other. The model has three domains that metal hydride, steel and water.

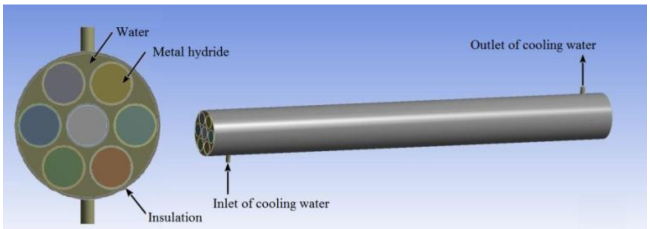

Fig. 3. The geometry of tank for simulation.

In the field of steel was set the contact area steel - metal hydride and steel - water. The last limit in domain steel is surroundings where was define coefficient heat transfer through insulation and temperature of surrounding.

V. Experimental Measurement of Filling Metal Hydride Tank

The Hydrogen Laboratory, where the measurements were made, is equipped with a comprehensive connection of energy facilities that allow hydrogen to be produced by electrolysis using electricity generated from a solar source. On figure 4 you can see the connection of all equipment.

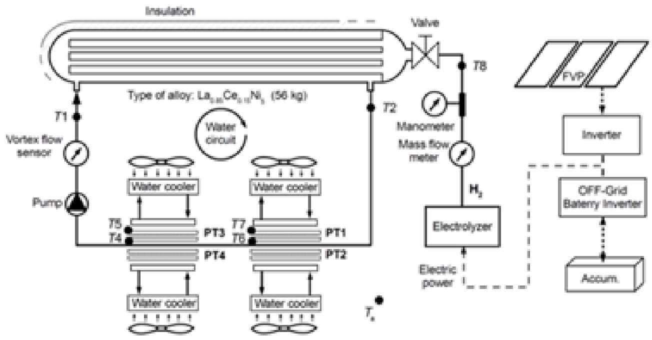

Fig. 4. Schematic diagram of equipment.

Hydrogen piping must be flushed before starting hydrogen storage. The hydrogen storage itself is monitored within the specified time interval.

Data collection:

- Time
- Flow
- Hydrogen temperature
- Cylinder pressure
- Power of the electrolyze
- Power of the analyzer
- Own consumption
- Cooler consumption
- Automatic data entry
- Cooling coil flow rate

After ending of measuremet is needed shut down the electrolize and to close metal hydride tank. Time of measuremnt of hydrogen storage was 2 hour and 15 minutes. Quantity of hydrogen for storage was 1 m^3.

VI. Measurement Results

On figure 5 is evaluation of temperature in 3 points. It can be seen in this chart that until approximately 310 seconds from the beginning of the simulation, the points were approximately the same. Gradually, this temperature varied depending on the distance from the inlet cooling water. Point 3, the most remote point, depending on the inlet of the cooling water, reaches the highest temperatures.

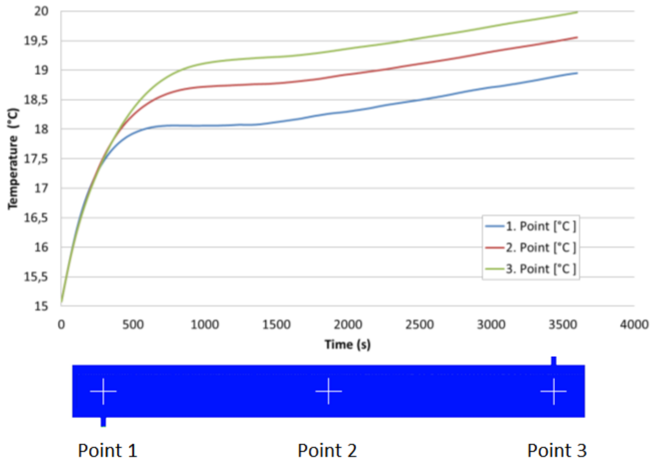

Fig. 5. The temperature course at selected points.

Except for these three 3 points was measurement the temperature of metal hydride tube according to figure 6. It is possible to monitor the distribution of the temperatures of the metal hydride in the tank after the simulation has ended. It is possible to see that the tray has a higher end temperature compared to the beginning. On figure 6 we can see the thermal contours are shown through the longitudinal section but also in cross-section at each level at the beginning, at the centre and at the end of the stack. The warmest place in the stack is the core of the metal hydride stack, precisely because of the heat source that was defined in the pre-run simulation settings. By the edges of these trays, it is possible to observe the places with lower temperatures that have been achieved by cooling water. Also, at the end of the tank we monitor the higher the temperature of the metal hydride than at the beginning. It can be assumed, therefore, that this temperature course also occurred during experimental measurements.

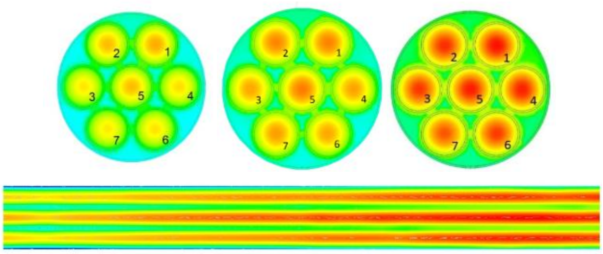

Fig. 6. Heat contours of the stack after the simulation has ended.

VII. Conclusion

At present, the rate of charging and discharging hydrogen is very important for metal hydride systems. Since absorption and desorption are exothermic and endothermic processes and the metal hydride is in powder form for the largest reaction area, the hydrogen absorption and desorption rate strongly controls the heat and mass transfer in the hydrodynamic bed. Therefore, such studies are very important because they allow you to understand the heat and mass transfer in metal hydride vessels. The temperature of the metal hydride reservoir is an important variable since the optimum temperature is from 20 °C to 25 °C. With its increasing temperature, its hydrogen storage capacity is decreasing.

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