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Heat Transfer in Metal Hydride Tank

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ABSTRACT

The article defines and characterizes the tray and describes a simple heat transfer in the tray. For the determination characteristic of the tray, mainly depending on pressure and concentration is necessary to know the temperature of the tray. In the performance of hydrogen storage it is important to remove heat of reaction, while during desorption of hydrogen must be added the heat. In the article is describes the properties of tray and simulation, Heat transfer in this tray. There are characteristics of the alloy and the principle of absorption the hydrogen into a lattice of alloy. The end of the article is an evaluation heat transfer of tray in the three points. The evaluation of temperature is compared with simulation in simulation program ANSYS CFX.

Keywords: hydrogen, hydrogen storage, simulation, metal hydride, tray for hydrogen

INTRODUCTION

The hydrogen is a very interesting source of energy. During combustion, it does not pollute the atmosphere. Its transport in the pipeline or in pressure vessel is easy. It does not addict of the fossil fuel if it produced from the renewable energy and it is used in the fuel cells. The stored hydrogen is an important problem for technical use in mobile and stationary applications. Storage in cryogenic or pressure vessels is rather dangerous. Safety in the storage of hydrogen in metal hydride is therefore a great advantage because in tray is lower pressure. Disadvantage of storage hydrogen in metal hydride materials is heavy sorbent material [1, 7].

FORMATION OF METAL HYDRIDE

The metal hydrides arise by the reaction of the metal or intermetallic compounds with hydrogen. In first α-phase are some molecules of hydrogen dissociated catalytically on the metal surface. Subsequently, they are dissolved in it. By increasing pressure is increases the concentration of hydrogen and it is being formed, the β-phase of the metal hydride with hydrogen atoms. The coexistence of α and β-phases are characterized by interdependent planes of pressure and temperature. In forming the β-phase (hydrogen absorption) it is important to remove heat of reaction, whereas for desorption of hydrogen to be added this heat [1].

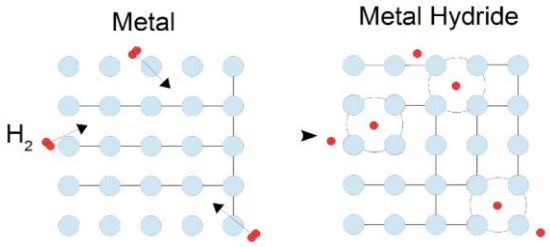

Figure1. *The basic principle of intermetallic hydrides [5]*

In the Figure 1 we can see the forming of metal hydride

The hydrogen forms the metal hydrides with a number of metals and alloys, which results a solid of storage at room temperature. Furthermore, an advantage opposite of the gaseous and liquid storage methods is security. Metal hydrides have a higher density than the gas or liquid hydrogen. Therefore, for transport applications, it is a metal hydride storage safe and effective method of storage volume [2, 5, 6].

HARACTERISTIC OF TRAY

The tray was distributed by Bulgarian-Finnish private company. The company was founded since 1993 in Bulgaria. Currently one it is of the largest manufacturers of containers for storage of hydrogen for stationary and mobile applications used in Europe.

Table1. *Tray parameters*

Capacity of tray	**9 $Nm^3(H_2)$**
Quantity of MH	**56 kg**
Alloy composition	**$La_{0.85}Ce_{0.15}Ni_5$**
The absorption capacity of the alloy	**Min. 160 Nl H_2 for 1 kg alloy**
Diameter	**168 mm**
Length	**1800 mm**
Heat exchanger	**SS**
Min. period of performance	**45 minutes**
Max. period of performance	**120 minutes**
Min. nominal flow rate	**3 $Nm^3.h^{-1}$**
Temperature range	**(-40 °C) - (+80°C)**
Max. operating range	**50 bar**

Hydrogen storage takes place in three trays. The capacity of each tray is 9 Nm^3 H_2. Each tray is produced from the stainless steel. Tray has an internal heat exchanger, internal filter and standard valve for hydrogen. The main technical parameters are in Table 1.

THE CALCULATION OF HEAT TRANSFER IN TRAY IN ANSYS CFX

During modelling of the tray was based the tray is formed of the double pressure tank and between tanks is flowing the coolant. The metal hydride is stored inside of inner tank. During modelling was not available drawing. Therefore, dimensions were used only measured or calculated. Modelling did not have the sketch of the tray [3].

Process modelling:

- The geometry of the tray.
- Networking and Regions (input, output);
- Defining materials, boundary conditions.
- Running the simulation and calculation [4].

Heat Transfer without an Internal Source in ANSYS CFX

The order of simulation is analysis of heat transfer in metal hydride tray (Figure 2) without internal source, respectively the stabilization period of temperature of tray when boundary conditions are changed.

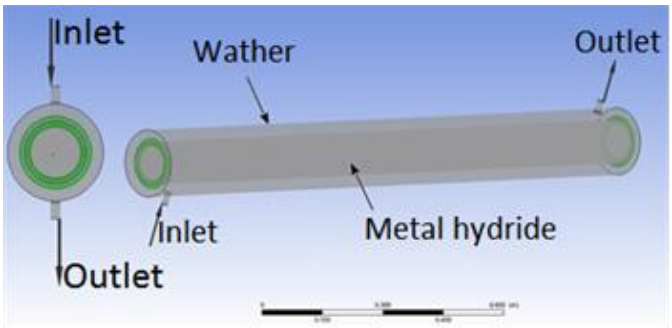

Figure2. *The geometry of the tray*

For the simulation were used following boundary conditions.

Boundary Conditions were assigned before Starting of Simulation.

Inlet:	
Flow regime:	subsonic
Heat transfer:	static temperature
Temperature:	22 (°C)
Mass and momentum:	mass flow
Mass flow	$5.6 \cdot 10^{-2}$ (kg·s^{-1})
Outlet:	
Flow regime:	average static pressure
Pressure mixture	$5 \cdot 10^{-2}$ (Pa)
Relative pressure	0 (Pa)
Cooling:	
Heat transfer:	heat transfer coefficient
Heat transfer coefficient:	1.78 (W·m^{-2}·K^{-1})

THE RESULTS OF CALCULATION

In the Figure 3 is displayed temperature distribution in the tray in time steps 300, 600, 900 and 1200 s.

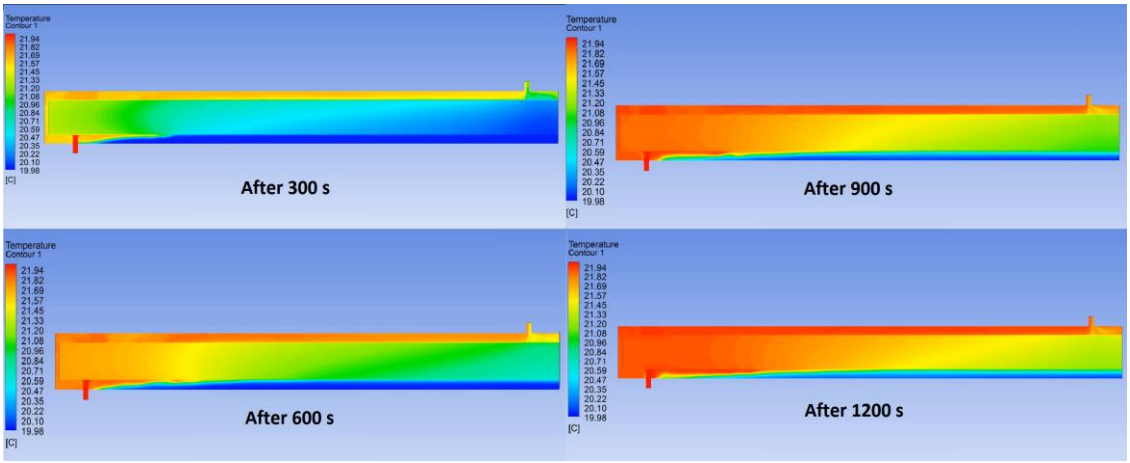

Figure3. *Viewing thermal contours at the time 300, 600, 900 and 1200s*

The goal of the simulation was to reach stabilization of the temperature tray. After stopping the simulation the temperature did not stabilize on 22 °C. The results of simulation were used for calculation of the time constant.

In the Figure 4 is displaying of time, temperature course of three points.

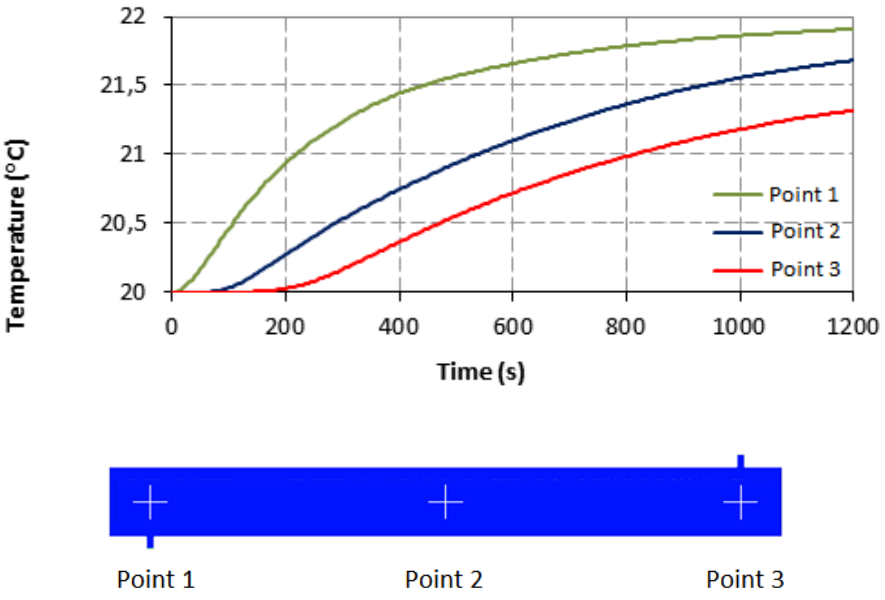

Figure4. *The temperature course at selected points*

The transient status in the tray can be described by the equation (1):

$$t = t_2 - (t_2 - t_1)\ e^{\frac{\tau}{\tau_0}} \text{ (s)} \quad (1)$$

Where

t - Temperature in time τ (°C),

t_1 - Temperature at the start (°C),

t_2 - Temperature at the end (°C),

τ - Time (s),

τ_0 - Time constant of transition (s),

τ_0 = 348.6 s

The tray had a constant temperature $t_1 = 20$ ° C before starting a calculation. After starting the calculation, in tray starts to flow water of a temperature $T_2 = 22$ °C. During heating the temperature of the tray changed with time (2):

$$t = f(\tau) \text{ (°C)} \quad (2)$$

Changing the tank temperature is displayed in Figure 5, wherein the black curve represents the course of the temperature in 1 from the simulation of ANSYS CFX and a program, the red curve shows the relationship (1):

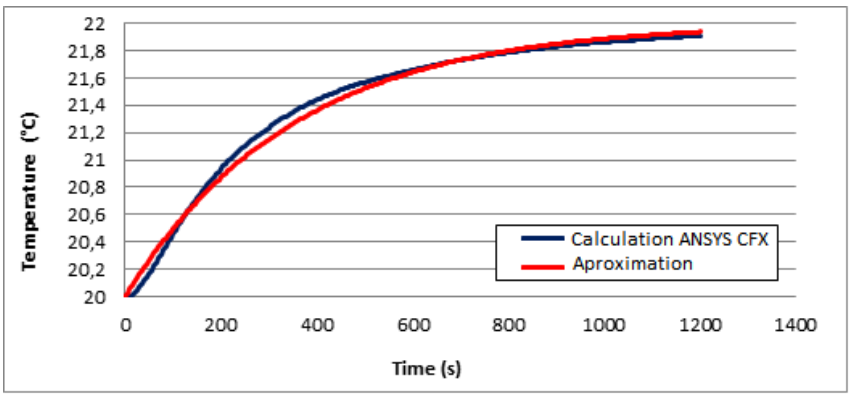

Figure5. *The view points*

CONCLUSION

In the present, the speed charging and discharging very important for metal hydride systems. Due to the fact, absorption and desorption are endothermal and exothermically processes and hydride of metal is in powder form, to ensure the biggest possible reaction areas , absorption rate and the hydrogen desorption strongly controls the heat and mass transfer in the hydride bed. Similar studies are very important because they allow understanding heat transfer and mass in metal hydride tray. The temperature of tray is an important quantity. Optimal temperature of metal hydride tray is 20-25 °C. If the temperature is growing the capacity of hydrogen storage drops.

The article deal calculation transient time-constant during heater of metal hydride tray from 20 °C to 25 °C. The time-constant is important for evaluation PCI diagrams respectively dependence of pressure and the concentration of metal hydride in the implementation of the tray. For simulation was used the simulation program ANSYS CFX.

The article describes heating of the tray at the steady state of the stack without internal source. After entering the boundary conditions and after running simulations it was found the course of the temperatures in three points of tray. For point 3 was calculated transient time-constant for the value of 348.6 second. Application of transient time-constant has been drawn curve exponential dependence; it describes with little deviation the course of temperature at this point. Through knowledge of the time constant is possible at this point calculate the temperature at any time within the range of 0 to 1200.

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