3D Modeling of Hydrogen Absorption in Metal Hydride Hydrogen Storage Bottles

R. Busqué[1], R. Torres[1], A. Husar[2], J. Grau[2]

[1]Escola Universitària d'Enginyeria Tècnica Industrial de Barcelona, Barcelona, Spain
[2]Institut de Robòtica i Informàtica Industrial CSIC-UPC, Barcelona, Spain

Abstract

The highly increasing energy demand and reduction of available fossil energy sources have made it important to develop new techniques for energy storage, being hydrogen a good alternative for the future. That is the reason why the storage of hydrogen as an absorbed element in metal hydride bottles has been studied.

To this end, a three-dimensional model of a charging process in a metal hydride container has been developed. This mathematical model has been implemented into COMSOL Multiphysics to allow obtaining results on the charging variables at different studied scenarios in order to be able to create a state of charge estimator in the future.

The absorption process of hydrogen includes several mechanisms. First, hydrogen flows through the pores of the metal. Then, it is absorbed into the metal through an exothermic reaction. Consequently the metal hydride density increases due to the addition of hydrogen.

A 2D-axisymmetrical model has been implemented as the bottle is cylindrical and a time dependent study has been carried out as the proposed problem has an evolution over time. Fluid flow in porous media has been modeled using Brinkman equations, temperature evolution is included with the Heat Transfer in Fluids interface and finally the density growth is calculated by the Domain ODE and DAE application mode.

The generated heat is extracted applying a heat transfer coefficient between the walls of the bottle and the surrounding air, which will force the temperature to decrease in the wall region (Figure 1). The effect of the cooling level has great impact on the charging process as the hydrogen absorption rate depends on the bottle temperature. The cooler the bottle is, the higher the absorption rate and the faster the bottle will be filled (Figure 2).

Besides analyzing the effect of the cooling level, a lot of parametric studies regarding metal properties have been carried out in order to discover their influence on the process.

The model has been experimentally validated showing a good agreement in different operating conditions.

All the experimental tests were performed at the PEM Fuel Cells Laboratory of the Institut de Robòtica i Informàtica Industrial (CSIC-UPC, Barcelona, Spain) and only possible due to its advanced equipment and proficient technical staff. This work has been partially funded by the Spanish national project MESPEM (Ref. DPI2011-25649) and the Spanish Council for Scientific Investigations JAE-INTRO2014.

Reference

H. Dhaou et. al., Measurement and modeling of kinetics of hydrogen sorption by LaNi5 and two related pseudobinary compounds, International Journal of Hydrogen Energy 32: 1922-27 (2007)

K. Jiao et. al., Effects of various operating conditions on the hydrogen absorption processes in a metal hydride tank, Applied Energy 94: 257-269 (2012)

J. Nam et. al., Three-dimensional modeling and simulation of hydrogen absorption in metal hydride hydrogen storage vessels, Applied Energy 89: 164-175 (2012)

Figures used in the abstract

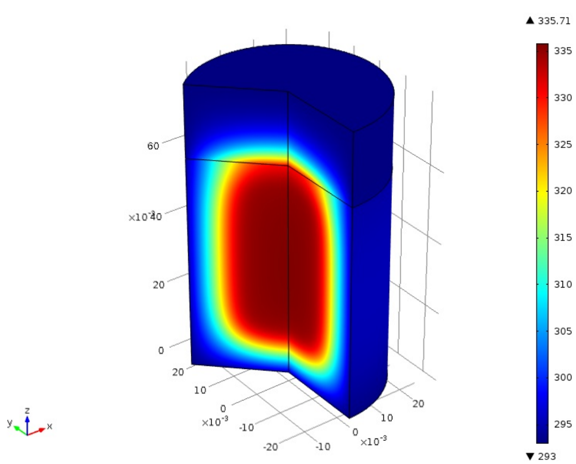

Figure 1: Temperature Distribution inside the bottle. Time=250s and h=1652 W m-2 K-1

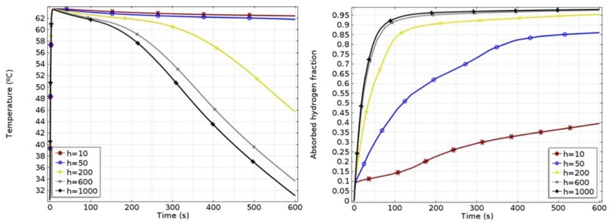

Figure 2: Effect of heat transfer coefficient on the evolution of temperature (left) and absorbed hydrogen fraction (right)