ADVANCED METAL HYDRIDE TANKS FOR INTEGRATED HYDROGEN APPLICATIONS

Berichterstattung

Projektinformationen

ATLAS-H2

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Projekt abgeschlossen

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Final Report Summary - ATLAS-H2 (ADVANCED METAL HYDRIDE TANKS FOR INTEGRATED HYDROGEN APPLICATIONS)

The ATLAS-H2 IAPP project started on July 1, 2010 and ended on June 30, 2014 according to the contract. It should be stated from the beginning that at the premises of both participating SMEs the originally foreseen final project outcomes (prototype Mg-based hydrogen storage tanks and prototype MH based hydrogen compressor respectively) have been successfully developed, tested and evaluated.

On the secondments side, there have been some initial delays with respect to the original plan which can be considered to a certain extent as normal, since the administrative departments of the partners as well as the researchers themselves needed some time to understand fully the rules and requirements of the IAPP scheme. An effort was made to overcome the problems based on a restructuring of the initial plan which was submitted by the consortium to the EC for approval. Concerning the finally implemented plan, it was managed to realize a total of 258 PMs of seconded / recruited staff, almost 83% of the originally foreseen number of PMs.

On the technical side, the main objectives and deliverables of ATLAS-H2 refer to:
(i) The development of Mg-based hydrogen storage tanks, and
(ii) The development of a pilot hydrogen compressor based on metal hydrides.
With respect to activity (i), partners CNRS and McPHY advanced significantly the relevant work in the course of the first 24 months (ahead of the originally foreseen schedule). Regarding activity (ii), the work at Hystore / NCSRD / CNRS premises proceeded as planned with emphasis placed during the first 24 months on the synthesis and characterization of metal hydride samples that could be potential candidates for the different stages of the hydrogen compressor. Consequently, over the last period, the emphasis moved gradually towards the construction and testing of the lab pilot of the MH compressor.

All technical objectives were fully attained including the building and operation of the pilot Mg-based hydrogen storage systems at McPHY and the laboratory prototype MH-based hydrogen compressor at the Hystore premises.

In particular, the work in the various workpackages can be summarized as follows:
 WP 1
WP1 has been finalised and fulfilled its objectives according to the initial plan. Various types of hydrogen storage materials were synthesized and characterized by the partners. These materials belong mainly to the AB2 (TiCr2 and ZrFe2 systems) and AB5 types (e.g. La1-xCexNi5 system).
 WP 2
WP2 has been completed. The lab-scale hydrogen MH compressor has been successfully delivered. A brief description of its main features is given below.
 WP3
WP3 has been finalized well ahead the initial plan due to the rapid developments of the McPhy adiabatic metal hydride tanks (with the assistance of CNRS). The main characteristics of the storage systems are summarized below.
 WP4
WP4 has been successfully finalised. The production of upscaled quantities of the nanostructured solid storage Mg-based material has been attained well ahead of the originally foreseen schedule. The pilot storage Mg-tanks have been successfully tested and evaluated by McPHY, while the pilot metal hydride

compressor has also been successfully demonstrated at Hystore premises.

The expected impact from the above is significant in various aspects:
The two prototypes built and tested / demonstrated in the project by the two participating SMEs with the aid of the research institutions (Mg-based storage systems by McPHY and MH-based hydrogen compressor by Hystore) constitute important outcomes addressing a host of potential industrially relevant applications related to renewable energy storage (in the form of hydrogen). Indeed, the hydrogen storage tanks are in the commercialization phase and benefit from the improvements in the material that resulted from the project. The lab prototype of the MH compressor that elevates hydrogen pressure to more than 200 bar using hot / cold water in six stages is intended to be upgraded and integrated in a complete hydrogen production / storage / utilization chain before its commercialization.
The SME and research partners acquired significant mutual benefits as a result of the Industry / Academia collaboration scheme of the IAPP projects. The SME staff had the opportunity to be trained and get hands-on experience with regard to several material characterization and system performance assessment techniques. The researchers from NCSRD and CNRS had the chance to work together with the industry, contribute to the solution of practical problems and be exposed to the needs and requirements of the market. Extensive training of the seconded and recruited scientists took place on a series of advanced experimental techniques related to material synthesis and characterization, hydrogen uptake measurements and chemical analysis, such as:

Materials selection for hydrogen storage purposes and handling
Alloy preparation (arc-melting) and heat-treatment
Alloy characterization
X-Ray Diffraction
Microstructure observation (Optical Microscopy, Scanning Electron Microscopy)
Pressure Composition Temperature (PCT) techniques (volumetric, gravimetric)
Analysis of results / Assessment of material properties
Specific alloy selection for application in the Metal Hydride Compressor
Analytical techniques (HPLC, GC-MS)

In addition, training was offered on modelling and simulation tools (Monte Carlo stochastic methods, Continuum approach using COMSOL) for the recruited staff and some of the seconded personnel. Several publications / presentations were prepared thus offering additional training on scientific paper writing to the seconded / recruited staff. Finally, certain seconded scientists took part in proposal writing tasks towards national and European funding bodies adding considerably to the level of training they received in the course of the project.
The secondments and recruitments, besides the important training and networking aspects mentioned above, brought further benefits to the SMEs in terms of acquired expertise on specific techniques, access to advanced instrumentation and in-house building and development of useful equipment (e.g. seconded researchers to Hystore assisted essentially the company to build at its premises a PCT device with obvious technical and economic benefits for the SME).
During the project, a large number of scientific journal and conference publications was produced thus disseminating the main project results to the wider community.

A brief description of the two main technical outcomes (two distinct prototypes) of the ATLAS-H2 project follows.

(i) Mg-based hydrogen storage systems

The prototype system incorporates improved, upscaled quantities of the nanostructured Mg-based hydrogen storage material. Indeed, compacted MgH_2 disks with adjustable radial thermal conductivity were developed. The process has been up-scaled at McPhy Energy were compacted disks of 30 cm in diameter are now produced suitable for commercial purposes. However, further tests were performed in collaboration between CNRS and McPhy, in order to optimise the properties and to better understand the behaviour of these materials especially under long term cycling.
The lifetime stability has been tested for up to 600 cycles. Hydrogen capacity was found to remain practically unchanged while the effect on kinetics was only slight.

Large-scale tanks using the improved MgH_2 compacted disks were developed and short tank loading times were achieved thanks to the optimisation of the heat exchanges. However, the enthalpy of formation of MgH_2 (ΔH = -74 kJ/mol H_2) corresponds to 31 % of the hydrogen Lower Heating Value (LHV). If this thermal energy is lost, it reduces the global storage efficiency of the system. It was then proposed to use a Phase-Change Material (PCM) to store the heat released during the absorption stage and to reuse it during the hydrogen desorption stage. A new PCM with suitable properties was investigated among metallic systems so that the PCM thermal properties wouldn't limit the tank loading time. A cylindrical tank including the qualified PCM was developed and tested under various experimental conditions. Its inner tube contains the stack of 10 kg of MgH_2 compacted discs made from ball milled magnesium hydride containing 4% atomic Ti-V-Cr. The external annular volume contains the PCM, which was filled in the liquid state under argon atmosphere.
The tank was instrumented with thermocouples located inside the MgH_2 compacted discs and inside the PCM. A series of hydrogen desorption and absorption tests were carried out to measure and assess the tank behaviour. The PCM seems to be very stable upon cycling. The loading time can be reduced to 3 hours by increasing the pressure up to 1.1MPa. Considering a 24h cycle, the daily efficiency of the PCM-tank system is about 69%. Improving the tank insulation or working with larger tanks would increase the daily efficiency by reducing the influence of the external heat losses. Nevertheless, the use of PCM material provided a large improvement of the storage efficiency since the initial stand-alone MgH_2 tanks could only achieve a daily efficiency of about 35%.

A PEM Fuel Cell delivering electrical power of 1.2 kW was used to test the ability of the tank to supply the required hydrogen flow rate for the operation of such a Fuel Cell. The tank was directly connected to the Fuel Cell, without any H_2 buffer or mass flow regulation. The tank responded very quickly and effectively to variations of power. The maximum power could be reached in 15 seconds and the system autonomy is about 10 hours at the maximum power. Based on these pilot results, upscaled units of 5 kg hydrogen capacity including PCM are presently being built for commercialisation by McPHY Energy. The main application envisaged for such systems refers to the storage of intermittent renewable energy.

(ii) Metal Hydride based Hydrogen Compressor

The construction of a multi-stage Metal Hydride Compressor with delivery pressure above 200bar at Hystore premises has been successfully demonstrated.

H2 Capacity
The compressor consists of 6 stages and is using only hot and cold water. The discharge pressure of the compressor is higher than 200 bar and the flow rate of the device is around 2000 liters of H2 per hour. The actual compression starts after allowing sufficient time for the system to be filled with H2 for the first time and for the recording of the behavior of the Metal Hydrides in the six stages. Filling cylinder is the "Red bottle" that contains H2 and is regulated at a pressure below 10 bar. ATLAS-H2 compressor is taking hydrogen from this "Red bottle" at 10 bar and it is compressing it to a pressure of above 200 bar, and then discharging it to the Filling cylinder which is an empty "Red bottle".

Compression ratio

Compression ratio calculated at each stage
Stage 1-2: 1:2 (10-20bar)
Stage 1-3: 1:4 (10-40bar)
Stage 1-4: 1:6.5 (10-65bar)
Stage 1.5: 1:11 (10-110bar)
Stage 1-6: 1:16.5 (10-165bar)
Stage 1-Output Pressure: 1:22 (10:220bar)
Overall Compression ratio: 1:22 (10-220bar)

Hydrogen Flow

Hydrogen flow is 2.5m^3⁄h

An extended publishable summary of the project is attached (including illustrative diagrams and photos). A table indicating the final status of the project deliverables as well as the final (approved by the PO) secondments / recruitments plan are also attached.

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