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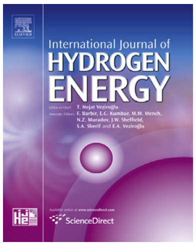

Short Communication

The use of air as heating agent in hydrogen metal hydride storage coupled with PEM fuel cell

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ABSTRACT

The possibility to refuel air-cooled PEMFC by hydrogen desorbed from low temperature metal hydride storage using the FC exhaust air was successfully demonstrated. The volumetric flow of hydrogen exceeded the values needed to ensure 1.1 kW (e) FC capacity level. Experimental setup, the results of experimental investigations are presented and discussed, as well as the reserves for the technology application for kW scale power production units based on air-cooled fuel cells.

Introduction

Low temperature metal hydride storage systems (MEHSS) have proved their feasibility for the kW scale FC based power production units [1,2] for stationary and some transportation applications [2–4]. In spite of relatively low gravimetric hydrogen contents the $LaNi_5$ based solid state hydrogen storage display the highest level of safety and reliability unreachable by other means. The problem of system integration in FC power sources, which use metal hydride storage is mainly induced by the intensions to utilize the low potential heat from PEMFC for the means of desorption process in MeH storage overburdened by high reaction heat (~40 kJ/mol H_2) and low effective thermal conductivity of highly dispersed metal hydride powder beds [5–9]. In Ref. [10] the possibility of successful thermal management of the system with 5 kW PEMFC and 13 st.m^3 hydrogen storage has been demonstrated. This result is based on the design of the heat exchanger of the reactor and operation regimes selection both optimized from the point of view of mass transfer crisis avoidance [11] the phenomenon, which is typical for the technology. The task of the demonstration of stability at power supply from MEHSS in Ref. [10] is simplified by the use of water (liquid) cooling loop and where PEMFC is the source of low potential heat (about 60 °C) and MEHSS is the heat absorber. However, water-cooled PEMFC stacks typically require complex water management subsystems that result in a larger system volume, weight and cost, while air-cooled PEMFCs that feature self-humidifying technologies developed to commercial level in recent years and are squeezing liquid – cooled PEMFCs out of the market at least in 1–10 kW range. The heat transfer coefficient at heat transfer from the metal hydride bed to the liquid accounts for more than 120 $W/(m^2\ K)$ [12] and these values are hardly achievable if one tries to heat up MEHSS by hot air from PEMFC outlet.

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Table 1 – The parameters of *Hoppecke H2.power@* PEMFC power generation units.

Installed H2 power (kW)	Air volume flow (m^3/h)	Air temperature at maximal load (°C)	Proposed area for in-and out air flow (cm^2)	Hydrogen consumption at maximal load (st. l/min)	Minimal stack inlet pressure (MPa)
1.1	391	50–55	289	13	0.0551–0.0830
2.5	883	50–55	660	30	0.0551–0.0830

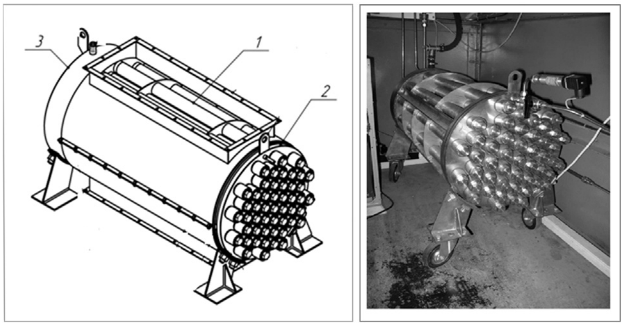

Fig. 1 – General view of the RS-1 metal hydride reactor 1 – single tube cartridge, 2 – hydrogen collector, 3 – water collector. On the photograph RS-1 without cover.

In this study we try to demonstrate in qualitative experiment the possibility of heating up of the semi-commercial (13 st.m^3 maximal hydrogen storage capacity) reactor initially designed for liquid cooling/heating by the air, having parameters similar to the outlet air of commercial air cooled PEMFC system with capacity in the range of 1–2.5 kW (e). The data on *Hoppecke H2.power* product lineup, kindly provided by the manufacturer, is taken for reference in this study, see Table 1. The main goal of the experimental investigations is to obtain the data on the volumetric hydrogen flow at discharge and how it corresponds with the demanded refueling flow of the PEMFC stack.

Another important issue is the maintaining of the pressure at the reactor outlet to fit the requirements of the PEMFC stack. Since the equilibrium parameters (*P-C-T*) of the hydrogen absorbing materials are mainly defined by the composition of the alloy [13–17] and $LaNi_5$ family gives wide opportunities to achieve the demanded parameters by the modification of the initial composition, here the question of the outlet pressure is recognized as secondary.

Experimental setup

The detailed design and operation test results of the reactor RS-1 used in the experiments are given in Ref. [10]. The reactor is stainless steel tube type heat exchanger (Fig. 1) with inner channels for liquid heating and metal hydride placed in the annular gap between the channel for liquid and the outer wall of each tube.

The reactor consists of 49 tubes with length of 65 cm united by common hydrogen collector. Each tube has stainless steel mesh filter at the inlet to retain metal hydride inside the tube. Total weight of $La_{0.5}Nd_{0.5}Al_{0.1}Fe_{0.4}Co_{0.2}Ni_{4.3}$ metal hydride is 81 kg at 70% fill of each tube. The alloy properties are given in Table 2 [8].

The reactor is designed for hybrid cooling both by liquid from inside and natural convection from the outer walls of the tubes. For this purpose the cover of the reactor has rectangle ducts (600 × 200 mm) on the top and the bottom of the cover. In the experiment the cover has been turned 90° to provide horizontal flow of air that corresponds to the flow geometry of commercial PEMFC systems under consideration (Fig. 2). Three electric finned tube-type heaters, 1 kW maximal power each, have been installed at the inlet of the curved duct. The heaters are connected in parallel and their power is controlled manually by voltage variation in the range of 0 ÷ 220 V (AC). The curved duct is used to avoid direct thermal radiation from the heaters to the first layer of the metal hydride cartridges not to violate the exclusively forced convection nature of the external heat transfer in the experiment. The heaters total thermal power Q was selected from the condition of heat withdrawal by 2.5 kW PEMFC cooling system, which is

$$Q > \frac{W_e(1-\eta)}{\eta},$$

here W_e and η are electric capacity and efficiency of PEMFC. Efficiency of the selected commercial systems with respect to hydrogen lower heating value accounted for $\eta = 0.46$. At the outlet of the cover a row of five PY-1238H240S axial exhaust fans each having capacity of 190 m^3/h has been mounted.

A probe hole for air flow temperature measurement has been drilled in the inlet duct of the reactor cover.

Preliminary tests included the tuning – up of electric heating parameters for better emulation of the air heating at coupling of RS-1 and commercial PEMFC. The target had been to obtain 50 °C inlet temperature which was reached at 1.7 kW electric power on the heaters. Velocity of air at the inlet of the curve duct was measured by thermal anemometer Testo 415 in several points giving the average of 0.7 ± 0.1 m/s. The

Table 2 – The properties of $La_{0.5}Nd_{0.5}Al_{0.1}Fe_{0.4}Co_{0.2}Ni_{4.3}$.

Temperature (°C)	Equilibrium desorption pressure (MPa)	Hydrogen mass content, max (%)	Desorption heat (kJ/mole H_2)	Heat capacity (kJ/kg °C)
25	0.11	1.1	35.3	0.42
80	1.16			

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