PROPOSAL OF MEASURMENT METHODOLOGY OF STORAGE CAPACITIES OF MATERIALS FOR HYDROGEN STORAGE

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Abstract

From an energy perspective, the hydrogen can be classified as a promising alternative fuels. As a result of the increase in energy consumption and in order to protect the environment, more and more attention is paid to this element. The present article deals with the properties of hydrogen, a description of the measuring device for storing hydrogen and measurement procedure. Attention is paid to practical step in the experiment into a container to store hydrogen at a pressure of 70 bar and a cryogenic temperature.

Key words: hydrogen, alternative fuels, hydrogen adsorption storage, experimental measurements

INTRODUCTION

The process of hydrogen storage is one of the major problems in the implementation of hydrogen technologies. Recently come to the fore adsorption and metal hydride storage methods. The present article is described with the measuring of the stand, which can measure absorption and adsorption properties of the storage material. There is also an adsorption process of storage and relations to calculate the mass of storage per cent.

SAFETY REQUIREMENTS FOR STEND

Explosiveness and flammability are features that are common to all types of fuels. Hydrogen is not an exception in with air and flammable and forms explosive mixtures in a wide range of concentrations (4-75% of the flammable mixture and 19-58% of the explosive mixture). Hydrogen has very low ignition energy. Very small electrostatic charge (0.02 J) may initiate ignition of the fuel [3].

Tab.1 Comparison of the characteristics of hydrogen and natural gas. Source: [4]

Characteristics	Hydrogen	Natural gas
Flammable limits	4-74 %	5,3-15%
Explosive limity	19-58%	5,7-14%
The energy needed for ignition (J)	0,02	0,29
Flame temperature (°C)	2045	1875

Moreover, low viscosity and small size of hydrogen molecules increase the demands on the tightness of the whole system. Leaks and spills of hydrogen cannot be detected by human senses. The very low density of the gas promotes rapid dispersion in the environment, leading to a rapid reduction in the concentration of the ignitable mixture. In our case, we work in a confined space, the whole situation more difficult. The whole measurement stend are therefore in a room that is equipped with a ventilation system, respectively well ventilated and includes detectors that during the measurement control environment surrounding the presence of hydrogen. In the event of an elevated concentration detector signals resulting status signal diodes.

LABORATORY EQUIPMENT

In Fig. 1 shows a diagram of the measurement system. All devices that are incorporated in the system are designed for use with hydrogen gas. They are not given higher requirements compared to conventional equipment designed to work with compressed air, natural gas or oxygen.

The system features a pressure vessel which contains hydrogen with a purity of 3.0 (99.9%) at a pressure of 20 MPa. Purity of hydrogen employed is sufficient to measure the adsorbent characteristics, given that the adsorbent is not susceptible to degradation capacity of the storage. For some types of metal hydride degradation occurs because of the ability, caused by the occurrence of various additives in a gas with a purity of 3.0. In the absorption process, it is therefore necessary to work with a higher purity hydrogen 5.0 (99.999%) [1].

It is possible to reduce hydrogen pressure by reducing valve can be reduced hydrogen pressure for pressure vessel at pressures up to 100 bar. The measurements will be converted at a pressure of 70 bar. The actual distribution of the gas

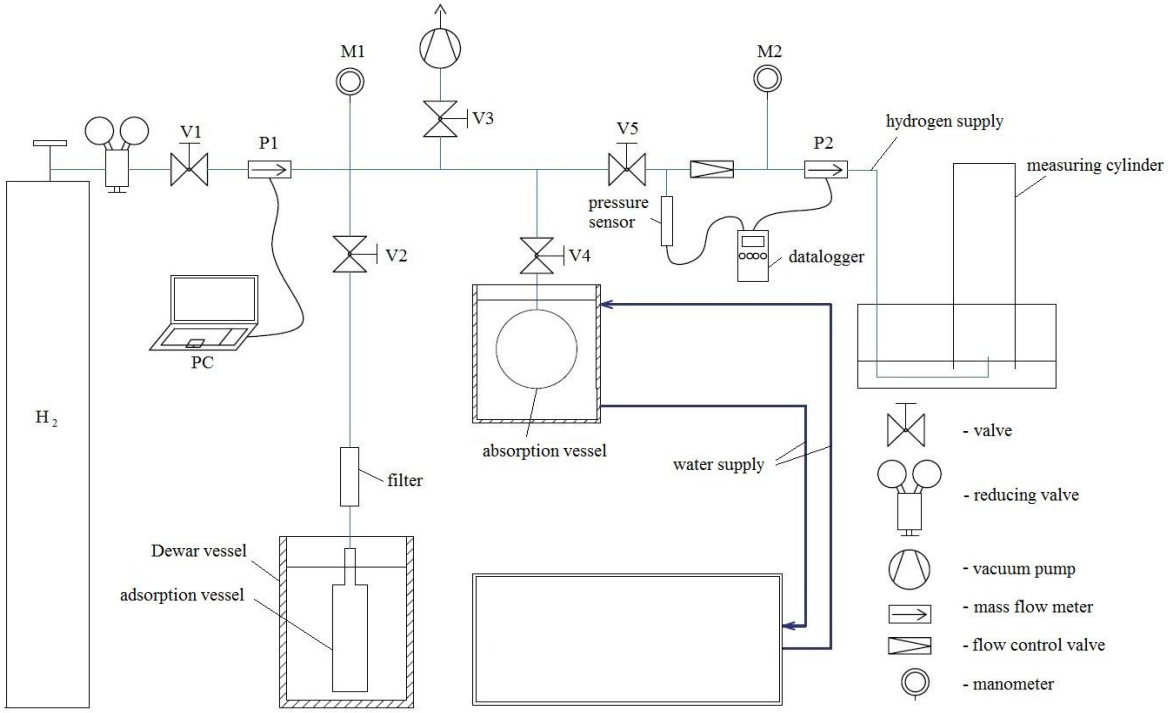

Fig. 1 Schematic diagram of the hydrogen laboratory

must therefore be sized to the above mentioned pressure were recorded no gas leaks.

System consists of a hydraulic duct with an outside diameter of 6 mm. The internal diameter of the tube is 3 mm, that the tube walls are 1.5 mm thick.

On the venting system used N816,3 kN.18 diaphragm pump with a minimum pressure of 1.8 kPa.

Hydrogen flow in the pipe can be controlled by five globular two-way valves. Their maximum working pressure is 180 bar. It is due to seal PCTFE and the material from which they are made. Connection to pipes with a diameter of 6 mm is due to the compression ring is very simple.

The most important part consists of a disposal container with an adsorbent with a volume of 215 ml. This delves in a Dewar vessel containing liquid nitrogen. Adsorption tank is cooled to the temperature of liquid nitrogen 77 K by the heat transfer [2].

MEASURING EQUIPMENT

Pressure in the hydrogen system is measured by two pointer-gauges and electronic pressure transmitter with connection to combined universal handheld measuring instrument ALMEMO 2890-9 with 9 universal inputs and 2 outputs.

Among the important equipments that are incorporated into the system include two mass flow meters used to measure the amount of hydrogen storage with a digital display.

Before the storage tank is included mass flowmeter P1 brands Aalborg, specifically model GFM37 whose working pressure is 70 bar.

For tank it is classified thermal mass flowmeter P2 Voegtlin by brand, model Red-y compact whose operating pressures are from 0.2 to 11 bar. Before this device must therefore be positioned throttle valve, through which you can manually reduce the pressure to the operating speed of the equipment [5].

Both flowmeters can be connected to Almemo and using the software AMR Control measurement data transfer to PC.

MEASURMENT METHODOLOGY

In determining the percentage of hydrogen storage we have to realize a very important thing, not the one that the empty tank is able to store a certain amount of hydrogen. Adsorbent, even with high porosity and storage characteristic, occupies a volume, which in the case of the empty storage tank was used exclusively to store hydrogen. For measurements will therefore determine the relative mass storage percentage. This represents a relative increase of the storage properties of various adsorbents compared with empty tank under the same physical conditions. Thereby we get the exact value and we can assess whether the use of adsorption additives will be useful or not.

PROCEDURE OF MEASUREMENT

Because of this, it is necessary, prior to measurement of the storage properties of the adsorbents to determine the adsorption capacity of the empty tank.

We will follow the following steps:

1. The evacuation system using pumps
2. The opening of the pressure vessel which contains the hydrogen with a purity of 99.9% at a pressure of 20 MPa.
3. Opening pressure reducing valve so that the pressure in the valve does not exceed the value of 70 bar.
4. Open the valve V1 and V2 - start filling the container with hydrogen adsorption and write data from P1 at defined time intervals
5. If the manometer M1 detects pressure 70 bar, it is necessary to close the valve V1
6. The release of hydrogen from the container, thus opening the valve V5 and gradually open the throttle valve, the pressure P 2 upstream from the meter was not higher than 2 bar.

By the last point the hydrogen starts realise from the tank. The data from flow sensors P1 and P2 are recorded during the whole measurement.

After determining the storage capacity of the empty tank, we move on to the next step and that is filled the tank by adsorbent additives. After that it can start measuring the adsorption capacity of the tank using the adsorbent. In this measurement, the procedure will be as above, except that the output of the tank is necessary to incorporate polyurethane foam filter. It is for this reason that when emptying the container with hydrogen, got out and adsorption powder. This filter allows release hydrogen gas, but prevents releasing of adsorption powder.

EVALUATION PROCEDURE

The hydrogen admitted to the storage device will be deducted from the flowmeter P1, which is incorporated prior to the container. The flow of hydrogen released will be recorded from the Mass Flow P2, which is included in the container.

Mass flow rate is a function of:

$$Q_m = f(\tau) \text{ (kg·s}^{-1}\text{)} \quad (1)$$

where Q_m is mass flow (kg·s^{-1}), τ is time (s).

For mass of storage of hydrogen in an empty well (no adsorbent) applies:

$$m_{\mathrm{H_2PN}} = \int_{t_0}^{t_n} Q_{m\mathrm{PN}}\,\mathrm{d}\tau \text{ (kg)} \quad (2)$$

where $m_{\mathrm{H_2PN}}$ is weight of the hydrogen storage without the use of the adsorbent, that is, the empty tank (kg), $Q_{m\mathrm{PN}}$ is the mass flow rate without the use of adsorbent (kg·s^{-1}).

The mass of hydrogen stored in a container using the adsorbent is determined from the relationship:

$$m_{\mathrm{H_2AD}} = \int_{t_0}^{t_n} Q_{m\mathrm{AD}}\,\mathrm{d}\tau \text{ (kg)} \quad (3)$$

where $m_{\mathrm{H_2AD}}$ is the mass of hydrogen storage by using the adsorbent present in the container (kg), $Q_{m\mathrm{AD}}$ the mass flow by reading the flowmeter using the adsorbent (kg·s^{-1}).

To compare the usability of different adsorbents we will consider with a relative weight percentage of storage

$$\psi_{\mathrm{r}} = \frac{m_{\mathrm{H_2AD}} - m_{\mathrm{H_2PN}}}{m_{\mathrm{ad}}} \cdot 100\% \text{ (\%)} \quad (4)$$

where ψ_{r} is relatively mass storage percentage (%), m_{ad} is the mass of the adsorbent (kg) [1].

DISCUSSION

The use of cryogenic temperatures and adsorption agents in the process of hydrogen storage leads to a marked reduction of pressure in storage tank, and therefore, this method is suitable for the storage. The aim of the development of storage materials is reaching the farthest Storage capabilities at the lowest possible weight of the entire device.

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