METAL HYDRIDE UNIT FOR HYDROGEN STORAGE / COMPRESSION

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Introduction

Usage of metal hydrides (MH) allows to make very compact, safe and technologically flexible hydrogen storage units. Also, selectivity of the reversible hydrogen interaction with hydride forming metals and alloys makes it possible to purify hydrogen from gas admixtures in the MH units. Finally, the availability to control output hydrogen pressure by the heat management in the MH bed allows to realise controlled hydrogen supply to a consumer under pre-set pressure, including increased one. All the mentioned processes, storage – purification – compression / controlled supply, can be combined in a single multi-functional unit. This feature is the reason of very high efficiency of similar applications [1,2].

Laboratory # 67 at the Institute for Problems of Materials Science (IPMS), jointly with Hydrogen Storage Group at Department of Energy Systems, Institute for Energy Technology (IFE), has developed a series of the laboratory sources of high-purity hydrogen enabling hydrogen output under controlled higher pressure (up to 200 bar). The sources use MH placed in a pressure container equipped with the internal heat exchanger on the basis of a finned tube [3]. The development is characterised by the fitting both the composition of the MH material and the container's layout into specification of an end-user. The container is made, whatever possible, from the standard component parts.

The present work describes the laboratory MH unit for hydrogen storage and compression which has been developed and tested at IPMS. The unit is intended for the operation with the new setup for the measurement of hydrogen sorption characteristics of nano-carbon materials. The main requirement to the unit is the availability to supply hydrogen into gas system of the installation (total volume, depending on the connected buffer cylinders, varies within 15…500 cm^3) under controlled pressure of 10 to 160 bar. The required H storage capacity (200 litres STP) allows to provide the intensive operation of the setup during 2 to 4 weeks without recharge of the unit.

MH container

The MH container (Fig. 1) is formed by the tubular stainless steel (SS) case (ø70x5 mm, *L*=306 mm) and the end SS flanges, 10 mm in thickness. One of the flanges is a part of the internal heat exchanger made on the basis of the standard finned tube (ø25.4x2.64 mm SS core tube, aluminium fins 58 mm in the external diameter and 0.4 mm in thickness, pitch of 2.3 mm). The internal surface of the core tube is machined to allow the push fit of the standard cartridge-type electric heater (ø20 mm, *L*=290 mm, 800 W in rated power at 220 V supply voltage). The shield for thermocouple measuring the temperature in the intertubular space is installed in the heat exchanger flange as well. The opposite flange carries the sleeve for the loading the MH material and the fitting for gas connection. The latter is united with the standard filter made of the porous SS tube, ø11 mm, *L*=250 mm, filter rate 5 μ.

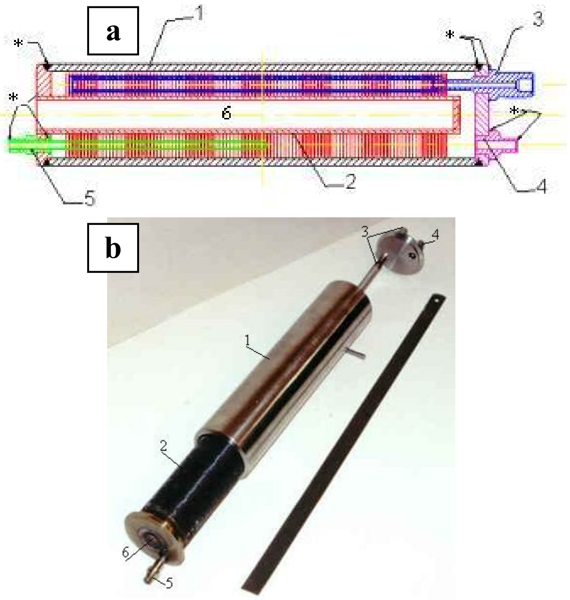

Fig.1. Assembly drawing (a) and the explode view (b) of the MH container: 1 – case, 2 – heat exchanger, 3 – filter with gas input / output fitting, 4 – sleeve for MH loading, 5 – thermocouple shield, 6 – place for electric heater, * – welded joints.

The strength calculations performed according to GOST 14249-89, assuming margin of safety of

1.5 and correction for the strength reduction by welding of 0.8, have shown that the allowed working pressure in the MH container can be as high as 190 bar at T=250°C.

The weight of the assembled empty container was of 5.2 kg.

MH material

The RE(Ni,Fe,Al)$_5$ hydrogen storage alloy made on the basis of the commercial cerium ligature (Ce /70%/ – La – Pr – Nd – Fe – Al), lanthanum and nickel (technical purity grade both) was used in the unit. The composition of the alloy was selected to provide hydrogen equilibrium pressure above the MH of ~10 bar at room temperature. The alloy was melted in an electric arc furnace (weight of an ingot ~100 g) under argon.

The ingots of the alloy were powdered (particle size less than 1 mm) and loaded into the MH container. Afterwards the loading sleeve of the container (item 4 in Fig. 1) was sealed by welding.

The weight of the material loaded into container was of 1.7 kg corresponding to the filling density of 3 g/cm^3.

The material was activated directly in the container, by vacuum heating up to 300 °C during 1 hour and cooling to room temperature followed by the exposition under hydrogen gas at P=50 bar and cyclic heating to 200°C followed by cooling to room temperature. When the last procedure has been repeated three times, the measured reversible H storage capacity of the material (P_{H2}=100…10 bar; T=20…200 °C) has approached to 120 cm^3/g STP (4.61 H/AB$_5$), corresponding to hydrogen storage capacity of the unit of 200 litres STP.

Test results

Fig. 2 presents a typical operation cyclogram of the unit corresponding to the volume of the setup gas collector of ~100 cm^3 and 130 litres STP in the residual H storage capacity of the unit (60% of the maximum one).

The starting hydrogen pressure in the preliminary evacuated hydrogen receiver corresponding to the equilibrium dissociation pressure of the MH at room temperature (13 bar @ 30 °C) is reached in 2…3 minutes. The following heating of the MH container at the maximum rated power supply results in pressure increase up to ~90% of the setpoint (145 bar) in less than 10 minutes. After that the pressure stabilisation mode of the compressor is established. Changing the setpoint by 10…15% results in the transient process, 5 to 6 minutes in duration. The power consumed by the electric heater in the course of the steady-state regime at the maximum setpoint (160 bar) does not exceed 100 W, or 12.5% of the heater's rated power. In so doing, the maximum temperature of the MH is 150 to 160 °C. If the residual H storage capacity of the unit is less than 30 litres STP, the temperature at the same heating power markedly increases without considerable pressure increase: at the residual H capacity of 15 litres STP the temperature approaches 200…250 °C, and the corresponding maximum pressure is as low as 7…10 bar.

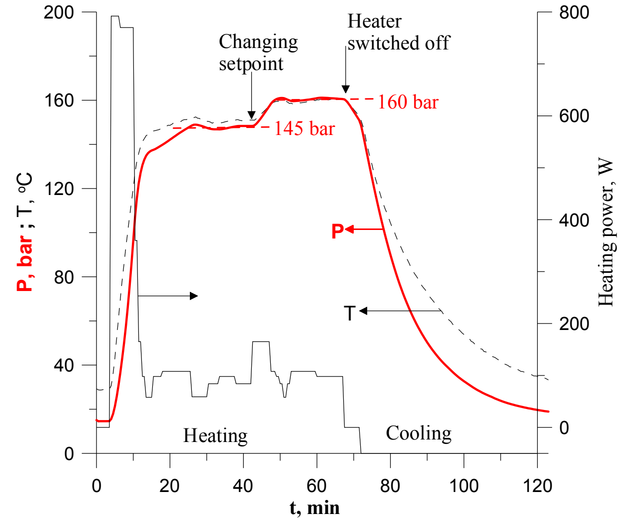

Fig.2. Typical operation cyclogram of the H storage & compression unit.

After switching-off heating and switching on the cooling fan of the MH container, hydrogen pressure drops from 160 to 50 bar in 20 minutes and to the value close to the starting one (15 bar) less than in 1 hour. The equilibration time for the cooling of the container can be reduced to 10…15 minutes by the purging-off therefrom the small amount (up to 10 litres STP) of hydrogen gas.

So, the developed metal hydride unit for hydrogen storage and compression is characterised by high compactness and relatively low temperature of the heating of MH when the high enough hydrogen pressure is generated. The unit has good dynamic characteristics as well.

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