PROCEEDINGS OF THE INTERNATIONAL CONFERENCE
NANOMATERIALS: APPLICATIONS AND PROPERTIES
Vol. **2** No 3, 03AET05(4pp) (2013)

Developing New Solid-state Hydrogen Storage and Purification Reactors

D.V. Blinov*, V.I. Borzenko†, D.O. Dunikov, S.P. Malyshenko

Joint Institute for High Temperatures RAS, 13 Bd. 2, Izhorskaya str., 125412, Moscow, Russia

(Received 19 May 2013; published online 30 August 2013)

New metal hydride hydrogen storage reactors is developed. Automatic diagnostic system capable of measuring the temperature of the porous bed metal hydride, pressure in metal hydride purification reactor, gas flow rate on the inlet and outlet of purification modules, the number of components of the gas mixture with a gas analyzer.

The estimations of hydrogen losses and purification capacity show certain advantages of the studied technology in comparison with PSA-like mode [1], especially from the point of view of operation regime simplification.

Experimental studies on the charge and discharge reactors RHO - 8 and RHO - 8I with pure hydrogen, to obtain data for verification of mathematical models [1, 2], and determine the effect of the configuration beds absorbing materials on the performance of the reactor.

Keywords: Hydrogen, Hydrogen storage, Purification, Metal hydrides, Intermetallide.

PACS numbers: 88.20.fn, 88.30.R

1. INTRODUCTION

Traditional for hydrogen storage (compressed gas and liquid) have numerous disadvantages making their use impossible in some cases [1].

Metal hydride hydrogen storage is free of these disadvantages [4].

For effective treatment of hydrogen by the usy of cyclic reactors [1] is a complicated problem having some disadvantages:

- the need for big (bulky) valve assemblies;
- the need to regulate the process of discharge of impurities from a free volume metal hydride reactors;
- great loss of hydrogen (20%), depending on the required purity of the product [1];
- thermal losses due to cycling heating/cooling of the reactors.

The method presented helps to simplify the technology of hydrogen purification, get rid of the cyclic removal of impurities from the free volume of reactor, thus reducing the amount of valves in the system and thereby reduce the capital cost of metal-hydride storage and purification systems.

2. THE EXPERIMENTAL TECHNIQUE AND THE OBJECT OF INVESTIGATION

2.1 The experimental reactor

In the laboratory of hydrogen energy technologies JIHT RAS has developed a new reactor with improved heat transfer characteristics RHO - 8 and its analogue research RHO - 8I (Fig. 3 and Fig. 4), based on earlier created design solutions. [5] Work reactors implies the vertical position, as in the case of a previously created reactor RHOP - 1 [5].

The reactor RHO – 8I is a vertical cylinder which is placed inside the alloy $LaFe_{0.1}Mn_{0.3}Ni_{4.8}$ (Fig. 1, 2). Gas inlet at the top, output - from below of the reactor. To provide cooling of the reaction chamber of the reactor RHO-8, the inner tube is provided along the axis of the cartridge, providing heat transfer from the reaction zone hydrogen alloy. Presence the temperature sensors allows to get bed alloy temperature during the experiment across reactor length.

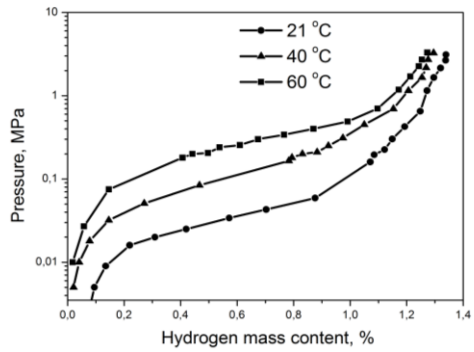

Fig. 1 – P-C-T diagram of the alloy compounds $LaFe_{0.1}Mn_{0.3}Ni_{4.8}$.

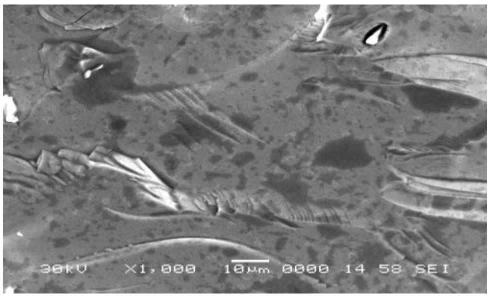

Fig. 2 – Photomicrograph of the alloy compounds $LaFe_{0.1}Mn_{0.3}Ni_{4.8}$

* deltaforces@mail.ru
† h2lab@mail.ru

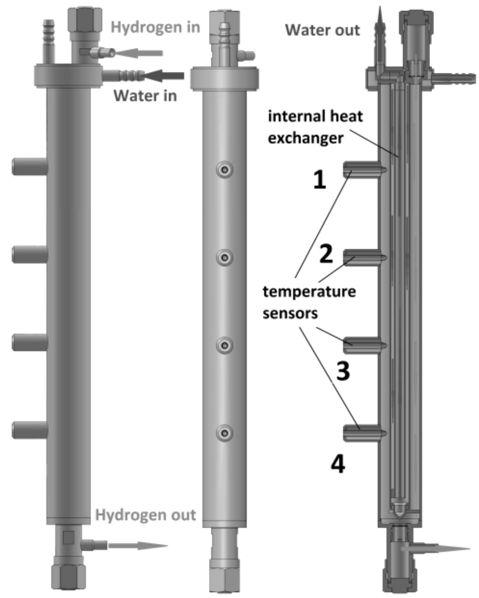

Fig. 3 – Reactor RHO – 8I of hydrogen purification by purging through metal hydride.

Experimental reactor (Fig. 3 and Fig. 4) was charged with 1000 g hydrogen absorbing material $LaFe_{0.1}Mn_{0.3}Ni_{4.8}$. The choice of $LaFe_{0.1}Mn_{0.3}Ni_{4.8}$ alloy is due to comparatively high mass content of in hydride (~ 1,3 mass.%), high desorption pressure (Pdes= 0,45 ÷ 0,60 MPa) in the working temperature interval (80 ÷ 100˚C) and resistance to CO_2 admixtures.

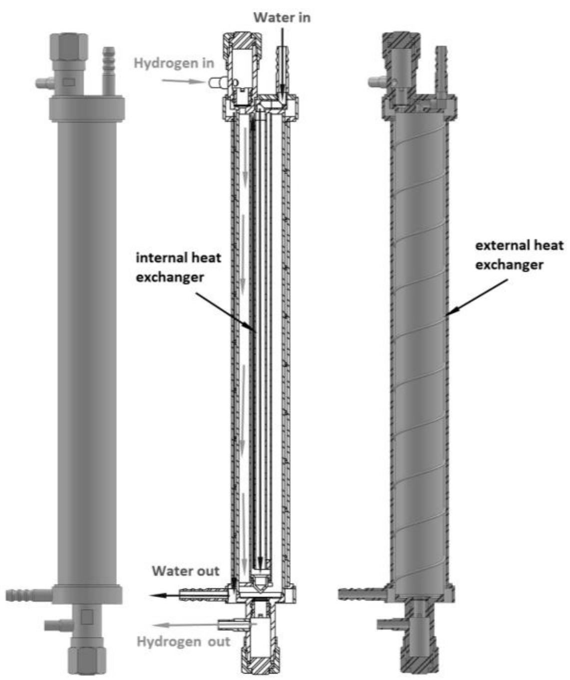

Fig. 4 – Reactor RHO-8 of hydrogen purification by purging through metal hydride.

The reactor RHO -8 is ensured effective liquid cooling not only internal but also external surface of the metal hydride cartridge using the scheme "pipe in pipe" (Fig. 4). The reactor has no temperature sensors inside the reactor.

2.2 The experimental apparatus

Experimental investigations of gaseous hydrogen [1] with a flow-type reactor were carried out at the experimental section (Fig. 5), a complex experimental stand at JIHT RAS, which consists of a ramp for the preparation of the gas mixture (1), of the investigated experimental reactor (2), a vacuum pump (3), the flow analyzer module (4), gas flow controllers (FR), valves (V), reducer (R) and pressure sensors (PS).

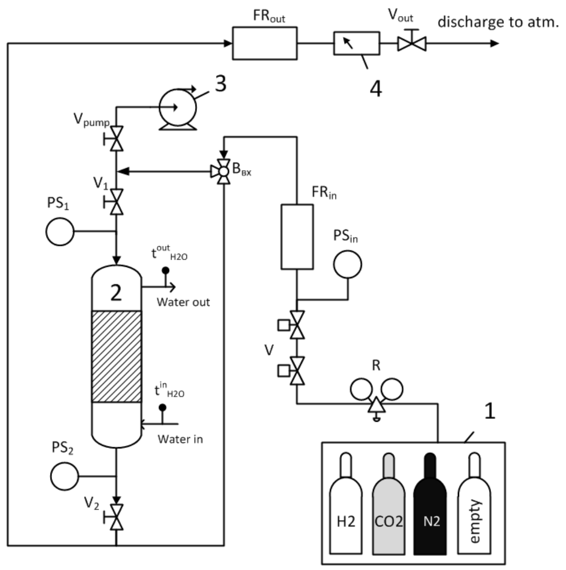

Fig. 5 – Scheme of the experimental section: 1 - ramp for the preparation of the gas mixture, 2 - Experimental Reactor, 3 - vacuum pump, 4 - flow analyzer, R - reducer, PS - pressure gauge, V - valve, FR - regulator of the gas flow rate.

2.3 The experimental technique

Experimental investigation on pure hydrogen charging reactors RHO – 8I and RHO - 8 were carried to activate metal hydride alloys as well as for sorption and temperature dependences of the new reactors.

Charging reactors was carried out as follows. Pure hydrogen was fed through the upper pipe (valve V1 is opened) (P_{in} = 0,5 MPa, see Fig. 6). The flow at the inlet and outlet was limited by flow controller (Fig. 7). Out of the reactor (the valve V2) is closed.

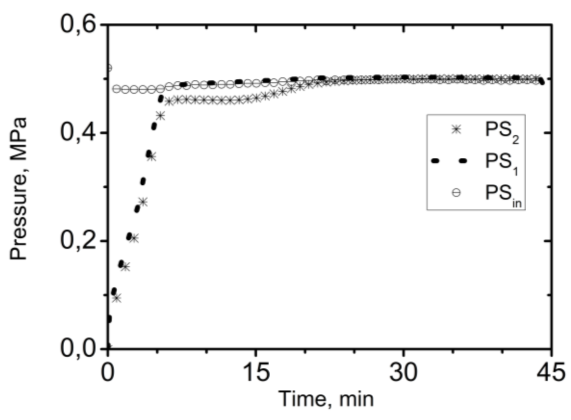

Fig. 6 – The absolute pressure while charging: PS_{in} - input pressure set, PS_1 - pressure before the reactor inlet, PS_2 - pressure at the reactor outlet.

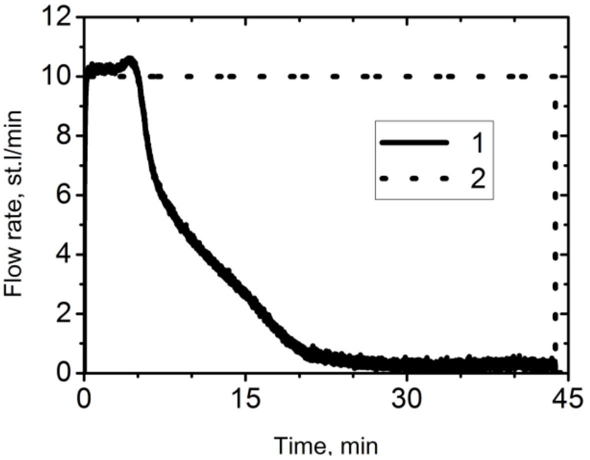

Fig. 7 – Flow rate pure hydrogen at the reactor RHO -8I inlet while charging. 1 – flow rate, 2 – setpoint.

When the maximum capacity (~ 120 st.l.) of a reactor valve V1 is closed. In the experiment, data were obtained by the pressure before and after the reactor and the temperature dependence within the reactor. (Fig. 6 and Fig. 8).

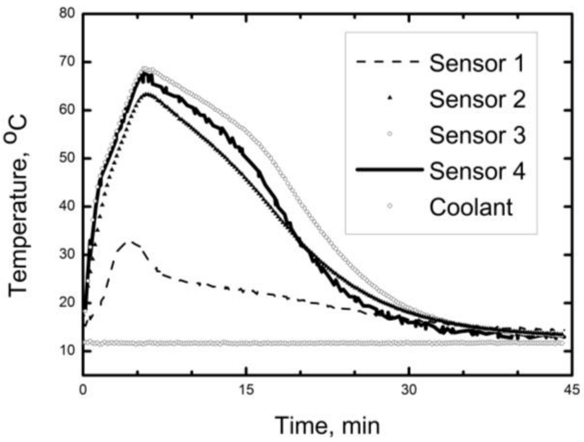

Fig. 8 – The temperature inside the reactor

By analogy with the previous experiment, the reactor RHO – 8 was investigated (Fig. 10 and Fig. 10).

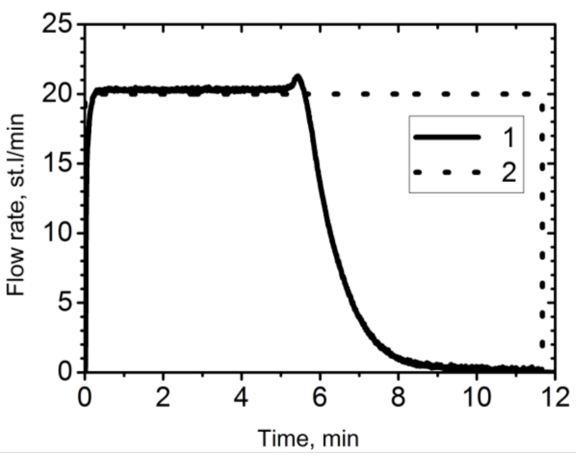

Fig. 9 – Flow rate pure hydrogen at the reactor RHO -8 inlet while charging. 1 – flow rate, 2 – setpoint.

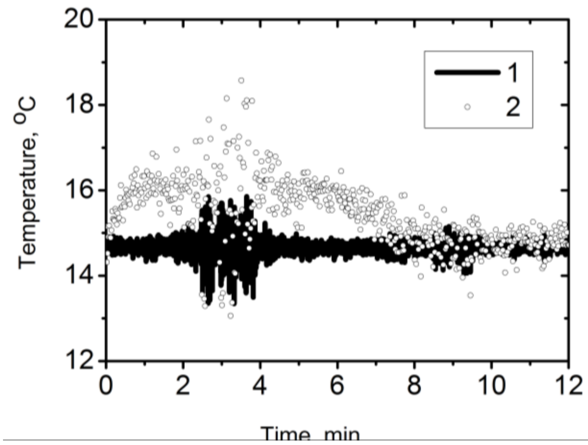

Fig. 10 – Coolant temperature: 1 - water temperature at the reactor inlet, 2 - the water temperature at the reactor outlet.

3. RESULTS AND DISCUSSION

One of the main characteristics of MH devices is the dynamics of hydrogen sorption i.e., the dependence of the hydrogen content (weight or volume) in metal hydrides on time (Fig. 11 and Fig. 12).

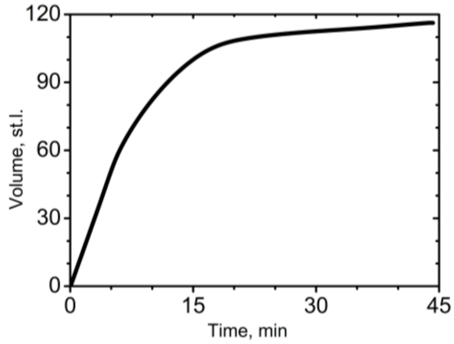

Fig. 11 – Dynamics of hydrogen sorption in the reactor RHO – 8I.

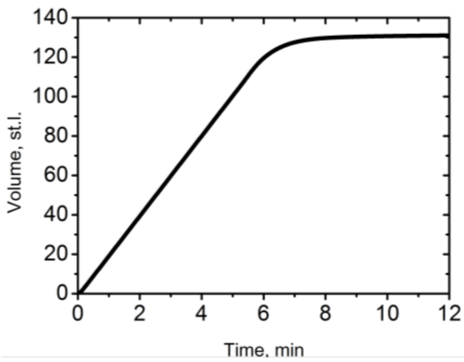

Fig. 12 – Dynamics of hydrogen sorption in the reactor RHO -8.

The data show that the developed reactors RCS and RCS-8I-8 showed greatly higher rates of charge / discharge as compared with the analogues on the market [6, 7].

The obtained characteristics filling dynamics developed reactors (Fig. 11 and Fig. 12) allow the conclusion that the reactor RHO - 8 provide the most efficient cooling of the surface metal hydride cartridge than the reactor RHO-8I.

4. CONCLUSION

1. Reactor optimization on the base of developed 3D heat and mass transfer model was carried out and new types of reactors with enhanced thermal characteristics were created.

2. The developed the new experimental reactors for purging method showed good performance and perspective of the method usage for hydrogen purification by purging through the metal hydride bed.

3. The conducted experimental investigations demonstrated high efficiency of the new reactors, which allows us to recommend this type of reactor to be used in a subsystem of hydrogen storage and purification [4].

AKNOWLEDGEMENTS

Authors are grateful to the Ministry of Education and Science of the Russian Federation for its financial support for research, V.D. Zhemerikin for an assistance in the experimental studies, S.V. Mitrokhin for developing hydrogen storage materials, I.A. Romanov for providing experimental data on the properties of hydrogen storage materials, B.P.Tarasov for providing materials on effects of impurities on the intermetallic alloys.

REFERENCES

1. Artemov V.I., Minko K. B., Yankov G.G. *The numerical modeling of processes heat and mass transfer in systems of solid hydrogen storage* // (National Conference on "Improving the efficiency, reliability and safety of power equipment thermal and nuclear power plants": Abstracts, Publishing House of MPEI, 2012).
2. D.V. Blinov, V.I. Borzenko, D.O. Dunikov. *Balance model of a metal hydride reactor / / Thermal processes in engineering*. (2013) (in press).
3. *Atomic –hydrogen energy and technology*. (Vol.8. Energoatomizdat, 1988), (in Russ).
4. V.I. Borzenko, D.V. Blinov, D.O. Dunikov, S.P. Malyshenko *Reversible Solid State Hydrogen Storage System Integrated with PEM Fuel Cell*. (18th World Hydrogen Energy Conference 2010, CD, Essen, Germany, 2010).
5. V.I. Borzenko**,** D.O. Dunikov, S.P. Malyshenko *Metal hydride hydrogen storage cartridge*. (Patent of Russian Federation number 80702, 2008).
6. D.V. Blinov, V.I. Borzenko, D.O. Dunikov, S.P. Malyshenko H*ydrogen purification by purging method through metal hydride, Vestnik MPEI*, №2, 44 (2012).
7. *Hydrogen energy storage system based on metal-hydride technology for stand-alone power plants that use renewable energy sources: research report (final)*], 176 (2012) (in Russia).