7–200 bar / 60 L/h CONTINUOUSLY OPERATED METAL HYDRIDE HYDROGEN COMPRESSOR

Lototsky M.*, Halldors H.[1], <u>Klochko Ye.</u>, Ren J., Linkov V.

South African Institute for Advanced Materials Chemistry / University of the Western Cape

PO Box X17, Bellville / Cape Town, 7535, South Africa

[1]Varmaraf, Ltd. Keldnaholt 112, Reykjavik, Iceland

**Fax: +27 (021) 9599314 E-mail: mlototskyy@uwc.ac.za*

Introduction

Thermodynamic features of the "hydrogen – metal hydride (MH)" reversible interaction allow for absorbtion of H_2 at low pressure and low temperature and the release of H_2 at high pressure and high temperature. This makes it possible to develop heat-driven MH H_2 compressors which have no moving parts [1–4, etc.]. The key issue in the development is the proper selection of MH materials, to provide specified operation pressures (up to 200 bar that is filling pressure for standard gas cylinders) in the available temperature range (below 150 ^{o}C). Another issue is design of MH containers providing safe, reliable and efficient operation. In addition, the optimisation problems associated with the total compressor's layout and the operational conditions should also be addressed.

This work deals with the development of the experimental prototype of the two-stage continuously-operated MH compressor characterised by suction pressure 7–10 bar, discharge pressure up to 200 bar and productivity up to 60 L/h.

Results and discussion

General layout of the two-stage MH compressor is shown in Fig.1. The "high-temperature" MH material is loaded in the containers forming the first stage of the compressor (input 7–10 bar, output ~50 bar), and containers filled with the "low-temperature" MH material form the second stage (50–200 bar). The MH containers are assembled in two compression elements (I and II) which can be cooled by running water to T_L~20 ^{o}C and electrically heated to T_H~130 ^{o}C. Continuous operation of the compressor is provided by periodic heating and cooling of the compression elements in the opposite phase. In doing so, low-pressure hydrogen (P_L=7–10 bar) is absorbed in the first-stage MH material in the cooled compression element (e.g., I). At the same time, heating of the MH material (compression element II) stimulates hydrogen desorption at P_M~50 bar therefrom followed by its absorption in the MH material located in the second-stage container in the cooled compression element. Finally, heating of the second-stage container causes desorption of high-pressure hydrogen from the MH and its output at P_H=200 bar. Due to rather high pressure differences in gas lines of the compressor, the gas flows are automatically switched with the help of check valves, and only periodic heating / cooling provides sufficient control of the compressor's operation.

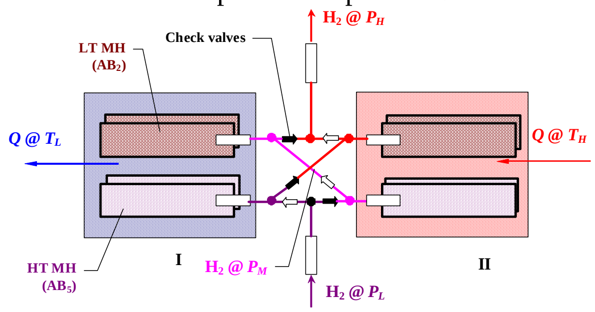

Fig. 1. General layout of the MH compressor.

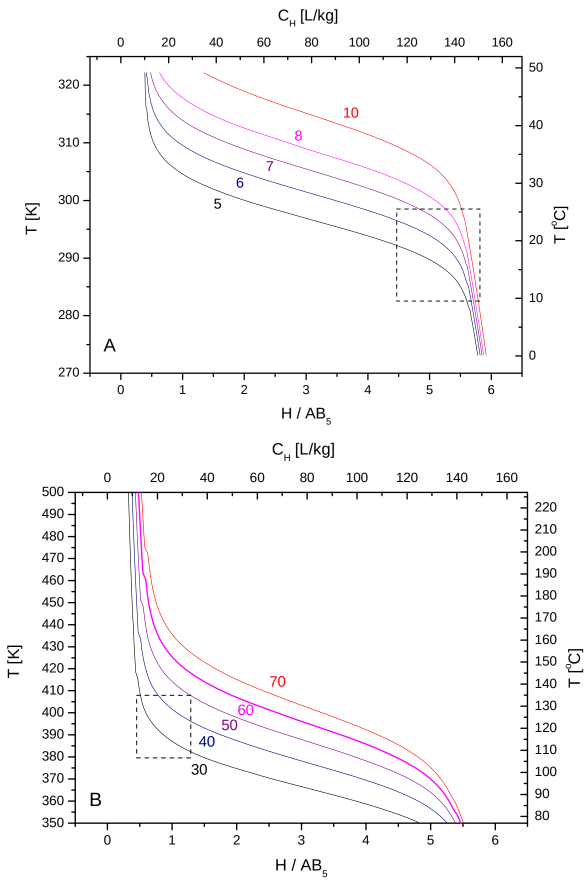

Fig. 2. Calculated hydrogen absorption (A) and desorption (B) isobars for AB_5 H storage alloy. Curve labelling corresponds to hydrogen pressure [bar].

On the basis of thermodynamic analysis of the commercially available hydrogen storage alloys, including experimental PCT measurements for the selected samples followed by data processing using model of phase equilibria in metal – hydrogen systems [5], the MH materials whose thermodynamic characteristics match to the specified $P - T$ ranges for the first and second stages of the MH compressor have been selected.

Fig.2 shows the calculated H_2 sorption isobars for the AB_5 material ((La,Ce)Ni_5) used for the first compression stage. Both absorption (A) and desorption (B) performances are strongly dependent on temperature and H_2 pressure. In the temperature range 10 to 25 ^oC and P_{H2}=5…10 bar (outlined area in Fig.2A) H absorption capacity 100 to 140 L H_2 STP per 1 kg of the alloy is achieved. H_2 desorption in temperature range 100 to 130 ^oC at P_{H2}=30…50 bar results in residual hydrogen concentration in the material 10 to 30 L H_2 / kg (outlined area in Fig.2B). It can be concluded that stable operation of the MH bed can be achieved at H_2 input pressures above 6.5 bar and cooling temperatures below 25 ^oC.

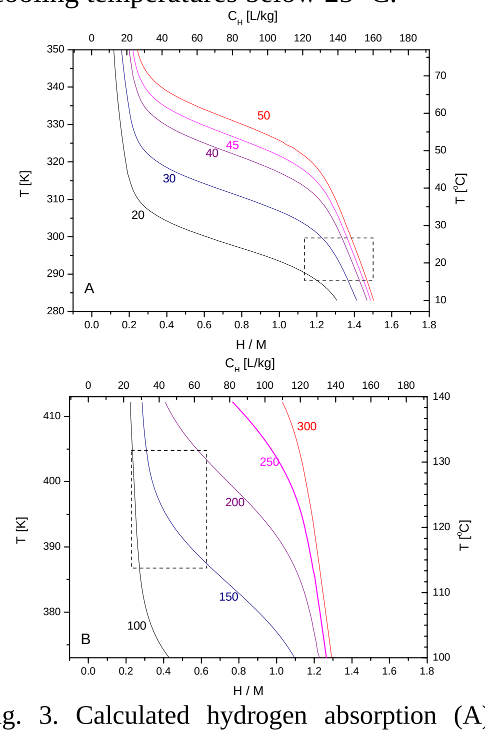

Fig. 3. Calculated hydrogen absorption (A) and desorption (B) isobars for AB_2-type H storage alloy. Curve labelling corresponds to hydrogen pressure [bar].

The calculated isobars of hydrogen absorption (Fig.3A) for the second-stage AB_2-type material (based on (Ti,Zr)(Cr,Fe,Mn)$_2$) show that in the temperature range 15 to 25 ^oC the absorption resulting in the H capacity 120 to 150 L H_2 / kg is achieved at P_{H2} above 30 bar, so that the intermediate pressure from the first compression stage is enough to provide the efficient operation of the MH bed in the suction mode. From the other hand, hydrogen desorption from the MH (Fig.3B) is very sensitive towards output pressure and temperature. In the temperature range 110 to 130^{o}C the residual H capacity varies from 30 (P_{H2}=150 bar) to 60 (P_{H2}=200 bar) L H_2 / kg; and the high-temperature H_2 desorption is the process limiting the output productivity.

General view of the MH compressor assembled according the schematics (Fig.1) is shown in Fig.4. The main component parts are two compression elements made as aluminium blocks carrying SS tubular containers (1/2'' OD) filled with MH materials and equipped with gas filters. Each of the compression elements comprises four MH containers two of which provide for the 1st and other two the 2nd stage of H_2 compression. The 1st stage containers are filled with 160 g of the AB_5-type MH material (H capacity 40 L). The 2nd stage containers comprise 120 g of the AB_2-type MH material (H capacity 36 L).The control block (top) provides periodic heating of the compression elements by powering built-in electric heaters, via temperature controllers synchronised with cooling of the opposite compression elements by opening / closing solenoid valves supplying water flow through cooling channels. The operation (including setting of the cycle time) is provided by a cyclic timer.

Fig. 4. General view of the MH compressor.

During the operation of the compressor, the output productivity corresponding to the rated value (60 L/h) has been achieved at cycle time about 10 minutes. The maximum discharge pressure was as high as 230 bar, at heating temperature of ~110 ^oC. It shows that the selected layout, including the combination of the MH alloys does allow to provide the required performances in the specified temperature range.

Acknowledgement

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