Metal hydride H_2 storage and compression units with low suction pressure

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Development of metal hydride (MH) hydrogen storage and compression systems with the low H_2 suction pressure is necessary for the utilization of H_2 produced using high temperature solid oxide electrolyzers and normally released at the pressure close to the atmospheric one. It also gives an opportunity to utilize the low-pressure hydrogen byproduct from chemical industries including chlorine production.

To achieve a reasonably high H_2 absorption productivity, the pressure driving force, i.e., the difference between the operating pressure (1 atm) and the H_2 equilibrium pressure at the cooling temperature for the used MH, should be as high as possible. At the same time, the MH should provide sufficiently high H_2 discharge pressure (at least, 2–5 atm) when heated up to a reasonable temperature, from 90˚C (provided by solar collectors) to 150˚C (low-grade industrial steam).

The most suitable hydride-forming materials which satisfy these requirements are AB_5-type intermetallics on the basis of $LaNi_5$ where Ni is substituted with elements (Al, Mn, Co, etc.) increasing the thermal stability of the intermetallic hydride as compared to $LaNi_5H_x$. Such intermetallics can be easily activated, and their H sorption characteristics are less sensitive to the impurities in H_2 (first of all, water vapors) than for the Ti based AB and AB_2-type hydrogen storage alloys [1].

This work presents results of activities of the co-authors representing FRC PCP&MC RAS (Russia) and HySA Systems (South Africa) on the development of systems able to absorb low-pressure H_2 and to further desorb it at the higher pressures.

The studies of the Russian team were focused on the $LaNi_{5-x}Al_x$ intermetallics (x=0.2–0.8). It was shown that the optimum for the application alloy composition corresponds to x=0.55 allowing to absorb 1.2 wt.% H at T=20˚C and P≤1 atm already after the first activation cycle (vacuum heating to 90˚C) and to desorb up to 1 wt.% H at P≥2 atm and T=90˚C. Further developed low-pressure hydrogen storage and compression unit (1.2 Nm^3 H_2 in the capacity) comprised of the MH powder loaded in cylindrical containment equipped with the internal and external heat exchangers. 9 kg of the $LaNi_{4.45}Al_{0.55}$ alloy powder was mixed with 1 wt.% of the earlier developed [2] graphene-like material doped by catalytic Ni nanoparticles (Ni/GLM). The use of the Ni/GLM catalyst allows to improve H_2 absorption/desorption kinetics, to increase effective thermal conductivity of the MH bed and to prevent agglomeration of the MH particles [3].

The developed unit providing H_2 absorption at ≤1 atm when cooled to 10–20°C with cold water and H_2 release at a pressure above 2 atm when heated to 70–90°C with hot water was successfully tested in integration with a solid oxide electrolyzer and showed high performance.

Further studies carried out at HySA Systems in South Africa showed feasibility of the use in the target application of a standard AB_5-type battery alloy (A=Mm, B=Ni+Co+Mn+Al). This alloy has hydrogen sorption performance close to the one for $LaNi_{4.45}Al_{0.55}$ and can provide reversible hydrogen storage capacity about 1 wt.%H during the operation at T=15–75˚C and hydrogen pressures from ≤1 to ≥2 atm. 8 kg of the AB_5 alloy powder mixed with 1 wt.% of expanded natural graphite (ENG) was loaded into a standard HySA Systems MH container for hydrogen storage and compression (2.68 dm^3 in the inner volume) also comprising inner and outer heat exchangers.

Results of the tests have shown that the total hydrogen capacity of the MH unit exceeds 1 Nm^3 of which about 0.85 Nm^3 are absorbed at the pressure below 1 atm during cooling of the container with running water at T=16–18˚C. About 80% of the low-pressure hydrogen (0.67 Nm^3) absorbs in 30 minutes with maximum flow rate of 30 NL/min. Further heating of the container by steam (T~120˚C) results in the desorption of hydrogen at higher pressures; in doing so, about 0.65 Nm^3 H_2 is desorbed from the unit at the pressure above 5 bar and flow rate of 10–30 NL/min.

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References

[1] G. Sandrock J. Alloys Compd., 293-295 (1999) 877-888
[2] A.A. Arbuzov, S.A. Mozhzhuhin, A.A. Volodin, P.V. Fursikov, B.P. Tarasov Patent RU 2660232 (2018).
[3] B.P. Tarasov, A.A. Arbuzov, A.A. Volodin, P.V. Fursikov, S.A. Mozhzhuhin, M.V. Lototskyy, V.A. Yartys J. Alloys Compd., 896 (2021) 162881.

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