

SOME QUESTIONS OF HYDRIDE REACTORS DESIGN

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Introduction

Metal hydrides are used in heat engines with the purpose of transformation low-potential (up to 200°C) by thermal energy in potential energy of hydrogen pressure, creation of safe hydrogen accumulators, thermo chemical (sorption) compressors and polluting-free heat devices (refrigerators, hydride heat pumps (HHP), heat transformers). Designs of heat engines on hydrides have an obligatory component - hydride beds or more general metal hydride elements.

There is large quantity of the publications speaking about the determining role of thermal physic characteristics of hydride beds on an overall performance of hydride devices. It is necessary to define their design data correctly.

In article the ideas included in designing of the basic HHP device - a hydride reactor-sorber are covered.

Results and discussion

Obligatory sorber elements are: the case designed as a rule on pressure 0.1-5 MPa; hydride (a covering, tablets, compounds, pressings, etc.); elements improving effective heat conductivity of a composition; elements uniformly collecting and distributing hydrogen (collectors, arteries, porous elements of a tubular design, etc.); filtering elements preventing hit in hydrogen lines of fine-dyspersated metal hydride particles; heat exchanging elements providing heat application/abstraction for realization of hydrogenation reactions (heat exchanging pipes, shirts of cooling, electric heating elements, etc.); stop and regulating armature in a hydrogen line.

Basic sorber element is hydride. To physical and chemical hydride characteristics technical characteristics (a powder, a grit, a compound, a composite) as which it is located in a reactor are added. In case of a powder covering or a grit porosity of non-uniform set on the sizes of irregular-shaped particles is close to irregular stacking and has porosity in range 0.38-0.40 /1/.

In article designing problems of all hydride reactor components are analyzed.

The metal hydride element (bed) represents complex physical object /2/ which is described with the help of the equations of the continuum theory. In it there are three basic types processes:

1) a filtration of hydrogen through a porous matrix of hydride and heat-conducting matrix;

2) a supply and removal of heat from a zone of hydrogenation;

3) a chemical sorption - desorption of hydrogen hydride.

The mathematical model heat and mass transfer in hydride elements can be received, proceeding from laws of conservation of mass, conservation of energy /3/ and the equation of a reaction kinetics of hydrogenation. The model at a number of assumptions will include the following:

1) The equation of continuity (for balance of amount of free hydrogen) with capacity of a source of the hydrogen, determined reaction of a sorption - desorption;

2) The equation of energy, as heat balance in micro volume (heat transfer by heat conductivity, heat evolution due to reaction and a convective heat exchange at a hydrogen filtration);

3) The kinetic equation of reaction.

For many hydrides the kinetics of chemical reactions at rather high temperature (it is more 260 K) is not a limiting stage and the assumption of local balance in each point between the free and connected hydrogen is made. It enables to use equilibrium P - C - T of dependence for hydride. It is supposed that convective heat transfer by hydrogen is small in comparison with heat transfer by heat conductivity. Thus, transfer processes to HHP are defined by processes of heat conductivity and processes of a hydrogen filtration.

In article the physical processes having a place in hydride reactors are analyzed. The complex of measures on improvement of reactor characteristics is considered.

We had been investigated two essentially different circuit designs of hydride reactors -

tubular and modular (monoblock). In work descriptions of these reactors-sorbers are resulted. Sorbers contain powder hydride and a heat-conducting insert. The estimation of effective thermal physic characteristics of a hydride bed (heat conductivity, heat-transfer coefficient) is given. Influence of contact resistance on thermal physic characteristics of a bed is discussed.

Calculated estimations of heat conductivity in hydride beds with various fillers, and also some results experimental definition heat conductivity coefficient of hydride beds for the developed reactors are carried out.

The designed sorbers are used in modelling installations /4, 5/. Activation of an initial alloy was carried out directly in a sorber. One of installations intended for an air conditioning in the car. It had a source of heat with temperature 80-100°C (T_h) and an ambient temperature as average temperature (T_m) /4/. Other installation intended for increase in temperature of water /5/ up to 110-115°C (T_h). It had a source of heat with temperature 80-90°C (T_m - an average level of temperatures) and the heat-carrier at an ambient temperature at the lower level of temperatures (T_l). Installations were one-stage and had on two pairs the hydride modules working in an antiphase. Brief descriptions of installations are resulted and their features are marked.

In article tests of hydride reactors results are stated in consisting of modelling installations. The achieved characteristics and their comparison with results of mathematical modelling /6, 7/ are resulted. Comparison of performance data of modular and tubular sorbers among themselves is carried out. The received results are evidence for the benefit of application of a tubular sorber. The reasons of differences in sorbers operation are analyzed. Data are evidence to difficulties of designing and realization of a modular sorber with good characteristics.

In a modular reactor it was not possible to receive the heat dissipation area comparable to the similar area at a tubular reactor at identical heat rating of reactors. Attempt of the further reduction of the sizes of internal pipes and increases in their quantity in a modular reactor strongly complicates manufacturability of this design.

Conclusions

Designing of hydride reactors is a complex multiplane thermal physic problem. It can be solved at the complex approach to designing with the help of mathematical modelling, technological and experimental optimization of separate units (it is especial characteristics of hydride beds). The general improvement of parameters of HHP can be expected at substantial increase of hydrogen capacity of hydrides.

Reference

1. Aerov M.E., Todes O.M., Narinsky D.A. Devices with a stationary granular bed. - L.: Chemistry, 1979. - 320 p. (In Russian).
2. Izhvanov L. A., Solovey A. I., Frolov V. P., Shanin Yu. I. Metal hydride heat pump-new type of heat converter. - Int. J. Hydrogen Energy, 1996, v.21, No.11/12, pp.1033-1038.
3. Fedorov E.M., Izhvanov L.A., Shanin Yu. I. Simulation of hydride heat pump operation.-Int. J. Hydrogen Energy, 1999, v.24, pp.1027-1032.
4. Astahov B.A., Afanasjev V.A., Bokalo S.Yu., etc. Development of small-sized refrigerating installations based on metal hydride heat pump. - 6th NATO Int. Conf. "Hydrogen Material Science and Chemistry of Metal Hydrides ", ICHMS ' 99. Abstract Book of NATO International Conference. Katsiveli, Yalta, Ukraine, September 02-08, 1999, p.306-307 (in English and Russian).
5. Astahov B.A., Izhvanov L.A., Lysenko A.A., etc. Development of installation based on metal hydride heat pump for heat and cold generation. - in the same place, pp. 360-361 (in English and Russian).
6. Shanin Yu. I. Simulation of hydride heat pump operation with reference to vehicle refrigerating devices. - In: Veziroglu T.N., Zaginaichenko S.Y., Schur D.V., Trefilov V.I. editors/Hydrogen Materials Science and Chemistry of Metal Hydrides. NATO science series. Series II: Mathematics, Physics and Chemistry - Vol. 82, 2002. P.97-106.
7. Shanin Yu.I. Simulation of operation heat or cold-making unit with hydride pump. In: Veziroglu T.N., Zaginaichenko S.Y., Schur D.V., Baranowski B., Shpak A.P., Skorokhod V.V. editors/ Hydrogen Materials Science and Chemistry of Carbon Nanomaterials. NATO science series. Series II: Mathematics, Physics and Chemistry. - Kluwer Academic Publishers. Vol. 172, 2004. P.233-242.