OPTIMIZATION OF HYDRIDE HEAT PUMPS OPERATION

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Introduction

Here the one-stage hydride heat pump (HHP) is discussed with the purpose of optimization some the factors influencing specific output power both important at the estimation operation and power efficiency.

Results and discussion

Thermal energy of HHP depends on thermodynamic, physical and chemical properties of metal hydride, and also from the resulted characteristics of hydride beds in a design a sorber (reactor)-heat exchanger.

At selection of pair metal hydrides it is necessary to be guided by hydrides /1/:

- With the big absorption of hydrogen;
- With high speeds of chemical reactions in the area of working parameters of pressure and temperature;
- With an optimum combination of enthalpies and entropies at hydrides for the chosen levels of temperatures (T_h, T_m, T_l);
- With high stability of an alloy a cycling.

To the analysis from the point of view of HHP optimization are subjected:

- A thermodynamic cycle of HHP;
- Efficiency; input, output powers and losses of energy;
- Structure rules and the characteristic of hydride beds and coverings, properties heat - and mass transfer of a metal hydride bed;
- The agreement of a heat transfer in a sorber and a heat exchanger and between sorbers;
- HHP operation cycle and management of it.

The thermodynamic cycle (ideal and real) HHP is defined static and dynamic characteristics of saturation curves of an alloy by hydrogen (pressure - concentration). Application of the hydrides having the minimal hysteresis and slope saturation plateau, increases amount useful transferable hydrogen between hydrides and expands limits of working temperatures. Real cycle realization always results in decline of its efficiency. The dynamic exchange of hydrogen between sorbers changes saturation curves aside their decline, there is a necessity to provide a mandatory difference of pressure between metal hydrides («driving pressure force»). Overall efficiency of a cycle worsens.

The choice of hydrides should be optimized under a concrete thermal task: the heat pump, a refrigerator, a heat transformer. The techniques of a choice using computer technologies /2/can help with it.

Efficiency of a cycle is related to thermodynamic and thermophysical properties of hydrides and with temperature cycle variables. Efficiency increase ways are:

- Increase in an enthalpy of formation of a low-temperature alloy;
- Design weight decrease;
- Decrease in deviations of working temperatures from an average level of temperature T_m. It results in decreasing of heat losses going on preheating (precooling) of hydrides;
- Application of regeneration for partial useful use of heat (cold) of preparatory cycle stages.

Optimization of a sorbers design and hydride beds on thermophysical and strength properties (σ, ρ, ρC_p, λ) should be carried out.

Use as a sorber of a tubular reactor allows to carry out optimization of its diameter from the point of view of increase in the relation of hydride weight to design weight at change of pressure in a sorber.

For maintenance of competitiveness on weight (and cost) with usual vapor compression refrigerating machines at an identical cold-productivity HHP should have output power on a mass hydride unit of ~1 kW/kg /3/.

Effective specific heat conductivity of a hydride bed plays the basic role in a heat transfer of HHP sorbers. At operation metal hydrides will disperse on fine-grained particles and form a bed of micron size powder. The powder hydride bed tends to self-condensation that hydrogen transfer can considerably reduce. Heat conductivity increase by addition in powders of high heat-conducting materials (copper, aluminium). Introduction of crimps and edges increases effective heat conductivity in one direction and does not solve the problem on increase of local heat conductivity in a hydride bed. Application of metal foams and addition in hydride of metal powders with the further pressing solves a problem of reception of a homogeneous bed. The weight portion of metal has *optimum sizes* and provides necessary effective heat conductivity

(~5…8 W/(m·K)) and gas permeability (~$2 \cdot 10^{-11}$ sm^2) a bed.
Heat exchange between a sorber and a heat exchanger in HHP should be optimized for reception of the maximal heat transfer coefficient. Thus it is necessary to remember, that determining thermal resistance is the hydride bed and requirements to external heat exchangers follow from the achieved characteristics of a bed and are secondary. Intensifications of a heat transfer always are necessary for achieving on the side of a hydride bed since equalization of heat transfer coefficient on the sorber side and a heat exchanger reduces a heat transfer coefficient twice, and essential overflow of heat exchange in external in relation to a hydride bed a heat exchanger does not raise heat transfer coefficient above heat transfer coefficient of a hydride bed.
Characteristics and an overall HHP performance depend on the large number of constructive and operational parameters. In the empirical way to define optimum values of these parameters rather difficultly. Modelling of HHP operation /2,4,5/ allows to investigate influence both design data and regime parameters on efficiency of output characteristics. The most expedient approach here - statement and the decision of corresponding optimization tasks. A basis of such approach is development of corresponding model of the pump and the processes occurring in it. At statement of an optimization task it is necessary to formulate criterion of optimization, i.e. is to define those characteristics which optimum value should be achieved during optimization. So, for the HHP working in a refrigerator mode , it is possible to optimize its cold-productivity or achievable temperature on low-temperature hydride.
In paper the one-dimensional non-stationary model of HHP operation is considered. The modelling equations system includes the non-stationary one-dimensional equations of thermal balance in hydride sorbers taking into account of thermal effects at hydrogen absorption/desorption. In computer calculations experimental data on equilibrium isotherms in systems a metal alloy hydrogen are used. HHP operation both in refrigerating and in heat step-up cycles is investigated. In calculations the time cyclogramme of HHP operation is determined: temperature distribution of constructive elements on radius of a cylindrical hydride bed, the hydrogen contents in sorbers, hydrogen pressure, energy and thermal capacity. The research of influence of the basic regime parameters of the heat pump (charging hydrogen pressure, temperatures and heat-carrier flow rate, cycle time) on its power characteristics and comparison of the computation and experimental results received on modelling installations of HHP is carried out.
There are optimum initial pressure in HHP sorbers, the optimum temperature modes providing maximal efficiency. Management optimization by HHP operation it is possible to reach optimum power characteristics and to choose necessary HHP cycle duration. Management of the hydride heat pump is its essential and as show the carried out calculations /4,5/ essentially influences efficiency of its operation.

Conclusions
Optimization of various parameters and operating modes HHP is possible, but increase of capacity HHP characteristics is connected to improvement of hydrides properties.

References

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