The Prototype of Metal Hydride Hydrogen Compressor with Heat Pump

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Abstract— *The metal hydride materials are characterized by a high pressure gradient as a function of temperature, which has been used in the construction of a compressor that compresses hydrogen by a chemical-thermal cycle. The present paper describes a prototype of a metal hydride compressor working using a heat pump that provides thermal management between metal hydride containers. The principle of the compressor is to use a suitable metal alloy that can absorb and desorbed hydrogen into its intermetallic structure. By heating the alloy, there is a significant increase in pressure, which makes it possible to compress hydrogen without directly contacting the moving parts, thereby increasing process safety.*

***Keywords*— hydrogen, metal hydride alloy, metal hydride compressor, heat pump.**

I. INTRODUCTION

The equipment is the prototype of compressor which it uses for hydrogen compression the chemical-thermal cycles of absorption and desorption of hydrogen into the intermetallic structure of metal. The used conception of hydrogen compressor rests in use, suitable alloy of metal which allows the hydrogen absorption into its structure at low temperature and pressure. Significant pressure increase occurs after heating of alloy what it allows compression of hydrogen without its direct contact with moving parts what it increase the safety of the process. Hydrogen compressor consists of a pair of tandem-connected metal hydride (MH) tanks with heat exchanger. The tanks are heating and cooling alternately while at hydrogen absorption in one of the tank occurs for hydrogen desorption in the second tank. The transport of heat for heating and cooling is secure by heat pump thanks which it occurs to considerable saving of electric energy. Control programme is launched in operating system Raspbian on Raspberry Pi.

II. DETAIL DESCRIBE OF EQUIPMENT

The basic principle of hydrogen compression is its absorption into a suitable metal alloy. Absorption takes place progress at reduced temperature wherein heat is taken from the storage tank by a heat pump. After absorption, it necessary to the alloy heat up to higher temperature resulting in a significant increase in pressure. Subsequently, hydrogen desorption occurs at elevated temperature and greatly increased pressure. After hydrogen desorption at higher pressure is necessary the alloy to cool again and lower the temperature to start value. In order to maintain the continuous operation of the compressor, it has been proposed to tandem the connection of two MH storage tanks between which heats is transported using a heat pump. At the time of absorption in the MH1 tank, hydrogen is desorbed from the MH2 tank. However, when the operating temperature change, neither of the tanks absorbs hydrogen and therefore the compressor is equipped with an intermediate MH tank. This tank has own temperature management which is based on a pair of Peltier cells. Using them it can be used to change the temperature within the required range. The compressor achieves a compression ratio in one degree. A middle value COP of heat pump is 3 which means that for compression is used 1/3 of electrical energy compared to with produced heat energy. This results in a reduction in the electricity consumption of hydrogen compression. The compressor works in one MH tank during one cycle with 0.3 m3 of hydrogen. In Fig. 1 is a view of the finalization of the equipment in the premises of the Faculty of Mechanical Engineering, TU in Košice [1-5].

FIGURE 1: View of the final construction of the metal hydride compressor

Electrically operated hydrogen valves, safety valves and pressure sensors with analog output signal are part of connection of hydrogen circuit. In Fig. 2 is a view of an embodiment of a hydrogen circuit.

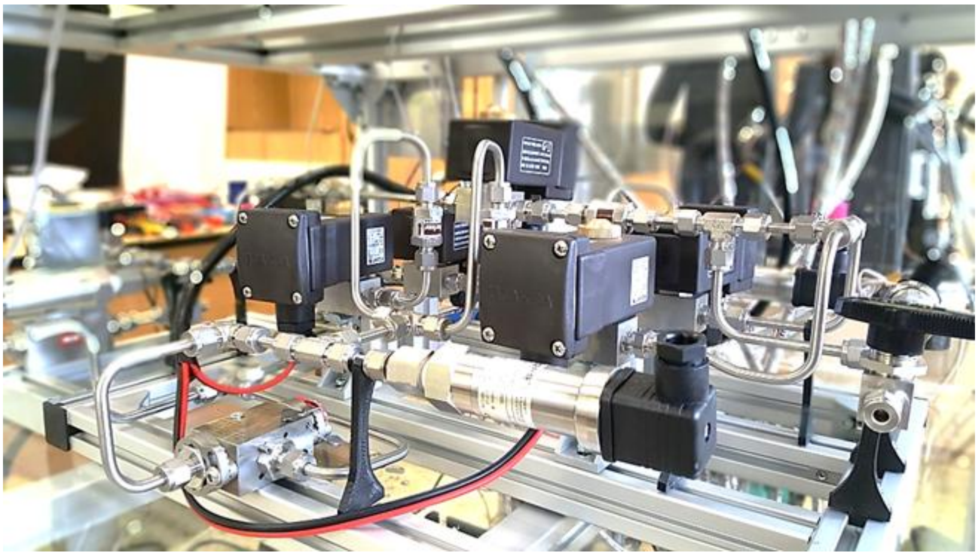

FIGURE 2: Photo of the hydrogen circuit

The role of the hydrogen circuit is to distribute hydrogen and measure its parameters during compressor operation. In Fig. 3 is a view of a tandem pair of MH tanks and intermediate tank with a temperature management.

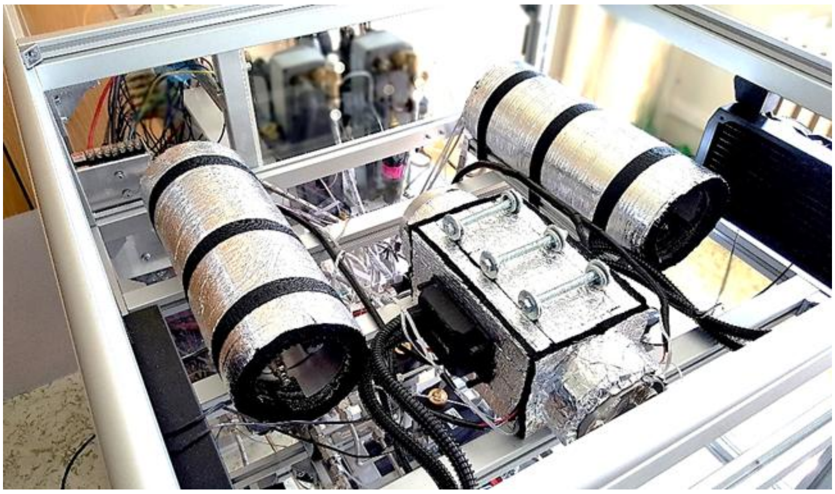

FIGURE 3: View of a tandem pair of MH tanks and an intermediate tank with temperature management

Using the electronically controlled three-way zone valves of the water circuit, it is possible to change the flow direction of the heat transfer medium from the heat pump condenser to the MH1 or MH2. This allows the temperature of both tanks to be cyclically changed. An external air cooler is situated on the condenser side to provide excess heat dissipation that results from greater heat output compared to with cooling.

The heat pump was made-to-measure in cooperation with Tatramat - water heaters, s.r.o. The view of its construction is shown in Fig. 4. In Fig. 5 is a view of a water circuit with valves, pumps and flow meters.

FIGURE 4: Modified heat pumps for MH compressor needs

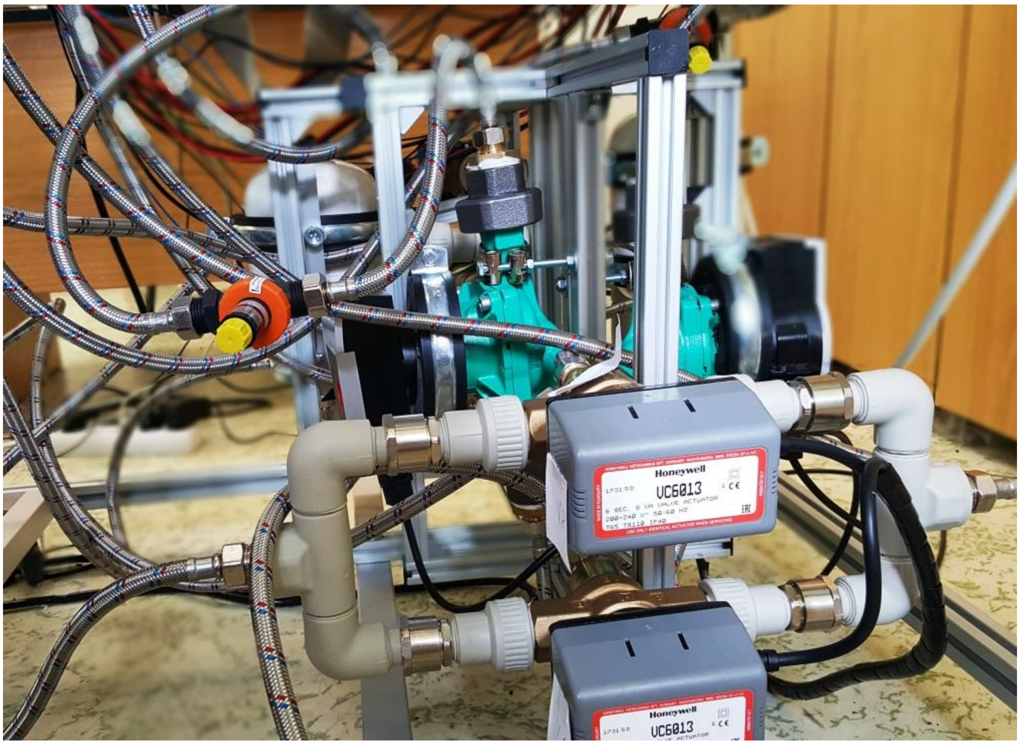

FIGURE 5: View of the water circuit of the MH compressor

The prototype MH compressor with heat pump is created in an autonomous version of the control. For this purpose, a mini-computer Raspberry Pi with additional cards is implemented (1-wire; A/D converter -16 inputs; I/O ports – 32x). The operating system is distributed by the Linux Raspbian. The control software is written in C ++ in the Qt Creator environment. A view of the basic window of the control program is shown in FIG. 9. In FIG. 10 is one of the side windows with a view of the measured parameters of the MH2 tank. The compressor is equipped with touch display for control and visual of measured data. One of the benefits to using minicomputers is that the source code of the controlled program is possible change and compile directly in the compressor and in a real short time. Therefore, measurement and control activities are possible to optimize.

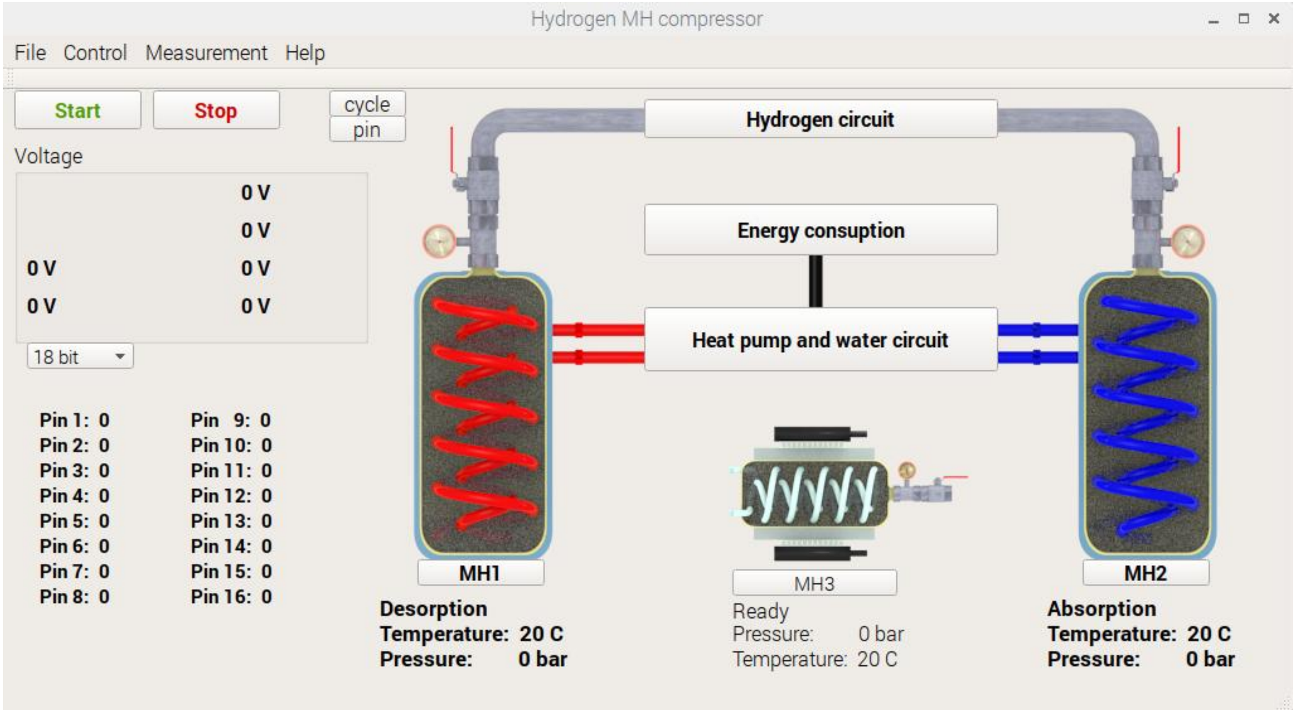

FIGURE 6: View of basic window of control program

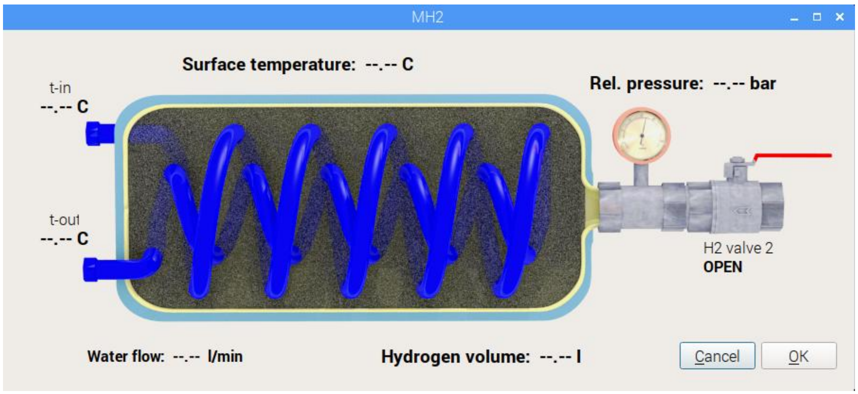

FIGURE 7: Program window monitoring the operation of the MH2 tank

Prototype of compressor was created for next research in area of MH compressors. Therefore, the design solutions as measurement stand. By design is compiled from independent modules for possible fast exchange during optimization of equipment. This allows the effective exchanges and design optimization. In total, 36 temperature sensors are connected to the control PC to monitor the temperature fields of the individual components. The measuring system also includes 7 pressure sensors (5 for H2, 2 for heat pump coolant) and 4 flow meters (1 mass flow meter hydrogen and 3 cooling water flow meter). At the output of the I / O ports are connected 27 relays, which can control all compressor devices (electronic valves, devices, coolers, etc.).

The prototype MH compressor is the first facility of its kind in Central Europe and allows research and development in the field of hydrogen technology. Employees of the Faculty of Mechanical Engineering, domestic and foreign students participate in the development of the facility.

III. CONCLUSION

A conclusion section must be included and should indicate clearly the advantages, limitations, and possible applications of the paper. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

ACKNOWLEDGEMENTS

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