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Preface

We would like to present, with great pleasure, the inaugural volume-11, Issue-7, July 2025, of a scholarly journal, *International Journal of Engineering Research & Science*. This journal is part of the AD Publications series *in the field of Engineering, Mathematics, Physics, Chemistry and science Research Development*, and is devoted to the gamut of Engineering and Science issues, from theoretical aspects to application-dependent studies and the validation of emerging technologies.

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Each article in this issue provides an example of a concrete industrial application or a case study of the presented methodology to amplify the impact of the contribution. We are very thankful to everybody within that community who supported the idea of creating a new Research with IJOER. We are certain that this issue will be followed by many others, reporting new developments in the Engineering and Science field. This issue would not have been possible without the great support of the Reviewer, Editorial Board members and also with our Advisory Board Members, and we would like to express our sincere thanks to all of them. We would also like to express our gratitude to the editorial staff of AD Publications, who supported us at every stage of the project. It is our hope that this fine collection of articles will be a valuable resource for *IJOER* readers and will stimulate further research into the vibrant area of Engineering and Science Research.

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Hydrogen Storage in Magnesium-Based Metal Hydride Alloys and Theoretical Design of a Storage Tank for Magnesium Alloys

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Abstract— *The article addresses the issue of hydrogen storage in magnesium-based metal hydride alloys, the kinetic properties of various magnesium hydrides, and the potential applications of these metal hydride alloys in the transportation sector. The article also includes a theoretical design of an atypical metal hydride storage tank that uses magnesium-based alloys.*

Keywords— Hydrogen, Metalhydride, Magnesium-Based Alloys.

I. INTRODUCTION

Hydrogen is receiving increasing attention both in Europe and around the world. The most important aspect is the fact that the energy recovery of green hydrogen in fuel cells does not produce any emissions into the atmosphere. It therefore represents a possible solution for partially decarbonizing industrial processes and economic sectors.

In the area of transport infrastructure, it is necessary to focus on alternative propulsion fuels and systems that are derived from renewable energy sources. Naturally, these systems will also contribute to the reduction of greenhouse gases. Currently, two technological platforms appear to be long-term fuel sources, namely electromobility and hydrogen-based transport systems. Slovakia has committed to ensuring that more than 20% of vehicles in public administration should be emission-free by 2021. Today, several EU member states, as well as other developed economies—such as the United States and Japan—are testing the possibilities of using hydrogen technologies in both individual and public transport through the implementation and deployment of hydrogen-based vehicle solutions. One of the key challenges is improving the safety of hydrogen fuel storage. At present, hydrogen fuel is stored at extremely high pressures of 35–95 MPa, which poses a safety risk.

Solid-state hydrogen storage materials, primarily metal hydrides, have proven to be promising candidates for storage applications due to their high volumetric density, low operating pressure—ranging from 1 bar to 3 MPa, which is significantly lower than that of high-pressure systems—and, last but not least, their high safety.

II. HYDROGEN STORAGE IN MAGNESIUM-BASED AB2-TYPE METAL HYDRIDES

The most commonly used metal hydride alloys in energy systems are of the AB type, mainly based on TiFe, because these alloys can absorb and desorb hydrogen at room temperature and exhibit high absorption and desorption kinetics. However, the main disadvantage of these alloys is their low storage capacity, which is only around 1.5 wt.% at a temperature of 50°C and a pressure of approximately 3 MPa. This means that a large amount of metal hydride is needed to be competitive with high-pressure systems.

Metal hydrides of the AB_2 group based on magnesium have attracted considerable attention for hydrogen storage due to their significantly higher storage capacity compared to AB-type TiFe-based alloys. For example, the MgH_2 alloy has a storage capacity of up to 7.6 wt.%, which is five times higher than that of AB-type TiFe-based alloys. [1]

Other advantages of magnesium-based metal hydride alloys include high reversibility, abundant availability, and low cost. However, this type of alloy also has its disadvantages, such as high thermodynamic stability—meaning that Mg-based MH alloys absorb and desorb hydrogen at high temperatures, typically from around 414 K. Therefore, they are also referred to as high-temperature metal hydride alloys. Additional drawbacks include slow absorption and desorption kinetics and, for some AB_2-type alloys, limited cycle life.

Extensive research efforts have been dedicated to identifying the fundamental characteristics of these materials and developing strategies to improve hydrogen storage properties. For example, alloying magnesium-based alloys can enhance certain hydrogen storage characteristics. Alloying generally increases the kinetics of hydrogen absorption and desorption, making these processes more efficient and stable.

Alloying can also reduce degradation of the metal hydride alloy, thereby improving its cyclic stability. The control of hydrogen storage properties can be achieved by adjusting the alloy composition, structure, and processing parameters, as well as by selecting suitable alloying elements to meet the specific requirements of a given application. Table 1 provides a detailed comparison of some examples of alloyed magnesium-based metal hydride alloys. 1 [7], [8], [9], [10].

TABLE 1
EXAMPLES OF MAGNESIUM BASED ALLOY AND THEIR PROPERTIES

Type of alloy	Composition of alloy	Hydrogen storage capacity (wt.%)	Desorption temperature (°C)	Adsorption and desorption kinetics
Mg-Ni	Mg_2Ni $Mg_2Ni_{0,7}Mn_{0,3}$	3,6 3,5	250-300 240-290	Medium Relative fast
Mg-Fe	Mg_2FeH_6 Mg-10wt.%Fe	5,5 6,2	320-350 330-360	Slow Relative slow
Mg-Co	Mg_2CoH_5 Mg-5wt.%Ti	4,5 6,8	280-320 300-340	Medium Fast
Mg-Ti	Mg-10wt.%Ti Mg-5wt.%V-5wt.%Ni	6 5,5	250-300 240-280	Fast Very fast
Mg-V	Mg-10wt.%V Mg-5wt.%V-5wt.%Ni	6,5 5,8	200-250 190-240	Very fast Fastest

III. THERMODYNAMIC AND KINETIC PROPERTIES OF MAGNESIUM ALLOYS

The thermodynamic and kinetic properties of magnesium-based alloys play a key role in determining their performance in hydrogen storage. In general, all alloy systems significantly reduce the desorption enthalpy of pure magnesium hydride (MgH_2), which is 74.5 kJ/mol. This corresponds to improved thermodynamics for hydrogen storage and release. Therefore, it is more suitable to use magnesium compounds, rather than pure magnesium alone, for hydrogen storage. For example, alloy systems based on Mg-Nb and Mg-Ti exhibit the most significant thermodynamic improvements [1].

Magnesium has a high theoretical hydrogen storage capacity of up to 7.6 wt.% and forms a binary hydride, magnesium hydride (MgH_2), through a reversible solid–gas reaction [2]. The process of hydrogen absorption/desorption in magnesium involves the dissociation of H_2 molecules into hydrogen atoms, which are subsequently absorbed into the magnesium lattice, forming MgH_2 [2], [6].

The absorption reaction is exothermic, while the desorption reaction is endothermic, as shown in the following equation [1].

$$Mg(s) + H_2(g) \leftrightarrow MgH_2(s),\ \Delta H = -74{,}5\ \text{kJ/mol}\ H_2 \quad (1)$$

The thermodynamic stability of MgH_2 is relatively high, with an enthalpy of formation of −74.5 kJ/mol H_2. This results in a high equilibrium desorption temperature (greater than 300°C at atmospheric pressure). This high thermodynamic stability presents a challenge for the practical use of magnesium-based alloys, as it requires high operating temperatures to release hydrogen [12].

The equilibrium pressure and temperature for hydrogen absorption/desorption are governed by the Van't Hoff equation [2]:

$$\ln(P_eq) = \Delta H / RT - \Delta S / R \quad (2)$$

where: P_eq is the equilibrium hydrogen pressure, ΔH and ΔS are the changes in enthalpy and entropy during the hydride formation reaction, R is the gas constant, T is the absolute temperature.

As shown in Figure 1a, the thermodynamic conditions for hydrogen storage in metals depend on their equilibrium pressure, which is determined by isothermal pressure and composition. According to the Van't Hoff equation, the equilibrium pressure depends on changes in enthalpy and entropy, as illustrated in Figure 1b; in this graph, ΔH/R is the slope of the line and ΔS/R is its y-axis intercept [5].

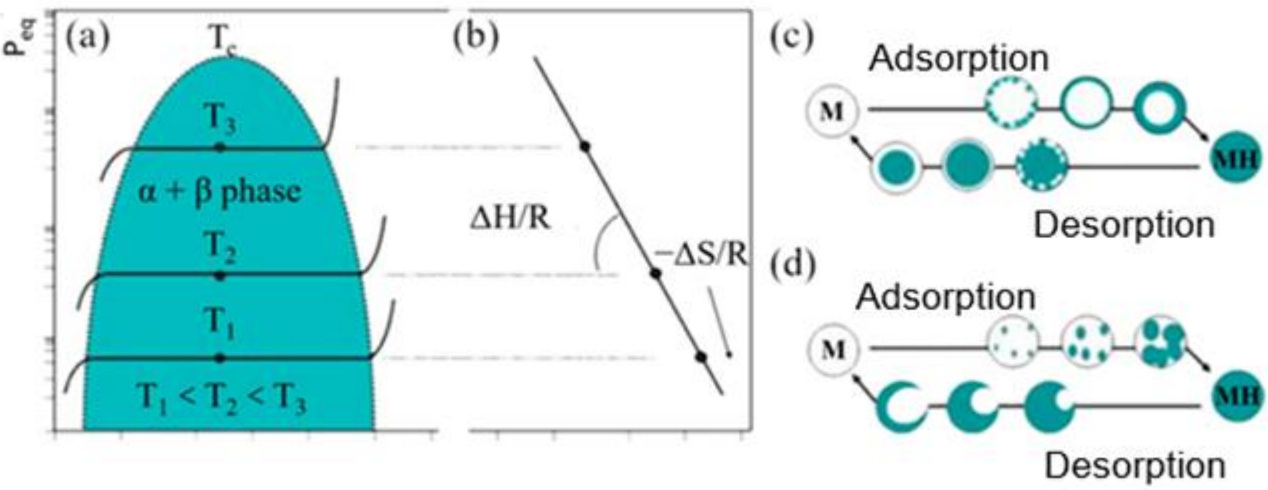

FIGURE 1: Hydrogen storage: a) Pressure–composition isotherm diagram for hydrogen–metal systems, b) Van't Hoff plot for the hydride/dehydride reaction, and schematic diagram of hydrogen absorption/desorption in magnesium: c) at high temperatures and pressures and d) at low temperatures and pressures

In addition to thermodynamic properties, the kinetic properties of magnesium alloys are also crucial for their practical use. The kinetics of hydrogen absorption and desorption in these alloys are often limited by several factors, including the dissociation of hydrogen molecules, the diffusion of hydrogen atoms, and the nucleation and growth of the hydride phase. The slow kinetics of magnesium alloys are attributed to the formation of a passivation layer on the surface of magnesium particles, which hinders the dissociation of hydrogen molecules and the penetration of hydrogen atoms into the bulk material. Moreover, the high stability of MgH_2 results in a high energy barrier for hydrogen desorption, which further limits the kinetics of the dehydrogenation process [3].

For this reason, modification of the metal hydride alloy and the addition of other elements are important to enhance the kinetic properties of magnesium alloys. One example is a magnesium–vanadium-based metal hydride alloy with the composition Mg–10 wt.% V, which exhibits excellent hydrogen absorption and desorption kinetics. Additionally, the hydrogenation and dehydrogenation processes occur at temperatures ranging from 200 to 250 °C, which is lower than that of the MgH_2-based alloy, whose working temperature range is between 300 and 350 °C.

The only drawback of the Mg–V alloy is its lower hydrogen storage capacity, which is around 6.5 wt.%, compared to MgH_2, which has a storage capacity of 7.6 wt.%.

IV. APPLICATIONS OF MAGNESIUM ALLOYS IN THE FIELD OF TRANSPORTATION AND THEORETICAL DESIGN OF A MAGNESIUM ALLOY STORAGE TANK

Magnesium-based hydrogen alloys have proven to be very promising for various applications, including mobile and stationary hydrogen storage, rechargeable batteries, and thermal energy storage. In the field of hydrogen storage, magnesium-based alloys can be used as solid-state hydrogen storage materials for applications such as fuel cell vehicles. The high hydrogen storage capacity, good reversibility, and low cost of these alloys make them attractive candidates for onboard hydrogen storage systems. However, the high desorption temperature and slow kinetics of magnesium-based alloys remain significant challenges for their practical use in hydrogen-powered vehicles [13]. The development of advanced magnesium-based alloys with improved thermodynamic and kinetic properties, as well as the integration of these alloys into efficient and compact hydrogen storage systems, are crucial for their successful implementation in the automotive industry.

However, in order to use magnesium-based metal hydride alloys in the automotive industry, for example, it is essential to design a storage system that utilizes these alloys while also meeting the mechanical strength requirements for operational conditions.

The biggest drawback of storing hydrogen in magnesium alloys is that the absorption and desorption processes occur at high temperatures—typically from 200 °C. The storage tank must be designed to withstand these high temperatures and endure as many cycles as possible under such conditions without material creep. Therefore, investigating the plasticity and creep behaviour of such storage tanks is of great importance.

One way in which the metal hydride alloy could be heated to high temperatures is, for example, that the tank is directly connected to an internal combustion engine and the exhaust gases from the internal combustion engine would heat the metal hydride reservoir. A flue gas pipe passes through the central part of the atypically designed reservoir, which serves to heat the reservoir to the desired temperatures. Fig. 2 shows the structural design of the proposed a typical tank.

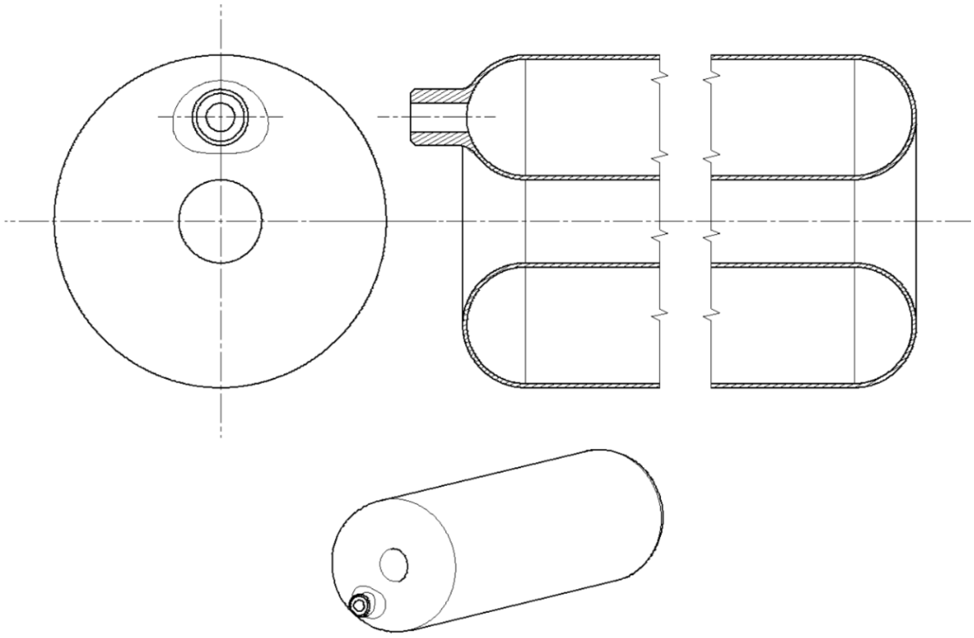

FIGURE 2: Design of an atypical tank for the use of magnesium-based metal hydride alloy

An important task is the choice of the material from which the given tank will be made and at the same time the chosen material must be compatible for hydrogen applications. A major disadvantage of this system is that the higher the operating temperature, the lower the yield strength and tensile strength of the chosen material. Therefore, the tank must be designed so that its strength meets the operating parameters such as pressure which is in the order of 1 MPa to 3 MPa and higher operating temperature of 200 °C. Table 2 shows an example of a compatible steel for hydrogen applications 1.4404-316L, which is determined according to European standards.

TABLE 2
OVERVIEW OF YIELD STRENGTH AND TENSILE STRENGTH OF 1.4404-316L STEEL AT ELEVATED TEMPERATURES

Temperature (°C)	Yield strength Re (MPa)	Ultimate strength Rm (MPa)
20	225	550
100	199	430
200	167	390
300	145	380
400	135	380
500	128	360

The first task after creating a 3D model of the tank is to statically analyse the strength characteristics. When calculating the reservoir, a metal hydride alloy based on Mg – V with a composition of Mg- 10 wt.% is considered, where the maximum temperature of hydrogenation and dehydrogenation occurs at a temperature of 250 °C. The second condition is the working pressure of the reservoir, which is determined at 3 MPa. The material of the reservoir is steel 1.4404-316L. The result of the static simulation of the created model is shown in Fig. 3.

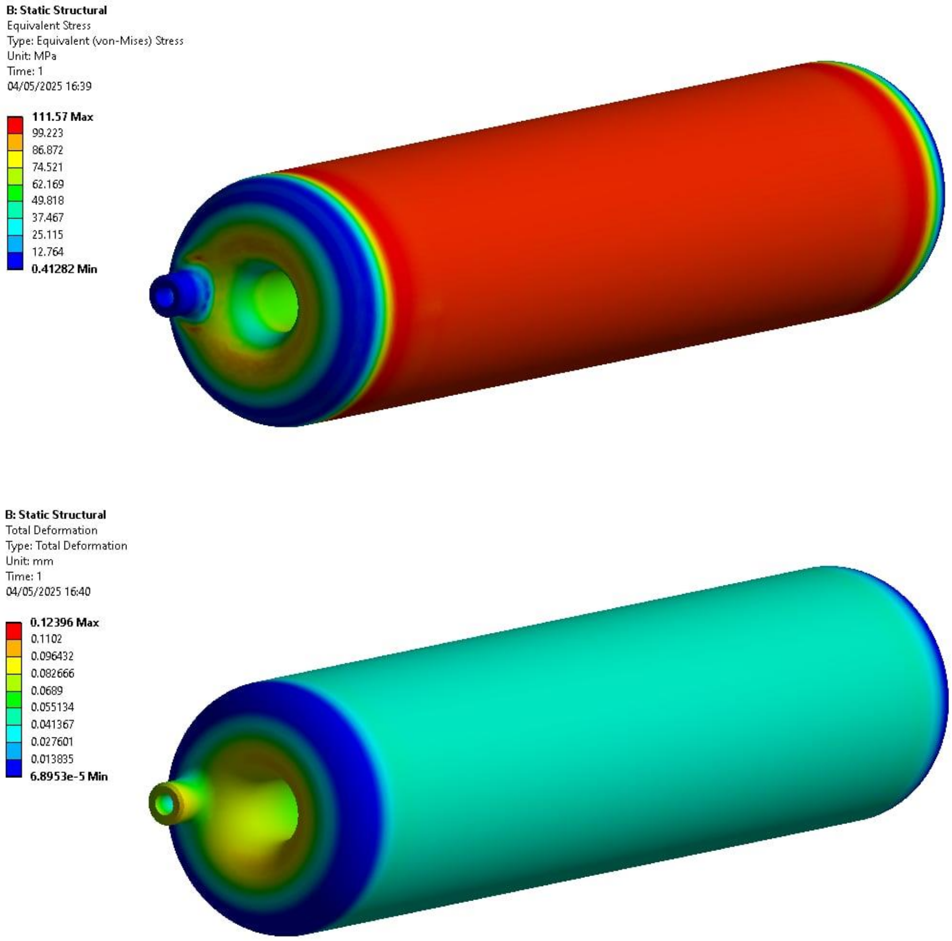

FIGURE 3: Static analysis of an atypical metal hydride reservoir using a Mg - V-based metal hydride alloy

Static analysis of the designed tank showed that the tank meets the operating parameters at an operating pressure of 3 MPa and an operating temperature of 250 °C. Another task for this designed reservoir is to determine whether the reservoir will not flow under cyclic loading.

V. CONCLUSION

This article addresses the issue of hydrogen storage in magnesium-based metal hydride alloys. The advantage of this type of storage is their significantly higher hydrogen storage capacity—reaching values of up to 7.6 wt.%—compared to the most commonly used AB_5-type alloys based on Ti-Fe, which only offer a storage capacity of around 1.5 wt.%.

The biggest drawback of this form of hydrogen storage is that, for example, in the case of the binary magnesium hydride MgH_2, hydrogenation and dehydrogenation occur at very high temperatures, typically from around 300 °C. Therefore, it is necessary to design an efficient system to heat the storage tank to the required operating temperatures.

This article also includes a theoretical design of a metal hydride storage tank that utilizes magnesium-based alloys. The tank consists of two seam-welded tubes. A smaller-diameter tube is placed concentrically inside a larger-diameter tube. The pair of tubes is joined by an atypical bottom so that a flue gas pipe, directly connected to an internal combustion engine, can be routed through the inner tube. The exhaust gases flowing through the pipe will heat the alloy stored in the tank. This heating of the selected magnesium alloy with exhaust gases to the desired temperature is necessary to reach sufficient temperatures for hydrogen absorption into the structure of the magnesium alloy.

Subsequently, a static analysis of the atypical storage tank was performed to assess its strength characteristics at an operating temperature of 250 °C and an operating pressure of 3 MPa. Based on the analysis, it was determined that the tank meets the required operational parameters. The next step in the research will be the analysis of material creep under cyclic loading and the subsequent optimization of structural parameters.

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REFERENCES

[1] Yaohui, X., Zhou, Z, Li, Y., Hao, Y., Wu, P. Magnesium-Based Hydrogen Storage Alloys: Advances, Strategies, and Future Outlook for Clean Energy Applications, Molecules, 2024.

[2] Guo, S.; Yu, Z.; Li, Y.; Fu, Y.; Zhang, Z.; Han, S. Preparation of Mg-Mg2Ni/C composite and its excellent hydrogen storage properties. J. Alloys Compd. 2024, 976, 173035.

[3] Liang, H.; Zhang, H.; Zong, Y.; Xu, H.; Luo, J.; Liu, X.; Xu, J. Studies of Ni-Mg catalyst for stable high efficiency hydrogen storage. J. Alloys Compd. 2022, 905, 164279.

[4] de Rango, P.; Wen, J.; Skryabina, N.; Laversenne, L.; Fruchart, D.; Borges, M. Hydrogen Storage Properties of Mg-Ni Alloys Processed by Fast Forging. Energies 2020, 13, 3509.

[5] Baum, L.; Meyer, M.; Mendoza-Zélis, L. Hydrogen storage properties of the Mg/Fe system. Phys. B Condens. Matter 2007, 389, 189–192.

[6] Andreani, G.D.L.; Miglioli, M.; Triques, M.; Roche, V.; Kiminami, C.; Botta, W.; Jorge, A. Hydrogen storage properties of 2Mg-Fe mixtures processed by hot extrusion at different temperatures. Int. J. Hydrogen Energy 2017, 42, 11493–11500.

[7] Ölmez, R.; Çakmak, G.; Öztürk, T. Combinatorial search for hydrogen storage alloys: Mg–Ni and Mg–Ni–Ti. Int. J. Hydrogen Energy 2010, 35, 11957–11965.

[8] He, Y.; Zhao, Y. Improved hydrogen storage properties of a V decorated Mg nanoblade array. Phys. Chem. Chem. Phys. 2009, 11, 255–258.

[9] Wagemans, R.W.P.; Van Lenthe, J.H.; De Jongh, P.E.; Van Dillen, A.J.; De Jong, K.P. Hydrogen storage in magnesium clusters: Quantum chemical study. J. Am. Chem. Soc. 2005, 127, 16675–16680.

[10] Ding, Z.; Li, Y.; Yang, H.; Lu, Y.; Tan, J.; Li, J.; Li, Q.; Chen, Y.; Shaw, L.L.; Pan, F. Tailoring MgH2 for hydrogen storage through nanoengineering and catalysis. J. Magnes. Alloys 2022, 10, 2946–2967.

[11] Huot, J.; Swainson, I.; Schulz, R. Phase transformation in magnesium hydride induced by ball milling. Eur. J. Control. 2006, 31, 135–144.

[12] Aguey-Zinsou, K.-F.; Ares-Fernández, J.-R. Hydrogen in magnesium: New perspectives toward functional stores. Energy Environ. Sci. 2010, 3, 526–543.

[13] Chong, M.; Karkamkar, A.; Autrey, T.; Orimo, S.I.; Jalisatgi, S.; Jensen, C.M. Reversible dehydrogenation of mag-nesium borohydride to magnesium triborane in the solid state under moderate conditions. Chem. Commun. 2011, 47, 1330–1332.

[14] Neatu, S.; Neatu, F.; Chirica, I.M.; Borbath, I.; Talas, E.; Tompos, A.; Somacescu, S.; Osiceanu, P.; Folgado, M.A.; Chaparro, A.M.; et al. Recent progress in electrocatalysts and electrodes for portable fuel cells. J. Mater. Chem. A 2021, 9, 17065–17128.

[15] Yang, X.; Zhang, J.; Hou, Q.; Guo, X.; Xu, G. Improvement of Mg-Based Hydrogen Storage Materials by Metal Catalysts: Review and Summary. ChemistrySelect 2021, 6, 8809–8829.

Theoretical Design of A Power Generator Powered by Hydrogen and A Fuel Cell

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Abstract— *The article deals with the theoretical design of a power generator using hydrogen combustion as an alternative source of electrical energy. The core of the article includes the design of a power generator utilizing the H-1000 XP fuel cell and MNTZV-60 hydrogen storage tanks. The design incorporates a hydrogen connection diagram, an electrical circuit diagram, a cooling loop, and the construction of a standalone power generator. The article also includes a theoretical analysis and verification of the system's functionality. The result is a power generator design capable of producing electricity in an environmentally friendly manner, with an emphasis on sustainability and the efficient use of alternative fuels.*

Keywords— hydrogen, power generator, metalhydride.

I. INTRODUCTION

Hydrogen is receiving increasing attention both in Europe and worldwide. The most important aspect is the fact that the energy conversion of green hydrogen in fuel cells produces no emissions into the atmosphere. It thus represents a potential solution for partially decarbonizing industrial processes and economic sectors.

In both mobile and stationary infrastructure, it is necessary to focus on alternative propulsion fuels and systems generated from renewable energy sources. Naturally, these systems will also contribute to the reduction of greenhouse gas emissions [1], [2].

Currently, two technological platforms appear to be long-term fuel sources: electromobility and hydrogen-based transport systems. One of the main challenges is increasing the safety of hydrogen fuel storage. At present, hydrogen is stored at extremely high pressures of 35–95 MPa, which poses significant safety risks. Solid-state hydrogen storage materials, primarily metal hydrides, have proven to be promising candidates for storage applications due to their high volumetric density, low operating pressures—ranging from 1 bar to 3 MPa, which is significantly lower than in high-pressure systems—and, last but not least, higher safety [3].

One of the devices in which hydrogen technologies can be implemented is the power generator. The aim of this article is to design a fuel cell-powered generator that uses hydrogen as the primary fuel.

II. DESIGN OF THE HYDROGEN CIRCUIT FOR THE POWER GENERATOR

The design of the hydrogen circuit for the power generator is based on the EC 79 standard, according to which a hydrogen circuit diagram was created, including all the necessary components. Fig. 1 shows designed hydrogen circuit of small power generator:

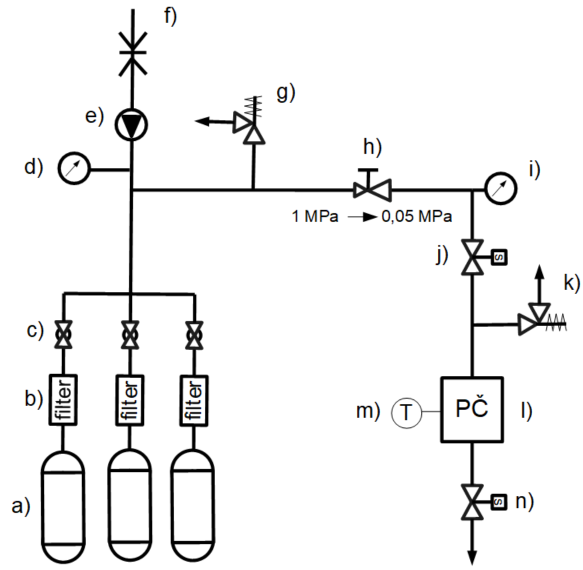

FIGURE 1: Hydrogen Circuit Diagram of the Power Generator

The components used in the network are as follows: a) metal hydride tanks MNTZV-60, b) filter, c) ball valves, d) analog pressure sensor, e) flow sensor, f) refueling nozzle, g) TPRD safety pressure valve, h) pressure regulator, i) analog pressure sensor, j) solenoid valve, k) TPRD safety valve, l) fuel cell, m) temperature sensor, n) solenoid valve.

The hydrogen distribution system consists of two branches: one for transporting hydrogen from the storage tanks to the fuel cell, and the other for refilling the hydrogen storage tanks. The individual components are connected by copper pipes with a diameter of 6 mm.

The branch for refilling hydrogen into the storage tanks consists of a refuelling nozzle that connects to the hydrogen distribution system. A flow sensor is located after the refuelling nozzle to determine the amount of hydrogen flowing into the storage tanks. Following the flowmeter, an analogue pressure sensor is installed for safety reasons and in accordance with standards, allowing the pressure in the system to be monitored.

The branch for transporting hydrogen from the storage tanks to the fuel cell starts with three MNTZV-60 tanks, which contain a metal hydride alloy branded Hydralloy© C5 from the German company GFe.

Each tank is equipped with a filter and a ball valve. The filter captures particles released from the Hydralloy© C5 metal hydride alloy, which exists in the tanks as a fine metallic powder with varying grain sizes. The grain size of the metal hydride alloy ranges from 0.1 to 2 mm, but after several cycles, it reduces to sizes between 100 and 5 microns. Significant particle size reduction occurs already during the initial activation of the alloy, so it is essential to place a filter at the beginning of the system. This prevents the passage of metal particles that could clog or damage valves, or even contaminate the fuel cell.

Behind the ball valve is a TPRD safety pressure valve, which serves a protective function in the distribution system. The TPRD safety valve is designed to activate at a predetermined pressure. If this value is exceeded, the valve opens to release hydrogen into the surroundings, and then closes again. This safety valve is intended to protect the storage section of the distribution system.

A pressure reducing valve is placed after the safety valve. It is essential in the system due to the higher pressure in the storage tanks. The pressure in the tanks is around 3 MPa, and this needs to be reduced to 0.05 MPa, as hydrogen can only be supplied to the fuel cell at such a pressure.

An analogue pressure sensor is located after the pressure-reducing valve. This analogue pressure sensor allows verification that the pressure-reducing valve is functioning correctly—specifically, it is used to monitor the pressure at which hydrogen is entering the fuel cell.

Next in the distribution system is a safety valve and a solenoid valve. Compared to the previously mentioned safety valve, this one has a preset lower pressure value, which corresponds to the pressure at which hydrogen may enter the fuel cell. If this pressure value is exceeded, the solenoid valve closes, thereby protecting the fuel cell.

The final component in this branch is a PEM fuel cell, specifically the Horizon 1000 XP model, which converts the chemical energy of the fuel into electrical energy. The basic parameters of the selected fuel cell are shown in Table 1. The fuel cell includes two temperature sensors: one for the fuel cell itself and one for ambient temperature.

Unreacted hydrogen and the by-product of the chemical reaction—water—are directed from the fuel cell into piping with a solenoid valve, and are then discharged into the surroundings:

TABLE 1
BASIC PARAMETERS OF THE SELECTED FUEL CELL HORIZON 1000 XP

dimensions (mm) (length x width x height)	264 x 203 x 104
Weight (kg)	4,9
Efficiency (%)	59
Hydrogen consumption ($l \cdot min^{-1}$)	12,5
Output voltage (V)	25-48

III. DESIGN OF THE ELECTRICAL CIRCUIT OF THE HYDROGEN POWER GENERATOR

Since the fuel cell generates electrical energy that needs to be delivered to an electrical appliance, it is necessary to design the electrical circuit of the power generator. The schematic of the power generator's electrical circuit is shown in Figure 2.

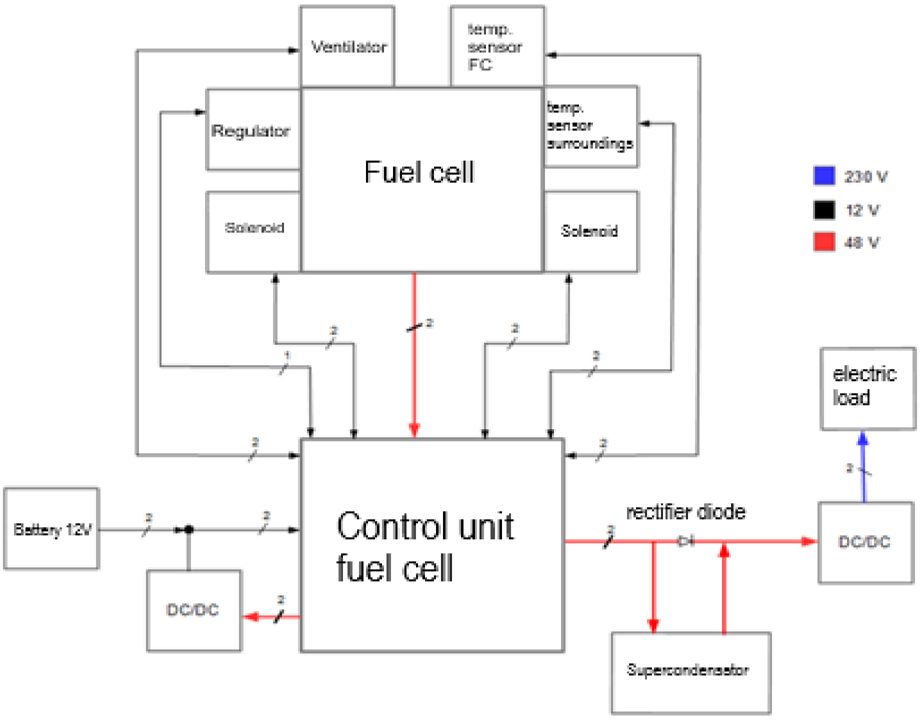

FIGURE 2: Schematic of the Electrical Circuit of the Power Generator

The electrical circuit begins with a starter battery with a voltage of 12 V. The starter battery's purpose is to power on the fuel cell control unit. Using the control unit, the PEM fuel cell H-1000 XP—as designed in Section 5.1—is subsequently activated. The value of the generated voltage and current depends on the output of the fuel cell. The fuel cell produces direct current (DC) voltage in the range of 25–48 V, but the electrical appliances powered by the generator require alternating current (AC) voltage of 230 V. Therefore, a power inverter must be included in the circuit to convert the DC voltage into AC voltage.

The circuit considers the use of the RSI 1KP-F31 inverter, designed by Absopulse Electronics, a company based in Canada. This inverter is used in railway transport vehicles. The parameters of this device meet the requirements for the proposed power generator.

A supercapacitor and a rectifier diode are placed between the control unit and the inverter. The rectifier diode is the simplest type of rectifier, characterized by low resistance in the forward direction and high resistance in the reverse direction. When current flows in the forward direction, there is a voltage drop in the range of 0.6 to 1.2 V. If the electrical appliance consumes all the energy generated by the fuel cell, the diode allows it to pass without restriction. However, if the appliance does not use all the generated energy, the diode redirects the excess to the supercapacitor, where it is stored. At the same time, the diode prevents reverse current flow back into the fuel cell, thus protecting the circuit from damage. In this system, the supercapacitor serves not only as an energy storage device for excess power but can also supply power during a short circuit, which could enable uninterrupted operation of the system without external power.

IV. COOLING SYSTEM DESIGN

The cooling system in a hydrogen power generator is a crucial component for the proper operation of metal hydride storage tanks, because during the absorption of hydrogen into the metal alloy structure, an exothermic reaction occurs, generating heat. This heat reduces the absorption capacity of the metal hydride alloy. Conversely, during desorption, the alloy becomes subcooled, which slows down the hydrogen release process from the metal structure. Therefore, thermal management of the proposed generator must be carefully addressed.

Before designing the cooling system, it is necessary to determine the cooling power that the cooler should be able to provide. The cooling power of the cooler will be determined from the following equation (1).

$$P_{CH} = \frac{Q_{MH}}{\tau_t} \quad \text{(W)} \tag{1}$$

Where Q_{MH} is the heat generated during the storage of hydrogen in the metal hydride, and τ is the time within which the hydrogen should be stored in the tanks. A filling time shorter than 90 minutes is considered. The heat generated during the storage of hydrogen in the metal hydride alloy $Q_{MH0} = 1.01\ MJ \cdot m^{-3}$. Since the hydrogen distribution system contains three tanks, it is necessary to determine the volume of stored hydrogen and the heat generated during storage in these three tanks. The volume of stored hydrogen is calculated using equation (2).

$$V_{H_2} = \frac{m_{H_2}}{\rho_{H_2}} \quad (\text{m}^3) \tag{2}$$

Kde: m_{H2} is the mass of hydrogen stored in the three tanks, amounting to 0.3 kg and ρ_{H2} is the density of hydrogen vapor, which equals 0.0898 $kg \cdot m^{-3}$ at a temperature of 20 °C and pressure of 101,325 Pa. Substituting these values into equation (2) results in a volume of 3.34 m^3. The heat generated during the storage of hydrogen in the metal hydride tanks is calculated using the following equation (3).

$$Q_{MH} = V_{H_2} \cdot Q_{MH0} \quad \text{(J)} \tag{3}$$

By substituting into equation (3), the generated heat in the MNTZV-60 metal hydride tanks is found to be 3.36 MJ, and thus the required cooling power can be determined from equation (1). Substituting into equation (1), the cooling power amounts to 561 W.

For cooling, a heat exchanger Alphacool NexXxoS UT60 with an Alphacool ES 120mm fan will be used, which can provide a cooling capacity of 800 W. These are commonly used for cooling processors and electronic components.

Design of the Structural Layout of the Power Generator

This chapter focuses on the design of the structure itself. When designing the structure, it is necessary to consider the dimensions and weight of all the proposed components. Since some devices have fans, it is important to ensure unobstructed air circulation between the power generator and the surrounding environment.

The structure will consist of a frame welded from aluminum profiles and a galvanized sheet metal panel attached to the frame. The individual components will be gradually mounted onto the galvanized sheet metal. The entire frame will be clad with galvanized sheet metal. Galvanized sheet metal was chosen due to its properties, which include high corrosion resistance and abrasion resistance.

The frame of the power generator is 1000 mm wide, 1000 mm long, and 300 mm high. The frame consists of two different aluminum profiles. The wider profiles are placed at the bottom of the frame because the galvanized sheet metal will be mounted on them, and thus they will bear the greatest load. The profiles have a rectangular cross-section, with a height of 20 mm; the wider profiles are 40 mm wide, and the narrower ones are 20 mm wide. The wall thickness of the profiles is 1 mm.

Since power generators are typically used in remote locations where electrical infrastructure is not available, there is a need to transport the power generator to these sites. Thanks to its compact dimensions, transportation by vehicles should not be a problem. However, situations may arise where it is not possible to transport the power generator to the intended location by vehicle, for example, due to difficult terrain. For this reason, the frame of the structure will be equipped with a simple chassis to facilitate transport under these conditions. The chassis consists of two shafts mounted on radial ball bearings and two pairs of wheels.

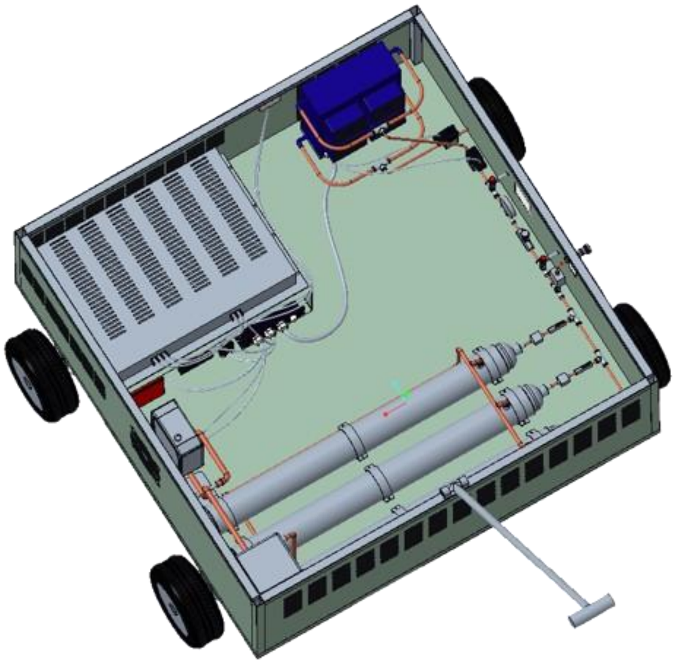

FIGURE 3: Model of the Designed Hydrogen Power Generator

The frame was subsequently strength-verified, with maximum stresses reaching 65.82 MPa, and the highest stress occurring at the point where the tanks are attached to the sheet metal. Plastic deformation will not occur anywhere since the yield strength of the material from which the sheet metal is made is not exceeded.

V. ENERGY BALANCE OF THE HYDROGEN POWER GENERATOR

In this section of the article, the amount of electrical energy produced, and the overall efficiency of the power generator will be determined. The amount of stored chemical energy is calculated using equation (5).

$$E_{chem} = m_{H_2} \cdot Q_{H_2} \tag{5}$$

Where the amount of stored hydrogen in the power generator is 0.3 kg and the combustion heat of hydrogen is 141.9 MJ.

$$E_{chem} = 0{,}3 \cdot 141{,}9 = 42{,}57\ MJ \tag{6}$$

There is 42.57 MJ of chemical energy stored in the tanks. This chemical energy is converted into electrical energy by the fuel cell. The efficiency of the fuel cell is 59%. The amount of electrical energy is defined by equation (7).

$$E_{el} = E_{chem} \cdot \eta_{\ P\check{C}} \tag{7}$$

$$E_{el} = 42{,}57 \cdot 0{,}59 = 25{,}116\ MJ \tag{8}$$

The fuel cell produces 25.116 MJ of electrical energy. Subsequently, the converter transforms direct current into alternating current. The usable energy is given by equation (41), considering the converter's efficiency of 80%.

$$E_v = E_{el} \cdot \eta_{\ M} \tag{9}$$

$$E_v = 25{,}116 \cdot 0{,}8 = 20{,}1\ MJ \tag{10}$$

The power generator outputs 20.1 MJ of electrical energy, which is equivalent to 5583.33 Wh. The overall efficiency of the power generator is determined according to equation (11).

$$\eta_C = \eta_{P\check{C}} \cdot \eta_M \tag{11}$$

$$\eta_C = 0{,}59 \cdot 0{,}8 = 47{,}2\ \% \tag{12}$$

The overall efficiency of the power generator is therefore 47.2%. The maximum power supplied by the power generator is determined using equation (13).

$$P_{max} = \frac{E_v}{\tau_s} \frac{5583{,}33 \cdot 3600}{25\ 100} = 800\ W \tag{13}$$

VI. CONCLUSION

The article discusses the design of a power generator that uses a fuel cell to generate electricity from hydrogen. The selected fuel cell, the Horizon H-1000 XP, was chosen based on its satisfactory technical parameters, particularly its efficiency of up to 59%.

Hydrogen storage is implemented using three MNTZV-60 tanks filled with Hydralloy C5 metal hydride alloy. The system's energy balance confirms that the generator is capable of producing up to 20.1 MJ of electrical energy, with an overall system efficiency of 47.2%. The maximum available output power is 800 W.

The work also includes a structural strength analysis of the frame and the chassis shaft. Simulation results confirmed that the maximum stresses and deformations in various parts of the structure do not exceed the strength limits of the materials used, ensuring sufficient mechanical durability.

The next task involves the actual implementation of the hydrogen power generator in a real-world application.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Anderson, J. Grönkvist, S. Large-scale storage of Hydrogen: Design, Deployment and Operation, strany 167-206, 2018.

[2] Galushkin, N. Yazvinskaya, N. Galushkin, D. A promising energy storage system based on high-capacity metal hydrides: Energies, strany 7871, 2022.

[3] Galushkin, N. Yazvinskaya, N. Galushkin, D. Oxide–nickel electrodes as hydrogen storage units of high-capacity: International Journal of Hydrogen Energy, strany 18962-18965, 2014.

[4] Bolarin, J. Zou, R. Li, Z, Zhang, Z. MXenes for magnesium-based hydrides: Applied Materials Today, 2022.

[5] Lin, H. Lu. S, Zhang, L. Recent advances in metastable alloys for hydrogen storage: a review, Rare Metal, 2022.

[6] Cho, Y. Cho, H, Cho, E. Nanointerface engineering of metal hydrides for advanced hydrogen storage, Chemistry of Materials, strany: 366-385 2023.

[7] Bowman, R. Fultz, B. Metallic hydrides I: hydrogen storage and other gas-phase applications

[8] Bellosta von Colbe, J; Application of hydrides in hydrogen storage and compression: Achievements, outlook and perspectives, International Journal of Hydrogen Energy, strany 7780-7808, 2019.

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