WESC-2026
The World Energy Storage Conference-2026
Agust 09-12, 2026
Istanbul, Türkiye

METAL HYDRIDE STORAGE CONCEPT FOR OFFSHORE WIND-DERIVED HYDROGEN

[1*] *Tugba Akkas Boynuegri* [1] *Ramas Al Qudah,* [1] *Lea Gewandt,* [1]*Marcus Adams,* [1]*David Grant*
[1]University of Nottingham, Faculty of Engineering, RAD Building, Nottingham, UK

*Corresponding author e-mail: tugba.akkasboynuegri@nottingham.ac.uk

ABSTRACT

Recently, significant research attention has been directed towards renewable energy technologies to support the global transition towards net-zero emissions. Within this context, offshore renewable energy combined with hydrogen offers a promising pathway for decarbonising energy-intensive sectors, transport, and industry in the UK. As part of the Hydrogen Research Group, one of our research objectives is to develop an alternative hydrogen storage concept based on metal hydrides (MHs), integrated with a wind-powered electrolyser to facilitate the storage and subsequent distribution of hydrogen. This conceptual work established a metal hydride hydrogen compressor (MHHC) and a metal hydride slurry system as part of the Ocean REFuel project. An AB_2-type modified $TiMn_2$ alloy was prepared, and the operating conditions of the MHHC were determined based on its pressure-composition isotherm (PCI) and the hydrogen outlet pressure of the proton exchange membrane (PEM) electrolyser, which was approximately 30 bar. In addition, an AB_5-type modified $LaNi_5$-based metal hydride was selected for slurry formation to enable the safe handling, storage, and pumping of hydrogen for its distribution.

Keywords: Hydrogen, Metal Hydrides, Storage, Offshore Renewable Energy

INTRODUCTION

Addressing today's growing energy requirements necessitates continued progress in the development of the fundamental elements that support a hydrogen-based energy system. As known, Scotland and some other UK regions have the potential to produce industrial-scale H_2 from onshore and offshore wind. There is no doubt that a crucial factor in the development of large-scale hydrogen storage is the availability of suitable locations for hydrogen production [1]. With in this context, Ocean REFuel project has been working on a system-level concept for converting offshore renewable energy into carbon-free hydrogen and ammonia fuels for transport, power, heat and industry [2].

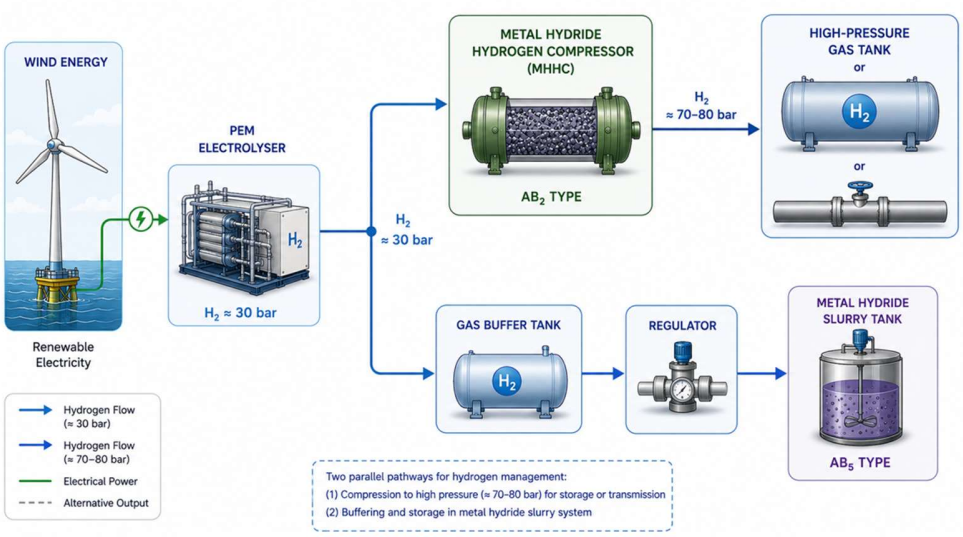


Fig.1 Hydrogen storage and distribution concept

Several hydrogen storage methods are currently available, including compressed and liquefied hydrogen, geological storage in salt caverns, and material-based storage using metal hydrides and ammonia, however long-term hydrogen storage and distribution have not yet been fully addressed in terms of economic viability and technological maturity. Therefore, intensive research specifically focused on metal hydrides is still ongoing.

A metal hydride hydrogen compressor (MHHC) system is a promising option for receiving hydrogen at approximately 30 bar, corresponding to the outlet pressure of the electrolyser. This approach offers the potential to deliver hydrogen to transmission pipelines at approximately 70 bar, which is the desired pressure for pipeline transmission. AB_2-based materials have demonstrated considerable suitability for integration into MHHC prototype systems, although further development is needed to reduce costs and enhance their overall performance. In addition, MHHC is a promising candidate to eliminate the high maintenance requirements associated with conventional mechanical compressors containing moving parts [1]. In addition, metal hydride slurries represent a potentially viable option for hydrogen pipeline transmission. MgH_2, Amonium boroane (AB), AlH_3 and $LaNi_5$ slurries were investigated and among them Lanthanum nickel-based slurries (in ethanol, cyclohexane and silicone oil) coul achieved H_2 capacity below 2 bar [3,4]. However, the use of metal hydride slurries for hydrogen transport through pipelines remains relatively unexplored [5].

To address this research gap, a $TiMn_2$-based material identified in the literature as a promising hydrogen storage material was prepared, and its pressure–composition isotherm (PCI) was obtained to establish the operating conditions for the MHHC design. In addition, a modified lanthanum-based $LaNi_5$-type material, also reported as a promising candidate in the literature, was characterised through PCI measurements to determine the conditions required for slurry preparation. Briefly, the proposed hydrogen storage and distribution concept is illustrated in Fig.1.

MATERIALS AND METHODS

A modified AB_2-type $TiMn_2$ alloy, $Ti_{30}V_{15.8}Mn_{49.4}Zr_{0.5}Cr_{1.1}Fe_{2.9}$, was prepared for the metal MHHC system. In addition, $LaNi_{4.7}Al_{0.3}$ was supplied by LCM for use in the metal hydride slurry system. Pressure-composition isotherm measurements were conducted at various temperatures using a Sieverts-type apparatus, as illustrated in Fig. 1. A slurry containing 5.0 wt% $LaNi_{4.7}Al_{0.3}$ was dispersed in 40 mL of silicone oil was subsequently tested in a reactor system, as shown in Fig. 2.



Fig.1. Sieverts-type apparatus

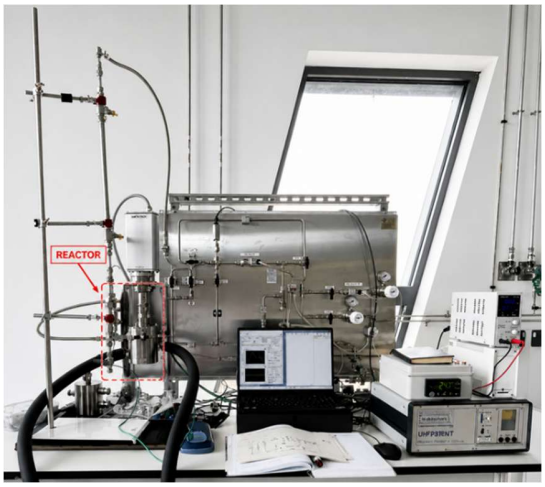


Fig.2. Reactor for slurry test

RESULTS AND DISCUSSION

The PCI graph clearly demonstrates that $Ti_{30}V_{15.8}Mn_{49.4}Zr_{0.5}Cr_{1.1}Fe_{2.9}$ alloy is a proper material for hydrogen storage applications. At 22 °C and a hydrogen pressure of 30 bar, corresponding to the typical operating conditions of a wind-powered electrolyzer, the alloy exhibits a hydrogen storage capacity of approximately 1.2 wt%. When the temperature is decreased below 22 °C, the hydrogen storage capacity increases to approximately 1.6 wt%, indicating enhanced hydrogen absorption at lower temperatures. Conversely, increasing the temperature promotes hydrogen desorption, resulting in higher equilibrium hydrogen pressures. This behavior is advantageous for supplying hydrogen at pressures suitable for pipeline transmission without requiring significant additional compression. Based on this concept, MHHC can be integrated directly downstream of an electrolyzer producing hydrogen at approximately 30 bar. Therefore, the modified $Ti_{30}V_{15.8}Mn_{49.4}Zr_{0.5}Cr_{1.1}Fe_{2.9}$ alloy represents a promising candidate for such integrated hydrogen storage and compression systems.

For the slurry-based system, the PCI graph of $LaNi_{4.7}Al_{0.3}$ indicate that the alloy can absorb up to 1.3 wt% H_2 at 30 °C under a hydrogen pressure of 5 bar. Under these mild operating conditions, the alloy remains in the hydrogenated state, enabling the safe long-term handling of hydrogen in slurry form. The resulting metal hydride slurry can be securely transported through pipelines, providing a safe and efficient medium for hydrogen transmission. Hydrogen can subsequently be released and utilized when required by the end user.

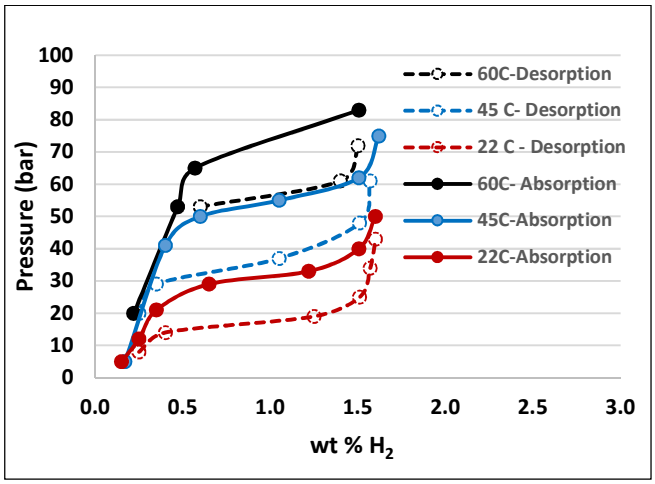


Fig.3. PCI graph of $Ti_{30}V_{15.8}Mn_{49.4}Zr_{0.5}Cr_{1.1}Fe_{2.9}$

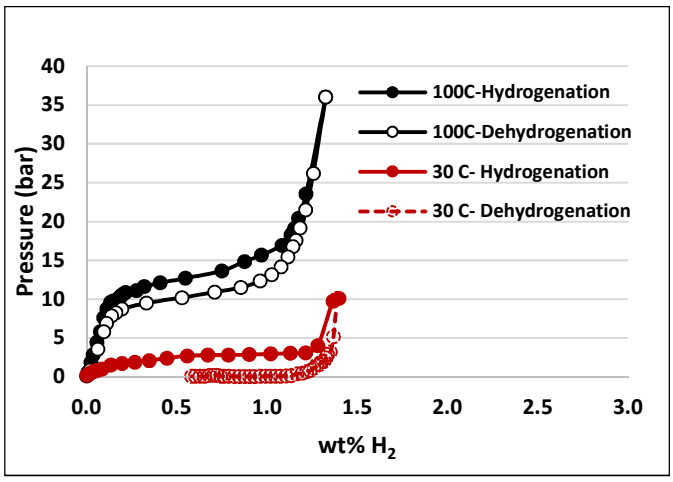


Fig.4. PCI graph of $LaNi_{4.7}Al_{0.3}$

To estimate the required mass of metal hydride for the proposed MHHC system, a preliminary assessment was carried out based on a single-bed, batch-operated configuration. It was assumed that 50% of the hydrogen produced by the electrolyzer is directed to the MHHC, corresponding to a hydrogen flow rate of 1264.7 kg h^{-1}based on Ocean REFuel research project. With a hydrogenation period of 2 h, the bed is required to absorb 2529.4 kg of H_2 per cycle. Considering an effective hydrogen storage capacity of 1.28 wt% (corresponding to 80% of the nominal storage capacity of 1.6 wt%), the theoretical mass of metal hydride required for the single bed is approximately 197.6 t. This value serves as the basis for the subsequent economic assessment of the proposed system summarised at the Table.1.

Table.1 Hydrogen storage parameters of wind-powered electrolyser integrated system

Parameters	MHHC system (**Single-bed,batch-operated**)
Electrolyzer hydrogen production rate	2529.4 kg H_2 h^{-1}
Fraction of hydrogen supplied to the MHHC	50%
Hydrogen flow rate to the MHHC	1264.7 kg H_2 h^{-1}
Hydrogenation temperature	15 °C
Hydrogenation time	2 h
Dehydrogenation temperature	60 °C
Dehydrogenation time	0.5 h
Nominal hydrogen storage capacity of the metal hydride	1.6 wt%
Assumed usable fraction of the nominal capacity	80%
Effective hydrogen storage capacity	1.28 wt%
Hydrogen stored per cycle	2529.4 kg H_2
Required metal hydride inventory, rounded	197.6 t

Based on the estimated metal hydride requirement of 197.6 t, the raw-material cost of the metal hydride for the proposed MHHC system was estimated to be approximately 1.78 million USD based on the data, given at the Table 2. This value represents a preliminary estimate considering only the cost of the alloy constituents derived from representative market prices. The analysis does not include alloy manufacturing and processing costs (e.g., melting, annealing, and activation) and other cost such as reactor fabrication, heat exchangers, thermal management equipment, hydrogen piping and

valves etc. The calculated value will be assessed in detail with whole system mentioned in the Ocean REFuel concept [2].

Table.2 Data for the raw-material cost calculation

Commercial raw material	Commercial Composition	Alloy (mol%)	Alloy (wt%)	Required amount (kg kg^{-1} alloy)	HS code	Representative price (USD kg^{-1})	Cost contribution (USD kg^{-1} alloy)	Price source # (2025 imports)
Titanium	Ti	30.0	27.51	0.2751	810820	12.85	3.535	UN Comtrade)
Ferrovanadium (FeV80)	81.4 mol% V + 18.6 mol% Fe	15.8	15.42	0.1928	720292	19.57	3.773	UN Comtrade
Manganese	Mn	49.4	52.00	0.52	811100	2.05	1.066	UN Comtrade
Zirconium	Zr	0.5	0.87	0.0087	810929	58.49	0.509	UN Comtrade
Chromium	Cr	1.1	1.10	0.0110	811221	11.58	0.127	UN Comtrade)
Total (1 kg alloy)	—	99.7*	100.00	1.0076†	—	—	9.01	—

* The nominal alloy composition reported 99.7 mol% due to rounding.
† The required raw-material mass exceeds 1 kg per kg of alloy because ferrovanadium (FeV80) contains approximately 20 wt% Fe in addition to the vanadium supplied to the alloy.
# Representative unit prices were derived from **2025 UN Comtrade** import statistics using trade-weighted average import unit values. https://comtradeplus.un.org/TradeFlow?utm_source=chatgpt.com

CONCLUSIONS

In this work, promising hydrogen storage materials were selected, prepared, and experimentally characterized to specify the operating conditions required for their integration into the hydrogen storage and distribution section of the proposed concept (Fig. 1). Based on the experimental results, the $Ti_{30}V_{15.8}Mn_{49.4}Zr_{0.5}Cr_{1.1}Fe_{2.9}$ alloy was identified as a appropriate material for the proposed MHHC, enabling direct hydrogen absorption at the electrolyzer outlet pressure of 30 bar. With our assumption of 50% of the electrolyzer hydrogen production is compressed by the MHHC, the required metal hydride mass was calculated as 197.6 t. A preliminary raw-material cost assessment based on 2025 UN Comtrade import statistics yielded an estimated alloy cost of 9.01 USD kg^{-1}, corresponding to approximately 1.78 million USD for the proposed MHHC system. Future work will focus on a comprehensive techno-economic assessment, including complete capital and operating cost analyses together with further optimization of the system combined with conceptual work given in the Ocean REFuel project.

ACKNOWLEDGEMENT

This work was supported by the Engineering and Physical Sciences Research Council (EPSRC), UK Research and Innovation (UKRI) under the Ocean REFuel project. The authors gratefully acknowledge the financial support provided by EPSRC and the valuable contributions of the Ocean REFuel project partners.

REFERENCES

1. Adams MJ., Wadge MD, Sheppard D, Stuart A and Grant DM.2024. Review on onshore and offshore large-scale seasonal hydrogen storage for electricity generation: Focusing on improving compression, storage, and roundtrip efficiency. International Journal of Hydrogen Energy 73: 95-111.

2. https://www.oceanrefuel.ac.uk/research/strawman . Accessed on July 23, 2026.

3. Brooks KP, Semelsberger T, Simmons KL, van Hassel B. 2014. Slurry-based chemical hydrogen storage systems for automotive fuel cell applications. J. Power Sources 268:950-959.

4. Goodell PD, Sandrock GD, Huston EL. Microstructure and hydriding studies of AB/sub 5/hydrogen storage compounds. United States: Final report; 1980.

5. Lamb KE, Webb CJ. 2022. A quantitative review of slurries for hydrogen storage - slush hydrogen, and metal and chemical hydrides in carrier liquids. Journal of Alloys and Compounds 906:164235.

6. Shiva Kumar S, Himabindu V. 2019. Hydrogen production by PEM water electrolysis - a review. Mater Sci Energy Technol 2:442-454.