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# Development of Energy Efficient Solutions for Hydrogen Powered Vessels: RESHIP Project

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**Abstract.** RESHIP project funded under the Horizon Europe programme aims to redefine energy efficiency for using hydrogen for ships with disruptive technologies in Energy Saving Devices (ESDs) and onboard hydrogen system for a seamless transition towards zero-emission. The project focuses on two key technologies, the Tubercle Assisted Propulsors (TAPs) and the liquid inorganic hydrogen carrier, HydroSil. TAPs technology is based on a novel and generic biomimetic passive flow control mechanism inspired by humpback whales, which have small bumps on their pectoral fins known as leading-edge (LE) tubercles. The research shows an improvement in the propeller efficiency, constrain the cavitation development and reduce the underwater noise level. HydroSil is an innovative patented liquid inorganic hydrogen carrier with a long storage life, stable, non-toxic, non-explosive and non-dangerous. This highly energy-efficient hydrogen carrier makes the solution cost-effective, with up to 40% savings due to the reduction in capital and operational expenditure.

Combining the features of the above two technologies, RESHIP aims to develop a prototype to be trialled at sea using the project target vessel, the Fortuna Crane, owned and operated by O.S. Energy. The project will analyse the results and reflect on the wider applications for sea-going and inland vessels.

**Keywords:** RESHIP · HydroSil · Hydrogen Carrier · Tubercle Assisted Propeller · Energy Saving Devices

## 1 Introduction

Several actions have been taken to reduce Greenhouse gases (GHG), improve the energy efficiency of the ships and meet the requirements of decarbonisation in shipping [1, 2]. The taken actions covered the different ship parts to take benefit of the optimization of each part and achieve the maximum improvement in energy efficiency.


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One of the most essential solutions suggested is fuel selection, as it directly impacts the reduction of exhaust emissions from the prime mover of the ship [3]. Utilised as an alternative fuel, hydrogen offers an appealing resolution for achieving forthcoming objectives set by the International Maritime Organization (IMO), and it is regarded as a feasible contributor within the context of a future vision for environmentally friendly shipping. In addition, hydrogen can be used to generate other types of fuels such as ammonia, providing higher flexibility to generate different types of green fuels [4].

Taking the United Kingdom as an example, the 'balanced pathway' scenario of the Sixth Carbon Budget established by the Climate Change Committee envisions the substantial growth of green or blue hydrogen by 2035, reaching a capacity equivalent to almost one-third of the current power sector. This hydrogen would find applications in areas less suited to electrification, notably within certain segments of industry and shipping [5]. Shortly, hydrogen could play an important role in marine transportation, used alone to produce electricity or in addition to conventional or biofuels in internal combustion engines.

In addition to hydrogen as a promising fuel in marine applications, the significance of energy-saving devices (ESDs) for ships has grown substantially due to the enforcement of rules and regulations that limit the utilisation of fossil fuels and encourage the adoption of zero-emission technology [6].

Therefore, the RESHIP (Redefine energy Efficiency solutions for hydrogen powered SHIPs in maritime and inland transport) project aims to redefine onboard energy-saving solutions with disruptive technologies in ESDs and onboard hydrogen management to propose a hydrogen-compatible solution for a seamless transition of zero-emission marine and inland shipping.

This project aims to enhance energy efficiency performance and address the current challenges for hydrogen usage onboard, including high energy demand, abrupt power spikes, and demanding energy storage requirements.

The project targets two distinct research topics; hydrogen-compatible ESDs and energy-efficient hydrogen onboard utilisation. The combination of both research outcomes will demonstrate a next-generation hydrogen power and propulsion system for zero-emission waterborne transport.

The consortium[1] gathers world-leading multidisciplinary experts with key patent holders from both the shipping and hydrogen sectors, forging a complementary stakeholder group. The implementation of the developed technologies will be validated at technical, environmental, cost economic, safety and regulatory levels to propose tailored solutions for newbuilds and retrofits in marine and inland waterways.

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## 2 Energy Saving Devices and Tubercle Assistant Propulsors Technology

As required by the vessels' operation profile and the capability needed to handle manoeuvring and high sea states, the propulsion loads vary significantly between particular situations, which also causes significant power fluctuation leading to damages to fuel cells and hydrogen supply systems. ESDs improving propeller flow conditions and reducing vessel motions help reduce shaft power fluctuation and are favored for hydrogen-powered vessels [6].

RESHIP aims to develop hydrogen-preferred ESDs with a minimum of 10% energy saving in a single application and 20% in combination. The project develops technology around Tubercle Assistant Propulsors (TAP), which offers a wide application for marine and inland vessels with energy saving, cavitation limitation and noise mitigation features; meanwhile, it also offers smoother shaft power delivery due to mitigated sudden stall and constrained cavitation development [7].

TAPs technology, as shown in Fig. 1, is based on a novel and generic biomimetic passive flow control mechanism inspired by humpback whales. They have small bumps on their pectoral fins, known as leading-edge (LE) tubercles, which aid in their ability to perform acrobatic manoeuvres to catch prey. The concept is initially believed to be able to control flow separation due to energised flow being more attached to the surface. Recently, through detailed aerodynamics, aeroacoustics and hydrodynamics studies, this concept has shown further capabilities in improving the aero/hydrodynamic performance of various applications, constraining cavitation development and mitigating noise. Researchers at UoS and UNEW have investigated the application in-depth on marine propulsors, driving the initial design, optimisation and analysis phase and developing the concept on both duct and propeller applications [6–9]. Their work provides valuable input for the design of future marine vessels and retrofit solutions for existing builds, where improving energy efficiency and reducing ship fuel consumption and carbon emissions are major concerns.

## 3 Hydrosil and Efficient Hydrogen Carrier

The big challenge that currently hinders the deployment of hydrogen as a real solution for carbon-free, efficient mobility is how to transport and store it in a safe and economic way. The ideal solution for mass delivery has to (1) be a liquid, to take advantage of the existing fossil fuel infrastructures, (2) be non-dangerous and stable to be easily and safely handled, (3) contain high hydrogen density and (4) be cost competitive. Hydrosil is an inorganic liquid hydrogen carrier developed by HSL technologies (formerly Hysilabs) [10]. It shows a hydrogen gravimetric content of 8.7% with a density ratio of around 1.15 and it can store 100 kg $H_2/m^3$.

To release hydrogen, Hydrosil is mixed with water in the presence of catalysts. The reaction is instantaneous, complete and exothermic, without any energy input. A silicate by-product is formed, which corresponds to twice the initial volume of Hydrosil. This by-product is stored, unloaded at the port and recycled into Hydrosil. The storage space and weight of the by-product are taken into account during the calculations.

(a) (b)

**Fig. 1.** (a) Humpback Whales "Source: https://www.pexels.com/photo/blue-whale-swimming-under-water-4781925/" and (b) leading-edge tubercle applications on marine propellers [9] "Source: Figure produced using OpenProp, an open source software".

"State-of-the-art hydrogen vessel" is hard to identify since no large scale hydrogen powered vessel has yet been put in service. However, compressed gas ($GH_2$) is currently the most advanced technology being considered for $H_2$ usage onboard ships [11]. It has been prototyped on small scale boats [12] and is considered for middle size applications. For this study, the standard $GH_2$ pressure considered is 350 bars as well as 590 bars as another alternative.

The need for stored energy is calculated taking into account the power of auxiliary generator sets (gensets), main engines, and, finally both, working 24/7 at 100% load for 30 days (maximum endurance of the boat). The corresponding energy amounts respectively to 540, 1,166 and 1,706 MWh. To meet such energy needs, the corresponding storage volumes and weights should be installed.

Based on the data provided, the solution based on Hydrosil would reduce the need for storage space to 25% compared to the use of $GH_2$ at 350 bars, while an increase in weight is detected by 20%. Compared to $GH_2$ at 590 bars, the solution based on Hydrosil would reduce the need for storage space to 38%, also the weight will be reduced by 20%.

Hydrosil thus represents an opportunity to drastically limit the storage space and, to a lower extent, the storage weight in comparison with compressed hydrogen. However, even with Hydrosil, the storage volume and weight exceeds the boat's capacity. To accommodate a shift to hydrogen-based energy, the autonomy of the boat would have to be reduced.

Assuming the storage volume could be extended to 600 $m^3$ by adding storage units on the deck, a total of 317,000 kWh could be stored onboard with Hydrosil, corresponding to 460 t onboard, to be compared to the current 420 $m^3$ (359 t) of marine gas oil (MGO). This would also mean the boat would have to be refueled 5.4 times more often than with MGO, or that autonomy would be limited to 5.5 days. These figures would be enhanced further with an optimised realistic usage profile of the boat.

## 4 Plan Demonstration

The suggested solutions in this project will be tested on the target vessel, the Fortuna Crane, one of the service vessels operated by O.S. Energy [13]. The energy efficiency measures proposed by RESHIP are based on two fundamental principles, ESDs, which are mainly based on ship propulsion hydrodynamics and hydrogen focused around a novel hydrogen carrier and its utilisation. Based on the two technologies, RESHIP will focus on demonstrating:

1. Proof of gains in vessel energy performance and operational efficiency through TAPs technology as well as the limitation of torque fluctuation. A comparative sea trials with live torque measurements will be presented before and after the retrofitting procedure. The amount of fuel consumption and loading conditions will be compared to achieve the exact improvement from the retrofit procedures.
2. The feasibility of an HydroSil-powered 50 kW genset, operating it at sea for 6 h as well as the gain in storage space and/or weight. The results will be based on operating the genset during a dedicated sea trial.

Furthermore, wider applications of the combination of TAPs and HydroSil will be studied to identify the most relevant use cases in maritime transport and/or inland navigation.

## 5 Conclusion

The technologies proposed in RESHIP are novel concepts and need further recognition. RESHIP will provide a concrete demonstration of their potential and provide a set of relevant use cases. Once mature, large-scale application of the solutions proposed in RESHIP would lead to:

1. A safe, clean, low-cost global ocean transportation. The development of the international shipping industry will accelerate the transfer and trading of goods between continents.
2. Enhance the energy utilisation efficiency of the renewable energy industry. The widely used hydrogen fuel will encourage the energy industry to produce hydrogen from the excess power from renewable energy devices as energy storage solutions. The low-cost hydrogen fuel will further promote the application of hydrogen energy.
3. Eliminate the GHG emissions in the ship industry and reduce the carbon footprint of human activities on the ocean.

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## References


1. Tadros, M., Ventura, M., Guedes Soares, C.: Review of current regulations, available technologies, and future trends in the green shipping industry. Ocean Eng. **280**, 114670 (2023)
2. Tadros, M., Ventura, M., Guedes Soares, C.: Review of the decision support methods used in optimizing ship hulls towards improving energy efficiency. J. Marine Sci. Eng. **11**(4), 835 (2023)
3. Tadros, M., Ventura, M., Guedes Soares, C.: Review of the IMO initiatives for ship energy efficiency and their implications. J. Mar. Sci. Appl. **22**(4), 662–80 (2023)
4. Karatuğ, Ç., Ejder, E., Tadros, M., Arslanoğlu, Y.: Environmental and economic evaluation of dual-fuel engine investment of a container ship. J. Mar. Sci. Appl. **22**(4), 823–36 (2023)
5. The Royal Society, The role of hydrogen and ammonia in meeting the net zero challenge. https://royalsociety.org/topics-policy/projects/climate-change-science-solutions/. Accessed 15 Aug 2023
6. Stark, C., Xu, Y., Zhang, M., Yuan, Z., Tao, L., Shi, W.: Study on applicability of energy-saving devices to hydrogen fuel cell-powered ships. J. Mar. Sci. Eng. **10**(3), 388 (2022)
7. Stark, C., Shi, W., Atlar, M.: A numerical investigation into the influence of bio-inspired leading-edge tubercles on the hydrodynamic performance of a benchmark ducted propeller. Ocean Eng. **237**, 109593 (2021)
8. Stark, C., Shi, W.: The influence of leading-edge tubercles on the sheet cavitation development of a benchmark marine propeller. In: 40th International Conference on Ocean, Offshore and Arctic Engineering (OMAE2021), pp. 1–8. Virtual Conference, Online. ASME (2021)
9. Stark, C., Shi, W., Troll, M.: Cavitation funnel effect: bio-inspired leading-edge tubercle application on ducted marine propeller blades. Appl. Ocean Res. **116**, 102864 (2021)
10. HSL Technologies, Hydrogen Stored as Liquids. https://www.hsl.tech/. Accessed 20 Sept 2023
11. HySeasIII. https://www.hyseas3.eu/. Accessed 20 Sept 2023
12. HYNOVA 40. https://www.hynova-yachts.fr/hynova-40/the-new-era/. Accessed 20 Sept 2023
13. O.S. Energy, Marine Power Solutions. https://www.os-energy.de/. Accessed 20 May 2023