The Orcelle Project – Towards Wind-Powered Ships for Deep Sea Cargo Transport

Apostolos Papanikolaou[1], Sofia Werner[2], Mikael Razola[3], Carl Fagergren[4], Lars Dessen[5], Jakob Kuttenkeuler[6], Vendela Santén[2] and Christoph Steinbach[7]

[1] National Technical University of Athens (NTUA), Greece
[2] RISE, SSPA Maritime Centre, Göteborg, Sweden,
[3]Alfawall Oceanbird, Tumba, Sweden
[4] Wallenius Marine, Stockholm, Sweden
[5]Wallenius Wilhelmsen Ocean AS, Barum, Norway
[6]Royal Institute of Technology, Stockholm, Sweden
[7]StormGeo, Bergen, Norway

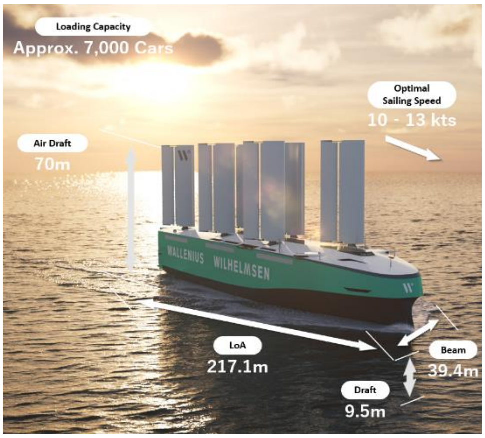

Fig. 1. The Orcelle demonstrator

Abstract. International regulations on greenhouse gas (GHG) emissions as well as strong market demand for zero-emission transport calls for a radical change in the shipping industry. Measures such as hull form optimization, use of alternative fuels and efficient machinery systems, new coatings, and smart routing have already improved the energy efficiency of the world fleet. However, it is far from enough. To effectively respond to the climate challenges, we must turn to *emission-free energy sources*. One such promising and well-proven zero-emission propulsion system for shipping is wind propulsion. Using wind to power cargo vessels re-started on a commercial scale about a decade ago and there are today more than 50 wind-assisted vessels in commercial trade or under construction. They are equipped with a variety of wind propulsion technologies like Flettner rotors, wing sails and kites, which may give fuel and emission reductions of up to about 20 %. With the goal of demonstrating that even higher energy and emission reduction, 11 representatives of the European maritime industry and research community have recently joined forces in the large-scale EU-funded project Orcelle, led by Wallenius Wilhelmsen Ocean. The present paper outlines the project's ambition, scope of work and expected outcome.

Keywords: Wind Propulsion, GHG Reduction, Wing Sails, Decarbonization.

1 Introduction

In alignment with the emission reduction goals set out in the United Nation's 2015 Paris Agreement, the International Maritime Organisation agreed recently on a revised plan to reduce the total annual greenhouse gas (GHG) emissions from international shipping by at least 20%, striving for 30%, by 2030, compared to 2008; and by at least 70%, striving for 80%, by 2040, compared to 2008; and CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, compared to 2008 (IMO-MEPC90, July 2023). These international regulations, as well as strong demand from the market, call for radical innovations in the frame of zero-emission maritime technology and shipping.

Various solutions are currently discussed in the maritime transport sector. Among others, Bouman et. al. (2017) have studied the CO_2 reduction potential of various improvement measures such as hull design, power & propulsion system, alternative fuels, alternative energy sources and operational measures. Out of many possibly viable solutions, a promising and well-proven solution with good market potential is *wind propulsion* (Nelissen et.al. 2016).

Using wind to power cargo vessels re-started on a commercial scale about a decade ago. Currently, there are about 50 wind-assisted vessels in commercial trade and/or under construction (EMSA 2023). The main implementations in practice are so far:

- *Flettner rotors*: E-Ship 1 (RoRo), Maersk Pelican (tanker), Fehn Pollux (general cargo), Annika Braren (general cargo) and Copenhagen (ferry). Rotors were recently also fitted to deep-sea ships: Sea Zhoushan (Bulk) and Sea Connector (RoRo).
- *Wing sails* (e.g., Ayro of OceanWings, WindWings of BARTech / Yara Marine, Wisamo inflatable sails by Michelin, OceanBird of Alfawall, advanced in the Orcelle project). Among the prototypes with wing sails, as of today, is the 121m long Ro-Ro cargo ship Canopée, delivered in December 2022. Its hybrid propulsion uses a combination of wing sails of Oceanwing type and traditional engines. Also, in late 2022, the VLCC New Aden was delivered to China Merchant Energy Shipping, built by Dalian Shipbuilding Industry Co; it is equipped with two pairs of new generation rigid wing sails.
- *Suction wings*; Ankie (general cargo), Frisian Sea (general cargo), and La Naumon (general cargo).
- *Soft sails*: Neoline (RoRo) and *kites* Beluga (Container), AirSea (RoRo) are less common and may have limited impact.

The wind propulsion systems, currently in use, deliver fuel reductions of up to (at best) 20% by assisting ship's main propulsion engine, which is in general a diesel or LNG fueled engine (hybrid WASP: Wind Assisted Ship Propulsion systems). These are partly significant savings, but far from enough to reach the international GHG emission targets. There are a few built ships with wind as the *main propulsion*, in the segment of private yachts and very exclusive cruisers, but not yet any large vessels for deep-sea cargo transport driven primarily by wind.

With the goal of demonstrating that a drastic reduction of emissions from deep-sea cargo transport is possible, 11 representatives of the European maritime industry and research community have recently joined forces in the EU-funded project Orcelle

(2023-2027). The consortium is led by Wallenius Wilhelmsen Ocean and includes Wallenius Marine, AlfaWall Oceanbird, RISE SSPA Maritime Centre, Royal Institute of Technology, StormGeo, National Technical University of Athens NTUA, DNV, Ghent University, Volvo Cars, and Maritime Cleantech. The efforts aim to advance several technologies from Technology Readiness Levels TRL3-4 to TRL7, including the wing system and ship design, as well as the simulation platform, safety regulation framework, business models and weather routing software. The advance of generated know-how will be demonstrated by two physical demonstrators, a retrofitted vehicles carrier (*MS Tirranna*, IMO: 9377523) and a newbuilding car-carrier, both of Wallenius Willemsen. The present paper outlines briefly the Orcelle project's background, ambition, scope of work and expected outcome. For a more detailed description of the project, see Werner et al. (2023).

2 The Orcelle Concept

The goal of the consortium's efforts is to build and start operations of a wind powered car carrier, namely Orcelle. The concept design of the planned ship is already mature through background research and development work in earlier collaboration between the project partners. The concept vessel of Ro-Ro car carrier type, measures 232 meters in length, 40 meters in beam and has the capacity to load approximately 7,000 cars or equivalent cargo. The optimal sailing speed with wind is predicted to be between 10-14 knots. The vessel size and capacity are chosen in relation to the identified transport route and cargo flows. The evaluation of energy efficiency has been performed for two different routes, a trans-Atlantic and a trans-Pacific route. The Atlantic route includes major ports on the EU-side, e.g., Zeebrugge and Bremerhaven, and Halifax and New York on the US east coast side. The trans-Pacific route includes ports in east-Asia e.g., Ulsan and Pyeongtaek and San Diego and Port Hueneme on the US west coast side. The great circle round-trip distances are 7.000 and 11.500 nautical miles for the trans-Atlantic and trans-Pacific routes, respectively.

The ambitious energy savings target is +50% for a year-round service. This has been determined by simulations on the basis of statistical weather data and applications of the employed simulation tools, developed by the consortium partners in the background research project "Wind Powered Vehicle Carrier", funded by the Swedish Transport Agency. The simulation tools platform comprises several modules and some main features of the simulation platform are briefly described in the following.

Hydro and aero modeling. Hydrodynamic modelling and analysis of the vessel hull, while experiencing large leeway angles and variable propeller load, is based on CFD (3D RANS). The employed numerical method has been validated using experimental tests in the towing tank of SSPA. The aerodynamic modelling of the wings and hull topsides, the interaction between the hull and wing systems, and interaction between the different sail systems on the hull topsides is based on a multi-fidelity approach mixing 3D RANS, 2D RANS and lifting line methods (Malmek 2020). Examples from the aerodynamic modeling are shown in Fig.2. The method has been validated using wind tunnel tests at SSPA (Marimon et al. 2022).

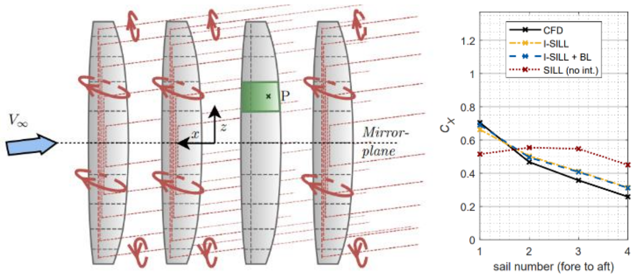

Fig. 2. Aero modelling examples and Multifidelity method (I-SILL) (Malmek 2020).

Velocity prediction. A velocity prediction program VPP has been developed, where the non-linear systems of constrained force and moment equilibrium equations of the vessel system is solved to provide a large range of performance parameters given certain wind and wave conditions (Olsson et al. 2020).

Routing. An optimal routing methodology, which enables the operational energy savings to be assessed on various trading routes across the globe, has been developed. The methodology considers the need for the vessel to fit into a logistics system regarding arrival time and lateness and considers ECMWF (European Centre for Medium-Range Weather Forecasts) weather data captured during the last decade (Fig.3) (Werner et al. 2021).

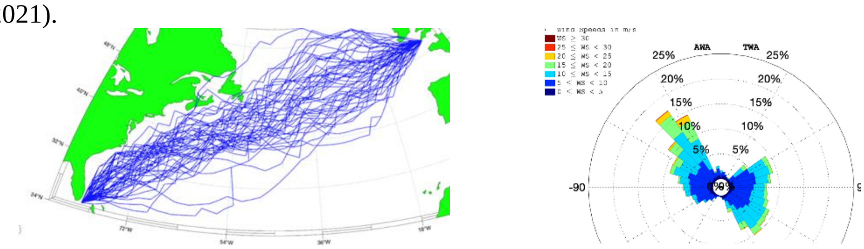

Fig. 3. Results from UK to NY routing simulations with wind statistics

Combined analysis. The above outlined methods together with the operational know-how of the consortium partners form the basis for the target energy savings potential of the Orcelle demonstrator vessel. The expected potential energy savings for the given trade scenarios shows that approximately 50% total energy savings is achievable at 14 knots and even increased savings, as the trading speed reduces, compared to the latest generation car-carriers operating with same amount of cargo at 16 knots. Comparing energy savings at the same vessel speed gives a total energy reduction of approximately 40% at 14 knots and 45% at 10 knots only from wing system. A part of the challenge for wind propulsion is to develop operational models and vessels for lower speeds, which is a key to moving to the largest emission reductions using wind.

The Oceanbird wing concept. Wing sail technology is not in itself a novel technology; it has been in fact utilized for sailing for a century or more. However, as to its application to commercial shipping, wing sails still have not entered the market to any significant degree. The wing sails solution for Orcelle, called *Oceanbird Wing*, has been developed by the Swedish company Alfawall Oceanbird. It consists of a 40m tall main wing and a flap, which can both be rotated independently to provide optimum thrust forces. The wings are made in composite shells, which provides the aerodynamical shape of the wing sail and transfers pressure loads to the main load-carrying structure. In unfavorable and extreme wind conditions and in port, the wings are folded down (https://www.theoceanbird.com).

Full Scale Demonstrators. The Orcelle project will realize two full scale demonstrator ships, namely one retrofit wind-assisted vessel planned for 2024 and one newbuilt vessel at the project's end (2027). The two demonstration campaigns have several purposes: to provide data for verifying and improving the simulation tools, to improve the next generation of the wing technology, and to prove that the solution is viable in commercial shipping. The retrofit demonstrator installation will be performed on an existing Pure Car and Truck Carrier (PCTC) vessel of the Wallenius Wilhelmsen fleet (*MS Tirranna*, IMO: 9377523). The planned newbuilding will be a PCC carrier with a capacity of 7,000 cars, bound to the Transatlantic route from Europe to the North-East Coast of USA.

A first adaptation of the developed weather routing system will be implemented onboard the demonstrator vessel to enable crew feedback and training as well as develop strategies for optimal onboard usage. The energy savings on retrofit market segment will be proven through dedicated sea trials as well as by analyzing fuel consumption over longer periods of operation. Sea trials consist of tests over a short time period (1-2 days) where the environmental conditions, the ship's speed and power consumption are recorded carefully while the ship is driven alternatively by engine and by sails. The new built vessel Orcelle ship (Fig 1) will be in commercial operation from day one. The viability will be proven throughout all aspects of ship operation from emissions, safety, crew aspects to logistics and cargo owners' perspective. Such holistic demonstration campaign goes beyond anything publicly known in this area. For the verification of energy efficiency, the Orcelle project will advance the newly developed sea trial procedure further to make it applicable to large ships in fully sailing condition. This will pave the way for open and transparent verification of all future wind ships.

Further Applications Feasibility studies will be carried out for a range of other ship types than the ro-ro car carrier Orcelle. At least four generic ship concepts (tanker, bulk carrier, containership, ferry) will be developed in close contact with the shipping industry. Design concepts that are based on a logistic and an operational profile, will include the ship's hull form, wind propulsion arrangement, machinery power and propulsion plant, cargo and other main arrangements. The validated simulation tool kit will be used to evaluate the CO_2-saving potential compared to conventional ships and demonstrate viable business models (Plessas-Papanikolaou, 2024).

3 Conclusions

Several cargo ships have already adopted wind assisted power solutions to reduce GHG emissions. However, for deep-sea shipping with large cargo vessels, wind solutions have so far been limited to systems providing yearly energy efficiency reductions of up to (at best) 20 %. The Orcelle project aims to develop and demonstrate a cost-efficient approach to reduce emissions and energy use more drastically, namely up to +50% (estimated for all energy used in operations) and further improve this margin through operational optimization or adjusted service speeds. The emission reduction is herein achieved through the drastically improved energy efficiency, while a part of the onboard energy is taken over by cost free and clean wind power. This means that alternative fuel approaches have the potential to become even more cost-efficient, making the two solutions complimentary (hybrid concept). A significant scientific impact of the project in areas such as multi-fidelity performance prediction methods, wind power control systems based on machine learning, and novel design processes is also foreseen. Finally, an impact on the traditional business scenario modelling by involving the cargo owners (here: Orcelle partner Volvo Cars and other interested European car makers) from the beginning may be expected.

Acknowledgements The authors acknowledge the financial support from the European Commission and its agency CINEA, project Orcelle, grant 101096673 and the Swedish Transport Agency under grant number TRV 2018/96451 (Vinddrivet biltransportfartyg).

References

1. Bouman, E., Lindstad, E., Rialland, A., Strømman, A.: State-of-the-art technologies, measures and potential for reducing GHG emissions from shipping – A review. Transportation Research Part D: Transport and Environment, vol. 52, part A (2017).
2. European Maritime Safety Agency (EMSA), Potential of Wind-Assisted Propulsion for Shipping (2023)
3. International Maritime Organization, Resolution MEPC.377 (80): IMO 2023 Strategy on reduction of the GHS emissions from ships, adopted on 7 July 2023, Annex 1 (2023).
4. Malmek, K.: Rapid Aerodynamic Method for Interacting Sails. Licentiate Thesis, Chalmers University of Technology, Report No 2023:06, Chalmers Reproservice, Gothenburg, Sweden (2020).
5. Marimon, G., L., Dhomé, U., Malmek, K., Persson, A., Wielgoz, C.: Multi-wing sails interaction effects, In: Proceedings of the 24th Chesapeake Sailing Yacht Symposium Annapolis, Maryland (2022).
6. Nelissen, D., Traut, M., Köhler, J., Mao W., Faber, J., Ahdour, S.: Study on the analysis of market potentials- market barriers for wind propulsion technologies for ships, Delft (2016).
7. Olsson, F., Marimon Giovannetti, L., Werner, S., Finnsgård, C.: A performance depowering investigation for wind powered cargo ships along a route. In: INNOVSAIL (2020).
8. Orcelle: HORIZON-CL5-2022-D5-01-03 project, Wind as Main Propulsion by ORCELLE, project number 101096673, 2023-2027.
9. Plessas, T., Papanikolaou, A., Optimization of Ship Design for the Effect of Wind Powered Ship Propulsion, Proc. 15th Int. Marine Design Conf. (IMDC), Amsterdam, June (2024).
10. Werner, S., Kuttenkeuler, J., Hörteborn, A.: Route evaluation methods for long-distance sailing vessel performance predictions. In: Proceedings of 7th High Performance Yacht Design Conference, Auckland, 11-12 March (2021).
11. Werner, S., Papanikolaou, A., Razola, M, Fagergren, C., Dessen, L., Kuttenkeuler, J., Santén, V., Steinbach, V.: The Orcelle project – Towards Wind-Powered Ships for Deep Sea Cargo Transport, SNAME Maritime Convention 2023, 27-29 September, CA (2023).