VOYAGE OPTIMIZATION WITH WIND PROPULSION

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SUMMARY

Wind propulsion has been proven to produce significant fuel savings on commercial vessels. The typical savings potential of wind propulsion on conventional cargo ships is 5-25%. On the other hand, voyage optimization and weather routing has been shown to produce similarly large fuel savings in the order of 15%. Wind is an intermittent energy source, and it often occurs together with waves, making ships installed with wind propulsion especially interesting from weather routing point of view. This means that a holistic approach is needed when conducting weather routing for ships with wind propulsion.

Using detailed simulations, this paper studies how the fuel savings potential of wind propulsion can be further improved by coupling it with state-of-the-art voyage optimization software. Via case study examples, it is shown that the savings potential of wind propulsion can be more than doubled by using voyage optimization.

1. INTRODUCTION

The shipping industry is facing increasing pressure to search for alternatives for common fossil fuels. There are multiple drivers for this development. First and perhaps most prominently, regulatory frameworks such as EEDI/EEXI and CII issued by IMO require ships to emit less and be more energy efficient. At the same time the oil prices have been steadily increasing after the pandemic. At the time of writing, the Brent quality crude oil is priced above $100 per barrel. Furthermore, there is new demand from the end customers and cargo owners to decarbonize the logistics chain. Finally, many financial institutions have integrated climate considerations into their lending considerations in frameworks such as Poseidon Principles [6].

There are various strategies to accomplish a shift from fossil fuel-based transportation to sustainable logistics chain. Much of the discussion has been revolving around the energy efficiency, which is of high importance. It is however impossible to reach carbon neutrality, or even significant decarbonization with efficiency alone. Some form of energy production is needed. This paper deals with the use of direct wind propulsion as means to supply the ship with significant source of thrust to propel the ship. As wind is an intermittent energy source, it is highly beneficial to couple the wind propulsion technology with modern voyage optimization tools to gain the maximal benefits from wind without added losses due to waves etc.

The purpose of this study is to investigate and demonstrate the additional benefits of voyage optimization on ships using wind assisted propulsion, namely Rotor Sails. The impact is studied on multiple global routes representing some of the busiest trading.

2. METHOD

In this simulation, 384 sailed voyages (using AIS data) are used as comparative baselines. These voyages are selected based on the departure-destination of their sailed routes, which are US – EUR, EUR – US, CN – SA, SA – CN, CN – AUS, AUS – CN. This simulation is conducted using NAPA Voyage Optimization, which provides solutions for improving operational efficiency by optimizing route and speed profiles for any sea passage. To study the impact of the Rotor Sails on the potential fuel saving for ships, a comparative simulation experiment is conducted with 6 types of routing methods listed in Table 1. The experiment is based on historical voyage data, which is indicated in Index 1 row.

Table 1. Routing types of the simulation experiment

Index	With Rotor Sails	Route type	Operation type
1	×	baseline	baseline
2	×	baseline	constant RPM
3	×	optimized	constant RPM
4	✓	baseline	baseline
5	✓	baseline	constant RPM
6	✓	optimized	constant RPM

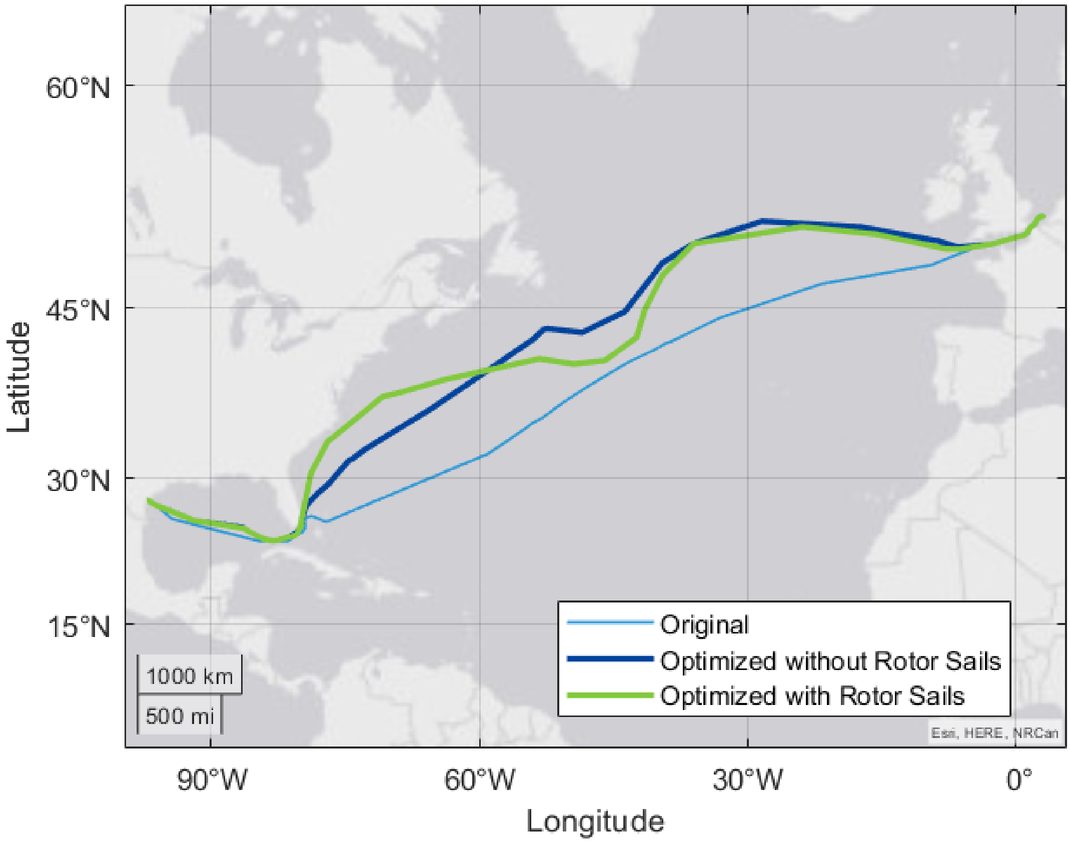
- baseline: the data is retrieved from real voyages
- optimized: route is optimized by NAPA Voyage Optimization tools

·	constant RPM: study ships sail with constant RPM while keeping the same arrival time as the baseline case

The performance model used for wind propulsion is the same that has been discussed earlier in [3]. The model is based on theoretical considerations, and it has been shown to produce results that match with the operational experience and long-term performance measurement.

The weather data considered in this simulation consists of wind, wind waves, swell and ocean currents.

An example of simulated routes on voyage US-EUR are shown in figure 1. It is seen that the original route (route collected from AIS) follows the rhumb line, whereas optimized routes are closer to great circle route, although not strictly. It is also seen that the introduction of Rotor Sails allows the route to be offset further away from the original. All of the routes have the same arrival time.



3. RESULTS

The influence of different voyage optimization schemes on the fuel economy of the vessels studied is presented in figure 2. It can be seen, that both voyage optimization and Rotor Sails are able to produce significant savings on their own. The average savings potential of Rotor Sails for the configurations studied is 7% when the ships operation is not adjusted to accommodate the Rotor Sails. With voyage optimization only the savings potential is 17% (when assuming a constant engine RPM). However, when these two technologies are combined, the accumulative savings potential reaches 24%. It is worth noting that the average contribution of Rotor Sails to the total propulsion power is rather modest in the cases studied. It can be anticipated that as the contribution of the wind propulsion increases, also the importance and benefit of the voyage optimization coupled with wind propulsion increases. Typically, the proportion of wind propulsion depends on the number and size of the sails installed. For example, the vessel considered in this study for the Persian Gulf – China route is a VLCC equipped with three 35m tall Rotor Sails with a diameter of 5m. Various concept studies have been made indicating that such vessels are feasible to accommodate at least six Rotor Sail units of such size [1], [2]. Recent analysis has shown that if the contribution of wind propulsion is modest, the savings potential can be estimated to increase linearly with increasing effective sail area. [4] While an exact threshold at which the savings should be considered "modest" is difficult to determine, the level at the current study (7% contribution to propulsion) is comparable to levels for which simple prediction methods have been proven useful [4].

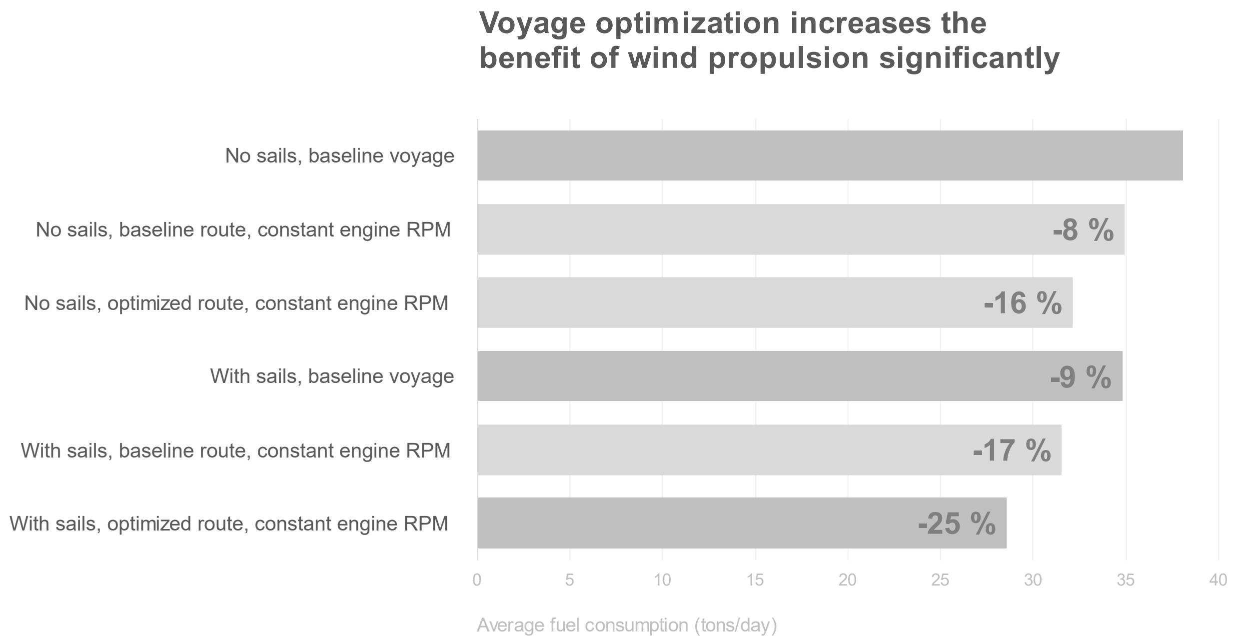


Figure 2 Impact of voyage optimization and 3 units of 35x5 Rotor Sails on the average fuel consumption.

As discussed in the introduction, a typical feature of wind propulsion is its intermittency. This means that the available energy in wind varies over time. Furthermore, the prevailing wind conditions vary over the location. At one place wind speeds are typically higher than in another. Similarly, the prevailing wind directions may be different from place to place. It is then important to consider differences of wind propulsion and voyage optimization potential on different routes.

Figure 3 illustrates the simulated savings potential on different routes. To allow comparison between routes of different length, the results are shown in a form of total fuel consumption divided by the total number of days spent on the voyages. This means any potential differences in arrival times are also taken into account. The savings in figure 3 correspond to cases "With sails, baseline voyage" and "With sails, optimized route, constant engine RPM" of figure 2 compared to case "No sails, baseline voyage".

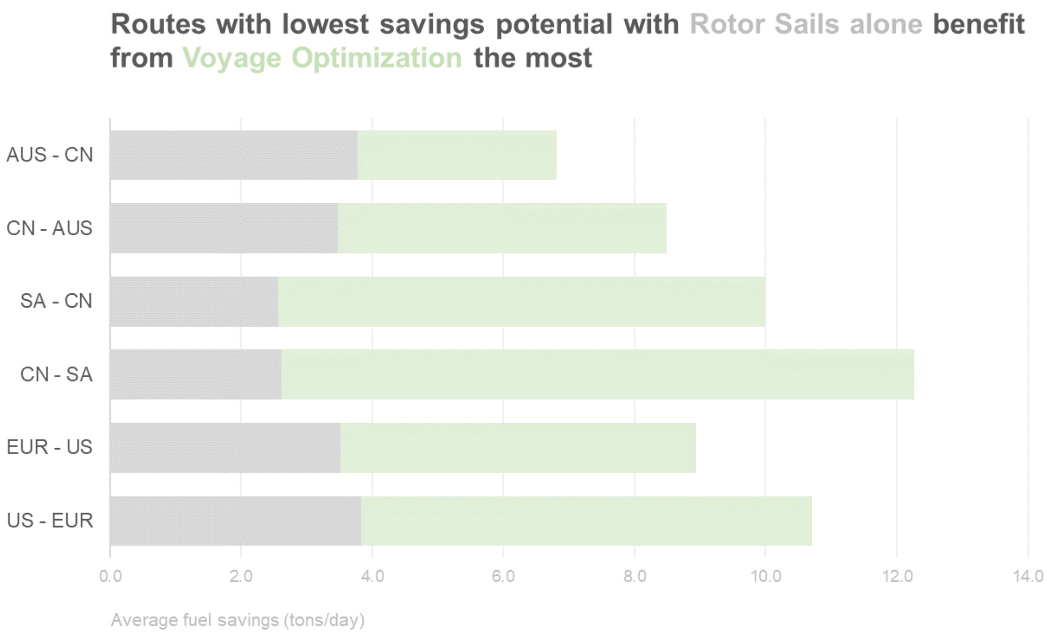


Figure 1 Savings potential on different routes with Rotor Sails and Rotor Sails coupled with voyage optimization.

It can be seen, that especially without voyage optimization (grey bars), the potential of wind propulsion is highly dependent on the route selected. It is well known that the typical wind speeds near the equator are lower than higher north or south. It is then not surprising that the potential on route Persian Gulf to China has the lowest potential and North Atlantic crossing the highest.

The results indicate that the potential of wind propulsion can be more than doubled when it is coupled with voyage optimization. This large increase in the savings potential is something that is very relevant for the overall ship design and thus it suggests that operational considerations and voyage optimization should be considered as an integral part of ship design cycle.

It is very interesting to note that voyage optimization evens out the differences between “good routes” and “weak routes” significantly. Similar findings were reported by Mason [5]. It then appears that voyage optimization supports especially those ships with wind propulsion that may have the weakest business case without it. This particular notion could indicate importance of voyage optimization in expanding the commercially viable market of wind propulsion. This could mean that voyage optimization can play important role in being an enabler technology for installing wind propulsion and as such contributing to improvement of energy efficiency of global fleet.

4. CONCLUSIONS

In this paper, results from NAPA Voyage Optimization simulations with wind propulsion were presented. It was shown that the voyage optimization can significantly improve the savings potential on wind propulsion and work as an enabler for wind propulsion technology. The results also indicate that savings are increased the most at conditions that would otherwise provide mediocre benefit with wind propulsion.

As the carbon footprint requirements for shipping get more stringent, it is likely that the wind propulsion becomes more integral part of the ships energy system. The higher contribution of wind propulsion highlights even further the benefits of voyage optimization. Furthermore, this opens new opportunities and interesting challenges: when the wind propulsion corresponds to larger parts of ships total propulsion, it is conceivable that the ships’ conventional engines can be downscaled. This would lead to the business case of wind propulsion being partly covered by the expense saved on the fuel engine. However, to achieve this, it is necessary to introduce the operational considerations at the design stage of the vessel to ensure the at the ship is capable to fulfil its mission requirements. For instance, that the passage times can be kept as required with high enough confidence level.

5. REFERENCES

1. Norsepower: https://www.norsepower.com/post/norsepower-collaborates-with-sws-for-cost-and-energy-efficient-vlcc-designs Retrieved 01.07.2022

2. SARSILA Severi. Comparison of Achieved Fuel Savings on Ships by Different Wind Propulsion Systems Using a 3-DoF Resistance Model. 2021

3. Paakkari et. Al. ROTOR SAIL GHG REDUCTION POTENTIAL, MODELLING AND SEA

4. TRIAL VALIDATION; *The 5th Int. Conference on Innovation in High Performance Sailing Yachts and Sail-Assisted Ship Propulsion, Gothenburg, Sweden. 2020*

5. IMO MEPC 76/INF.30

6. MASON James C. Quantifying voyage optimisation with wind-assisted ship propulsion: a new climate mitigation strategy for shipping. 2021

7. Poseidon principles, https://www.poseidonprinciples.org/finance/about/, Retrieved 01.07.2022

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