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Viking Grace Rotor Sail Performance analysis results

Introduction

In April 2018 one 24x4 Norsepower Rotor Sail unit was installed onboard Viking Line Cruise ferry Viking Grace. The Rotor Sail utilizes so called Magnus effect to produce additional thrust from wind. This additional thrust force reduces the loading of the propeller and results in fuel savings. The performance of the Rotor Sail has been extensively investigated during the first year of operation in order to determine, how much fuel can be saved with the technology in long term. Three separate measurement campaigns have been conducted, all using somewhat different approaches. Three of the campaigns have been conducted by third parties (ABB, NAPA and Chalmers), and the fourth campaign was done by Norsepower in co-operation with an external provider of strain gauge measurements and related strain force data. In the following chapters, short summaries of each performance analysis campaign and the respective measurement and analysis methods are given.

ABB

The performance analysis by ABB is based on the propulsion power analysis. MS Viking Grace is equipped with ABB's propulsion power monitoring and analytics software system. From the operational data, the system can identify the effect of various variables (such as trim, list, draft, …) on the propulsion power requirement. When the Rotor Sail had been installed onboard Viking Grace, relevant variables for Rotor Sail were initiated, and ABB's analytics system started to monitor also the effect of the Rotor Sail on the propulsion power. As the software has collected data a propulsion power breakdown model can be made, this model can consider the influence that the Rotor Sail has on the propulsion power requirement of the ship in different conditions. With this model, it is then possible to estimate the effect of the Rotor Sail over the measurement period. ABB's analysis had the longest time-window with data collected and analyzed from July 2018 until March 2019.

NAPA

The performance analysis by NAPA was based on difference in propulsion power measurement when Rotor Sail was "enabled", meaning that it is allowed to optimize it's net effect in all conditions, and when the Rotor Sail was "disabled", meaning that it was not allowed to be used even if the wind conditions would be favorable. NAPA performance monitoring campaign utilized carefully designed measurement setup, in which special attention was given to eliminate the effects of the measurement conditions. Basically, the idea was to make the measurement setup as close to "laboratory tests" as possible. This was achieved by defining measurement legs, on which the Rotor Sail was tested and forcing the Rotor Sail to "disabled" mode every other crossing over certain leg. To further eliminate the effects of other factors than the Rotor Sail, a

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statistical regression analysis was conducted for the measurement data. While the use of pre-defined measurement legs enables better measurement conditions, the analysis cannot be directly applied to areas outside of the measurement legs. The major reason for this is, that the wind conditions and behavior of the Rotor Sail outside the measurement legs (mostly Archipelago) is not included in NAPA analysis and thus no conclusions can be made. NAPA performance analysis campaign utilized data from October 2018 until January 2019.

Chalmers

The performance analysis by Chalmers is based on simulations done with ShipCLEAN, in-house developed propulsion power model. The simulation model was validated regarding the ship and the Rotor Sail model with the measurement data logged onboard of MS Viking Grace from September 2018 through end of January 2019. The simulation predictions were compared to the measured propulsion power and were stated to have sufficient accuracy for this study. The simulation prediction of the annual savings is based on the environmental data recorded onboard during 2018. The obtained savings are net saving, i.e. including losses due to drift and rudder. According to the author they don't think that the Rotor Sail could interfere with vessel's normal operation.

Norsepower

In contrast to the three other campaigns, Norsepower measurements were not based on monitoring the propulsion power or simulation, but on measuring the forces produced by the Rotor Sail. From the force data, which was delivered by an external provider of strain gauges, it was possible to observe how much the Rotor Sail was pushing the ship forward. This force could then be converted into propulsion power savings based on the knowledge of vessel's speed and efficiency. The force measurement data was collected between November 2018 and mid-March 2019. The force measurements where compared to simulation model by Norsepower, enabling to assess the accuracy of Norsepower's simulation model. With the verified simulation model, it was then also possible to make long term performance estimates based on long term wind statistics. Force measurements also enable observation of the Rotor Sail performance independent of vessel's speed.

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Combined results of all performance analysis methods

Summary of Performance analysis results		ABB	NAPA	Chalmers	Norsepower
Analysis period		July 2018 - March 2019	October 2018 - January 2019	2018	November 2018 - March 2019
Open sea legs of Viking Grace route					
Estimated average net saving when Rotor Sail enabled	[kW]	341	282	N/A	257
Equals annual fuel saving (on open sea legs only)	[ton]	109	90	N/A	82
Average forward thrust when Rotor Sail enabled	[kN]	N/A	N/A	N/A	17
Archipelago legs of Viking Grace route					
Estimated average net saving when Rotor Sail enabled	[kW]	153	N/A	N/A	99
Equals annual fuel saving (on archipelago legs only)	[ton]	122	N/A	N/A	79
Average forward thrust when Rotor Sail enabled	[kN]	N/A	N/A	N/A	11
Complete route of Viking Grace					
Measured average saving Jul 2018 - Jan 2019, including also periods when Rotor Sail has been force-disabled	[kW]	125	N/A	N/A	N/A
Measured average saving Feb 2019 - Mar 2019, with no periods with Rotor Sail force-disabled	[kW]	220	N/A	N/A	N/A
Long term					
Estimated long-term average net saving based on all data	[kW]	(207) *	(282) **	(287) ***	211
Equals annual fuel saving (on all legs of Viking Grace route	[ton]	(231) *	(315) **	(320) ***	236

*Long term potential is assumed to be the same as average saving during the measurement campaign when Rotor Sail was enabled. Due to the enable/disable measurement campaign, this is likely to be underestimate (half of the opean sea legs, with highest savings, are absent).

**Long term potential is assumed to be same as average savings during the measurement campaign. Due to neglecting the archipelago legs (with lowest savings), this is likely to be overestimate.

***Long term potential is assumed to be same as simulated results with enironmental data on board during 2018

Remarks on results

- Estimated savings of all measurement approaches are quite close to each other, proving the fuel savings potential of the Rotor Sail.
- Propulsion power saving potential of the Rotor Sail is greater on open sea legs than on archipelago legs. Annual fuel savings are anyhow expected to be similar between these two, as the vessel sails more in the archipelago.
- This has been anticipated by the original Norsepower simulations, and there are two reasons for this: vessel speeds are higher and wind conditions are better on the open sea legs.
- The end of enable/disable campaign, which occurred in the end of January 2019, can be clearly seen in the increase of average savings reported by ABB starting from February 2019.