OPERATIONAL EXPERIENCES AND RESULTS FROM THE FIRST REFERENCE INSTALLATION FROM NOV-2014, RORO-SHIP ESTRADEN (9700 DWT)

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SUMMARY

The Norsepower Rotor Sail Solution is a modernized version of the Flettner rotor – a spinning cylinder that uses the Magnus effect to harness wind power to propel a ship. It has been primarily developed to complete propulsion system of a vessel by using wind as an auxiliary propulsion measure. The system enhances energy efficiency, reduces emissions and pollution. The Norsepower Rotor Sails are designed to be an affordable off-the-shelf product to be retrofitted into existing vessels or installed into new-build vessels.

The first Norsepower Rotor Sail system was built April 2014. After half a year land testing, November 2014 it was installed on RoRo-ship Estraden (9700 DWT). The second rotor sail was installed one year after, November 2015. This paper represents the operational experiences from the reference installation so far, including installation, usability and system availability, maintenance etc. The performance results assessed by different parties from the period of trials and operation will be reviewed as well. Additionally, the derived performance figures of the alternative rotor sail size are represented with an installation example.

1. INTRODUCTION

Norsepower Oy Ltd is a newly established company that operates at the business area of auxiliary wind propulsion systems for cargo vessels. The technology of Norsepower is based on a Rotor Sail solution, which can help ships reduce fuel consumption by as much as 30% when the system is operated as auxiliary propulsion system. The solution can be applied both as retrofit and new build.

The principle on which the Norsepower Rotor Sail operates is known as the Magnus effect. When wind meets a spinning object, the object accelerates the wind speed in the direction of rotation (and resists it against the rotation) creating a high and low pressure differential not unlike the principle of an aircraft wing. This can also be observed in cricket (spin bowling), tennis (top spin) and football (curling free kicks). The Magnus effect is described in the following picture.

The Magnus force can be utilized in ship propulsion by placing a cylinder on the open deck of the vessel and by rotating it around its main vertical axis. For the rotation an electric drive system is used, which is powered by the auxiliary grid in the vessel. This kind of device, originally known as a Flettner rotor, is shown in the following picture.

Norsepower has developed several new innovations to the original application. The Norsepower Rotor Sail Solution is ten times more efficient than a conventional sail and requires no extra crew. It offers “push button sailing” from
the bridge. This allows the main engines to be throttled back, saving fuel and reducing emissions, while maintaining same voyage time. The rotor technology was originally invented by the Finnish engineer Sigurd Savonius and later demonstrated by Anton Flettner as far back as 1926. This wind power utilization technology however materialized too early and sailing ships were replaced by steam and diesel power. Now, the time is right due to higher fuel costs and environmental regulations.

2. INSTALLATION

2.1 On-shore installation and tests
Norsepower’s testing operations before ship installation are done at the Norsepower test site in Naantali, Finland, at the facilities of one of Norsepower’s production partners, Turku Repair Yard Ltd. On the test site the relevant instrumentation for testing was installed, e.g.; met-mast, foundation and grid connection. The surrounding infrastructure of Turku Repair Yard also supported the testing activities. Other important factors for test site selection were good average annual wind speed and clean sectors in order to get faster useful good quality data. The rotor sail installation was done in April 2014 and took one day.

![Figure 2. Calibration of the strain gauges](image)

The purpose of the land tests was to test the mechanical system thoroughly, driven to its limit, for finding any possible teething problems there might be. The automation system enabling “push button sailing” required also a long testing period. The on-shore tests took all in all approximately 7 months. During this period minor modifications were done to the mechanics, the automation system was fine toned and the lift- and drag performance were measured as well as dynamic properties of the system under operation.

2.2 Ship installation
The installation of the first unit took place in November 2014 in Turku, Finland. The steel foundations of the rotor sail unit were installed a year before during an ordinary docking stay. The cabling work and automation equipment installations were done during normal harbor stays in autumn. The installation was made from the pier using a mobile crane, an aerial platform was used for installing the wind instrumentation. The actual Rotor Sail installation took from start to rotating rotor only 7 hours and was done well within the limits of scheduled harbor stay, unloading and loading of the cargo.
The second installation was made a year after. The first rotor had been fully functional the whole time, meaning only minor cosmetic changes were done to the second unit. The installation took place this time in Rotterdam since MS Estraden did change in the meanwhile its charter party and route. This time no additional instrumentation was required and the installation took from start to finish only 5 hours.
The main specifications of the Rotor Sail first units are
- Height of the cylinder 18.0 m
- Diameter of the cylinder 3.0 m
- Diameter of the end plate 5.0 m
- Rotation speed 250+ rpm
- Mass of the Rotor Sail unit 20 t

The main specifications of MS Estraden are
- Type Ro-Ro Cargo Ship
- Built 1999 Aker Finnyards, Rauma, Finland
- Length (Loa) 162.7 m
- Breadth moulded (B) 25.7 m
- Draft max (Tmax) 6.60 m
- Freeboard (F) 11.1 m
- Gross tonnage (GT) 18 205 t
- Deadweight (DWT) 9 700 t
- Machinery 2 x Wärtsilä 8L46A, 7 240 kW/500 RPM each, total 14 480 kW
- Service Speed (v) 19 kn (Turku – Harwich), 16 kn (Rotterdam – Teesport)

3. OPERATIONAL EXPERIENCE

3.1 The first rotor installation

The first rotor sail was taken directly in operation after the installation. The first month the vessel was operating in Turku, Finland to Harwich, UK route. One of the reasons the installation of the rotor sails were done in phases was to see the possible effect on ship normal operations, maneuverability and system reliability. Quite quickly it was seen that there were no recognizable effect on rudder angles or leeway. Also the system was working reliably and caused no excess vibrations or noise. The crew also noted that the system had a stabilizing effect on the roll motion of the vessel. The system also proved its efficiency quite quickly, for example the original location of the wind sensors had to be changed. Even though the sensors were quite far from the system, the down wash of the operating Rotor Sail turned the flow direction by 90 degrees in some cases. After a short commissioning period the automation system was operating fully independently and as designed. During the first year of operation the system was unavailable for operation for few days only due to a minor mechanical issue or communication error. During the first month of operation, December 2014, the system was also operated in winter conditions with sub-zero temperatures and events of snowing. No ice accretion was observed. There is a possibility of ice accretion when the rotors are running on low rpm in straight head wind or idling in harbor. Ice accretion can be minimized with specific operational modes and other icing prevention measures which can be optionally offered by Norsepower for the Rotor Sail Solution.
3.2 The second rotor installation

The second rotor was installed a year after. No changes were seen in respect to operation. Due to minor enhancements made, the second rotor sail was running a bit more smoothly with lower power consumption. The complete system maximum rpm was also upgraded. The automation system was set to automatically detect when reaching the harbor, meaning the only thing the crew needs to do when operating the system is to turn it on when leaving the harbor. In general the system is easy to operate and the crew is able to use it after a short training, comments from the crew: “Operating the system does not increase my workload at all. I just turn it on and forget it.” During almost 2 years of operation so far the mechanics of the system has been proved, the Rotor Sail system availability has been 99% including all the maintenance and down time.
Figure 6. MS Estraden with 2 Rotor Sail units installed

4. PERFORMANCE

The performance was evaluated by 2 different parties: VTT Technical Research Centre of Finland and Napa Oy. VTT joined the project already in the on-shore test phase and did perform the Lift- and Drag curve analysis for the unit. Onboard MS Estraden VTT studied the mechanical performance and response of the system, re-analyzed the Lift- and Drag performance and analyzed the vessel overall performance over specific voyages. Napa used their ClassNK-NAPA GREEN, the vessel performance monitoring and verification software for the analysis of fuel savings.

4.1 VTT analysis

The Rotor Sail system is equipped with multiple amount of different kind of sensors from which all the data was in addition to Norsepowers own system was also collected by the VTT signal collection system. Additionally strain gauges installed to the Rotor Sail system and vessel performance was followed by using vessels own sensors. The first indication of the Rotor Sail system performance was seen in thrust and thrust reverse tests which were performed by rotating the rotor into different directions with different speeds. It was clearly seen the effect and the range was what expected, for quantifying the exact effect large number tests are required to minimize the influence of the external effects.
Figure 7. An example of the VTT tests

In the Lift and drag analysis wind was measured from different points and heights with multiple anemometers (ultrasonic). These wind speeds and directions then were correlated with the simultaneous data from the strain gauges. This correlation work was quite rigorous due to eg. wind turbulence, flow disturbances and wind shear. These results were in the level expected based on the CFD-analysis made before and also literature publicly available eg. [1] [2].

Individual voyages and the fuel savings in them were also analyzed showing roughly expected performance. These randomly performed tests indicated a level of savings equal to 2-12% in fuel consumption with 2 Rotor Sails on. However due to varying nature of wind conditions, sea state and vessel operation, this kind of analysis cannot give an exact answer on fuel savings. This is why Napa was also participating the project.

4.2 Napa analysis

For this analysis purpose the Rotor Sail Solution was operated randomly ON/OFF. It was set doing this to investigate the difference between those two modes and find out the gain of the rotor sail to the ship performance. In the analysis a statistical regression model was built in order to assess the relationships between variables of interest, such as propulsion power, speed through water or fuel consumption, and vessel operational controls (rpm, pitch and draft), weather conditions (wind, waves, swell), shallow water and, in this particular case, the rotor sail utilization.

According to the analysis of the difference between the model predictions the average gain of the rotor sail number 1 usage for the propulsion power is 198 kW. According to the analysis the estimated savings in the speed range and the environmental conditions similar to the test period, the vessel can save approximately 450kW in average when utilizing two rotor sails. The difference between the two sails can be partially explained by the fact that the second unit is experiencing less flow disturbances. Additionally the period of measuring the performance of one rotor sail unit is different from the period of measuring two units. During the period of measurement the rotor sail system reduced propulsion power usage 79% of the time. This matches well with the long period wind data from the operating region of the North Sea. The average wind conditions during the operation period were also compared to the long period data from NASA Merra which also showed a good match.
In figures 8 and 9 the crosswind effect can be seen. Typically crosswind increases fuel consumption with most vessels. The analysis shows, that the Rotor Sail System decreases fuel consumption in the cross wind conditions or increases speed which also results to fuel consumption reduction due to shortened voyage time.
In figure 10 the power curves are set to certain conditions for illustration purposes: headwind=5 m/s, crosswind=20 m/c, draft= 5.8 m, trim=0.7 m, water depth >100m. The green dots represents all the cases, which is the reason for the shift between the dot cloud and the curves. There is more inaccuracy below 12 knots and above 16 knots due to lesser data points.

All in all the system proved to save in average 6.1% in fuel during a measurement campaign which lasted close to a year, had a wind speed and direction distribution equivalent with long period average (Nasa Merra), and included all seasons of the year. MS Estraden sails with a regular schedule 6 days per week.

Figure 11. The route of typical voyage from Europoort to Teesport, (www.marinetraffic.com)
5. AN INSTALLATION EXAMPLE

5.1 Case Study: Ecoship Peaceboat

Norsepower Rotor Sail system can also be used in a ship having passengers onboard. The Flettner Rotors do not induce similar air-borne noise as for example wind turbines because there are no blades passing thru the air causing trailing edge or blade tip noise. The only relevant source of noise is the mechanics inside the Rotor Sails. Norsepower has developed and patented technology which enables manufacture of extremely well balanced rotors with unique bearing system. Therefore Norsepower is confident the Norsepower solution meets the passenger pleasantness requirements set by eg. DNV GL [3].

Figure 12. Peace boat Ecoship equipped with 6 times 24-4 Rotor Sails

In the figure above one example configuration is shown of Norsepower Rotor Sail system on a passenger ship. Alternatively a zig-zag formation could be utilized. The rotor sail system can be also equipped with a tilting system in case of possible air draft limitations due to bridges or so. The elevated positions of the rotor sails offer very good efficiency for the system.
The polar diagram above is showing the efficiency of a single Rotor Sail from different wind directions and on different wind speeds. The polar plots have been drawn for the service speed of 17 kn. The number next to the name of each “Series” of the polar diagrams refers to the corresponding true wind speed (TWS, m/s).

For the analysis leg-specific wind statistics were used: Generalized NASA Merra data, period 1979-2013, from DTU Wind Energy’s Global Wind Atlas [4], height: 50m. All in all 65 way points were analyzed with leg specific service speeds and leg specific service powers. The calculation method, which has been used for main engine power...
reduction of the Peace Boat Ecoship with Norsepower Rotor Sails, is the same which has been proposed by IMO MEPC to be used at the EEDI calculation for wind propulsion systems [5].

5.2 Results

6 times 24-4 Rotor Sails with the assumption of SFOC: 160 g/kWh
- Average Net Savings in equivalent main propulsion power 1271 kW
- Average Net Savings in fuel consumption 15.9%
- Kg of fuel saved per sailing day 5492

6. DISCUSSION

Technical publications concerning Flettner rotors made earlier have been lacking information from field testing and practical designs. These test results confirm the excellent performance of the rotor sail system in full scale in Ro-Ro vessel M/S Estraden with medium-speed diesel machinery and this performance can be repeated with other ship types as well. According to the simulation model developed and validated by Norsepower the savings potential of the Rotor Sail system ranges from 5 to 30 % depending on system configuration i.e. number and size of the Rotor Sails, ship design etc. as well as the area and the route the vessel operates.
REFERENCES

[1] Da-Qing Li et al. “Performance and vortex formation of Flettner Rotors at high Reynolds numbers” in 29th Symposium on Naval Hydrodynamics Gothenburg, Sweden, 26-31 August 2012


