norsepower™

Norsepower Rotor Sails

Proven fuel saving and emission reduction technology

Naples Shipping Week
Sept. 27, 2018

- Visit https://www.youtube.com/watch?v=G-fuPbhtTFo to see the video

Company

Background and current status

- Norsepower has brought to market the first proven auxiliary wind propulsion system
- The first Rotor Sail was tested on land during 2014
- The first commercial project with two Rotor Sails was delivered between 2014-2015 to Bore's M/S Estraden
- Viking Line's cruise ferry Viking Grace started Rotor Sail assisted cruises in April, 2018
- Two Rotor Sails were installed on the Maersk Pelican in the end of August, 2018
- Next delivery projects are ongoing

Introduction

Auxiliary Wind Propulsion

- Depending on wind conditions up to 50% of service power is replaced with wind propulsion
  → HYBRID system
  - Average savings depend on configuration and on the wind conditions of the route / route area
- Norsepower's technology is well suited to:
  - Tankers
  - Bulk cargo vessels
  - Ro-Ro, Ropax, Ferries, Short Route Ferries
  - Cruise ships
- Compatible with all other ways to save fuel

DELTAMARIN®

Physics:
Magnus -effect

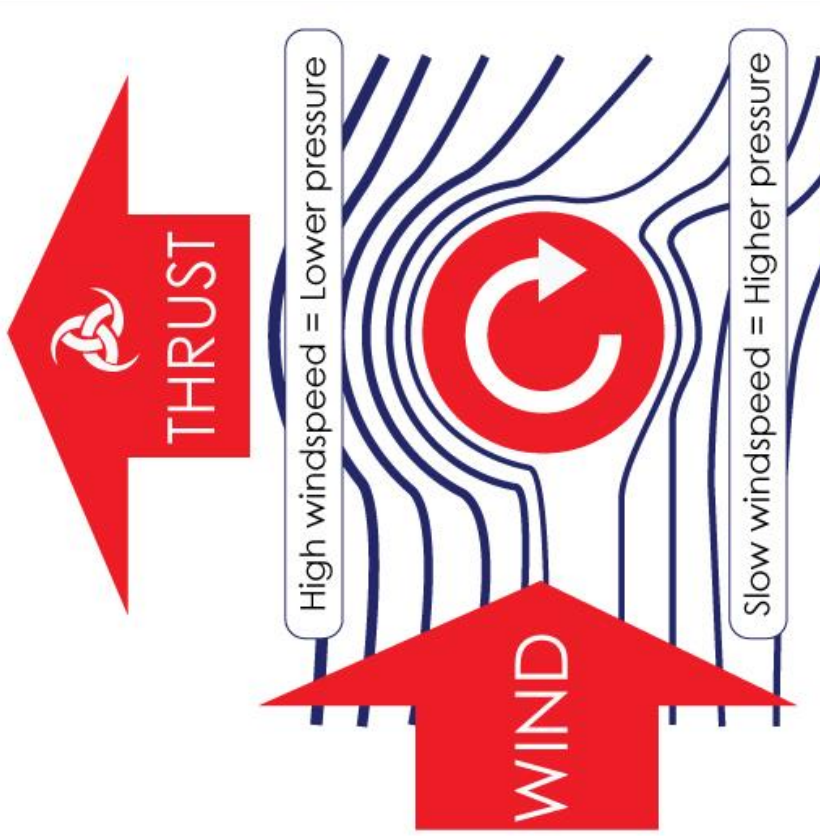
- Visit http://tinyurl.com/nmjyzmo to see the video

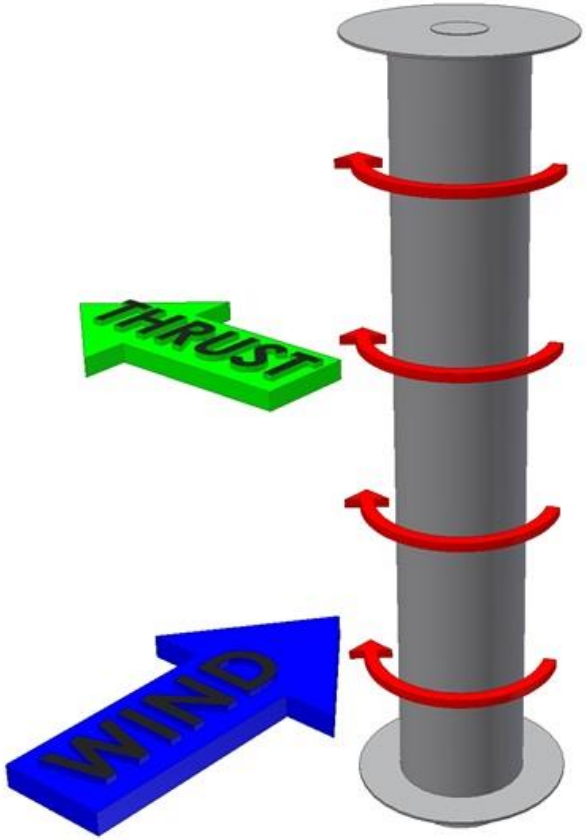
Source: YouTube

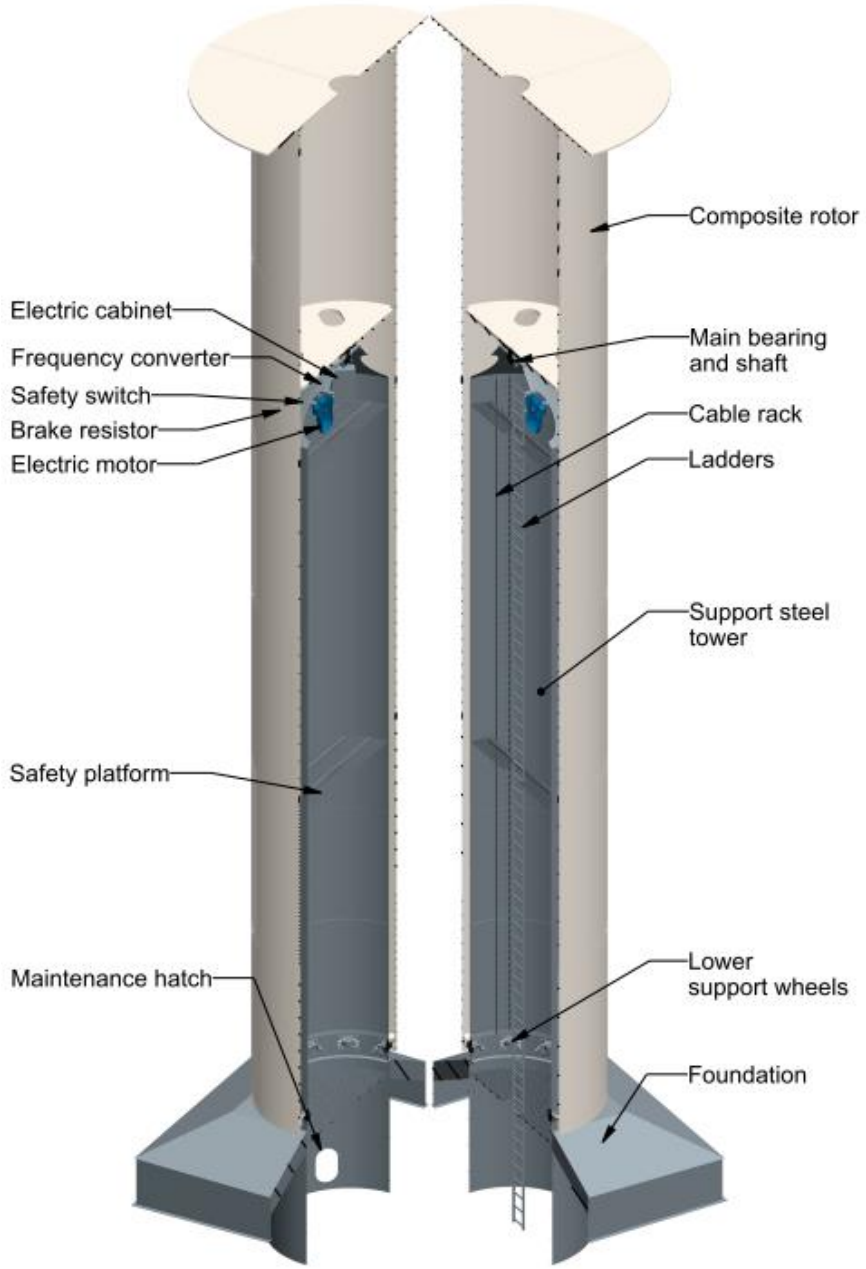
Rotor Sail

Physics of the Rotor Sail: Magnus Effect explained

- When wind meets a spinning object, it results in a high and low pressure differential, which creates thrust at a 90 degree angle to the wind
- Flettner (DE) and Savonius (FI) discovered the fundamentals of a "Flettner rotor" in 1920s
- Norsepower has modernised the technology entirely by introducing high tech materials and automated operation







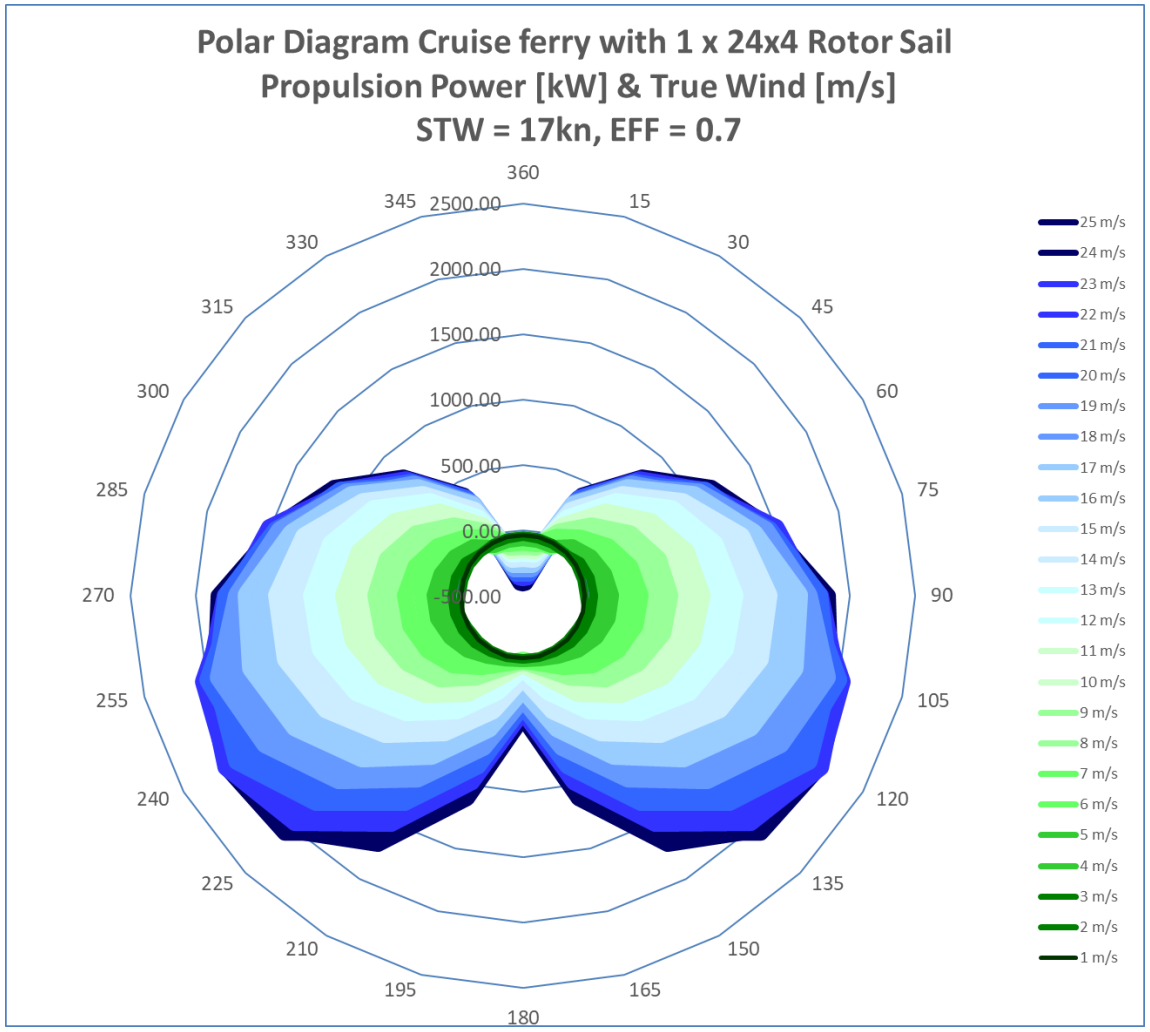
Norsepower Rotor Sails

- Main components
  - Composite rotor
  - Internal support steel tower
  - Upper support main bearing
  - Motor and drive for rotation
  - Lower support rollers
  - Foundation on ship's deck
- Properties

Rotor heights	18m, 24m, 30m
Rotor diameters	3m, 4m, 5m
Weight	20…45t
Revolution speed	max. 250rpm
Average el. consumption	15…35kW

Rotor Sail

Typical polar diagram



- The main-engine equivalent power produced by one Rotor Sail is represented in the polar diagram for different true wind speeds (the number of each coloured line represents the corresponding true wind speed in m/s). The power produced by the rotor is given in radial direction, the angle from vertical is the true wind angle.
- Parameters:
  - Service speed: 17 knots
- As can be seen at the polar diagram, the Rotor Sails start to save fuel already at a 20 degrees true wind angle, when the true wind speed is at least 7 m/s.
- The savings are maximized when the true wind angle is about 120 degrees and when the true wind speed is 20 m/s or more.

Most promising route areas for Rotor Sails

- The technology performs best when the average wind speed is high and typical winds are coming from the beam
- Examples of routes and areas with a high savings potential:
  - Northern Pacific crossing
  - Northern Atlantic crossing
  - North Sea and Baltic Sea areas

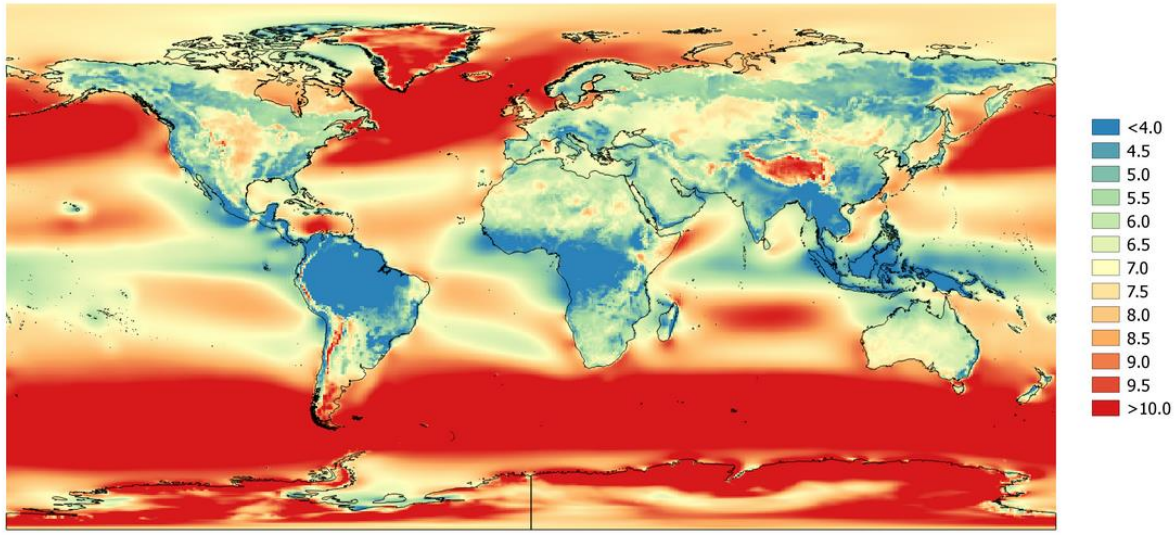


Figure 1
Mean wind speed at 100m from MERRA reanalysis. Period 1979-2013.

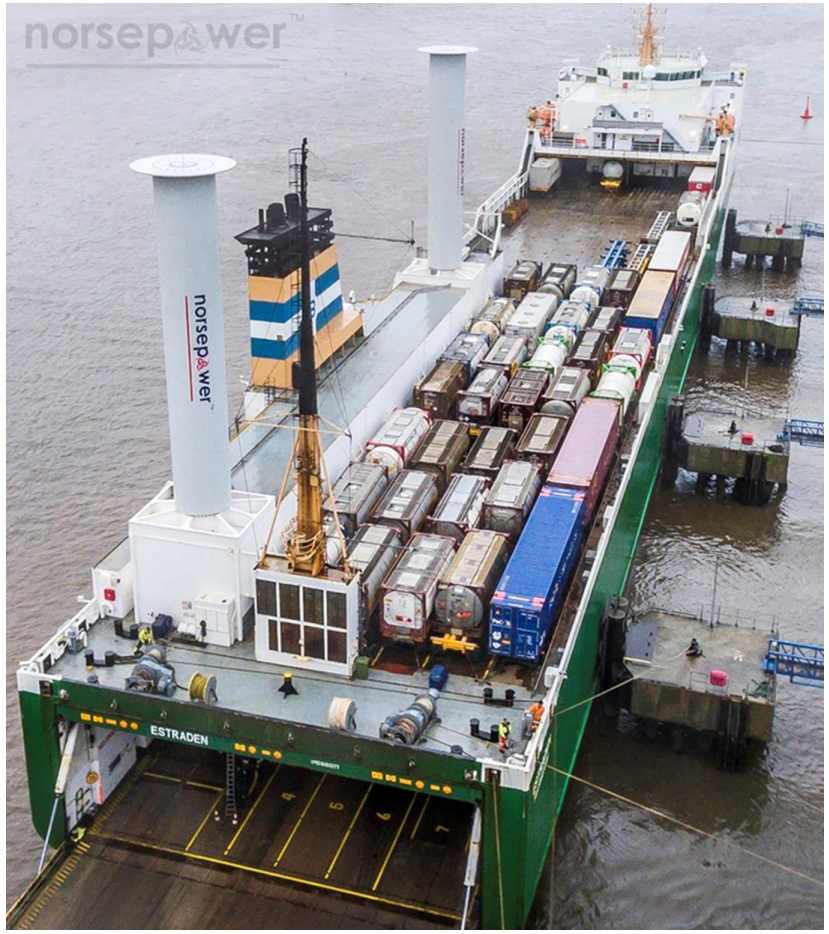
Experiences from M/S Estraden

Technical performance

- Thrust performance as expected
- System availability exceeds 99%
- Noise and vibrations remain at low levels
- The automation system works as intended

Operator experiences

- The rotor has a stabilising effect on the roll motion of the vessel
- No recognisable effect on rudder angles or leeway
- The system is easy to operate and the crew is able to use it after minimal-training



Average annual net savings: **6,1% (400 t of fuel and 1200 t of CO2)**
Payback period: **<4 years (MGO, 500 USD/t)**

Viking Grace project

- The foundation installation and cabling were done during a docking in January 2018
- One 24 x 4 Rotor Sail was installed as a retrofit onboard Viking Line's Viking Grace in April 2018
- The Rotor Sail-assisted cruises started on April 12, 2018

Viking Grace: targeted savings potential based on simulations

- LNG savings: 300 t/year
- CO_2 emissions reduction: 900 t/year

The most recent installation and next projects

Maersk P-class tanker

- Two 30 x 5m Rotor Sails were installed in the end of Aug. 2018 as a retrofit on a Maersk P-class oil products tanker
- The estimated average fuel savings on typical global shipping routes are expected to be 7 - 10% .
- Norsepower estimates that up to 20% average fuel savings are possible on routes with favourable wind conditions

Viking Line newbuilding

- Viking Line has placed an order for one 2800 passenger cruise ferry newbuilding with Xiamen Shipbuilding Industry Co. Ltd.
- Norsepower has an order from Xiamen Shipbuilding Industry for delivery of two 24 m high Rotor Sails
- Operation is planned to start in 2021

Future option: design with tiltable Rotor Sails

MISSION

To reduce the environmental impact of shipping by providing efficient, easy to use and reliable auxiliary wind propulsion for ships.

VISION

To maintain the market leader position in a growing market for auxiliary wind propulsion systems for large ships.

norsepower™

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