5-1 **An agent-based model of climate-energy policies to promote wind propulsion technology in shipping**

Richard Karslena, George Papachristos, Nishatabbas Rehmatulla

Date: June 2019

Abstract

The global trade share of international shipping is approximately 80% and it is therefore critical to the global economy. Carbon emissions from international shipping are expected to increase significantly in line with global trade trends. Several niche technologies for ship propulsion provide solutions to reduce shipping CO_2 emissions. These technologies face innovation barriers that potentially limit their diffusion. An agent-based model is developed to explore the effect of imperfect agent information and split incentives barriers that current shipping models omit. A transitions perspective is adopted to analyze the diffusion of Flettner rotor technology in time charter drybulk shipping with the model. Simulation results are more conservative compared to those models and show how barriers impact the diffusion of rotor technology, even on favourable shipping routes. The simultaneous introduction of carbon pricing and demonstration projects greatly increases CO_2 emission reductions to 2050 relative to either policy introduced in isolation.

https://www.sciencedirect.com/science/article/abs/pii/S2210422418301084
https://discovery.ucl.ac.uk/id/eprint/10069735/1/Rehmatulla_Accepted%20manuscript.pdf

5-2 **Harnessing wind energy on merchant ships: case study Flettner rotors onboard bulk carriers**

Ibrahim S. Seddiek & Nader R. Ammar

Date: February 2021

Abstract

Shipping faces challenges of reducing the dependence on fossil fuels to align with the international regulations of ship emissions reduction. The maritime industry is in urgent need of searching about alternative energy sources for ships. This paper highlights the applicability of harnessing wind power for ships. Flettner rotors as a clean propulsion technology for commercial ships are introduced. As a case study, one of the bulk carrier ships operating between Damietta port in Egypt and Dunkirk port in France has been investigated. The results showed the high influence of the interaction between ship course and wind speed and direction on the net output power of Flettner rotors. The average net output power for each rotor will be 384 kW/h. Economically, the results reveal that the use of Flettner rotors will contribute to considerable savings, up to 22.28% of the annual ship's fuel consumption. The pay-back period of the proposed concept will be 6 years with a considerable value of levelized cost of energy. Environmentally, NO_x and CO_2 emissions will be reduced by 270.4 and 9272 ton/year with cost-effectiveness of $1912 and $55.8/ton, respectively, at annual interest rate of 10%.

https://link.springer.com/article/10.1007%2Fs11356-021-12791-3

5-3 Influence of Kite Characteristics on Propulsive Power Applied to Ship Auxiliary Propulsion

Q. Penloup, K. Roncin, Y.Parlier

Date: September 2021.

Abstract

A Design of Experiment method was applied combined with a performance prediction program to assess the influence of four design parameters on the propulsive capacity of kites used as auxiliary propulsion for merchant vessels. Those parameters are the lift coefficient, the lift to drag ratio or drag angle, the maximal load bearable by the kite and the ratio of the tether length on the square root of the kite area. These parameters are independent from the kite area and, therefore, they could be used with various kite ranges and types. The maximum wing load parameter is the one that shows the most influence on the propulsive force. Over 50% of the gains obtained through this study are directly attributable to it. Then the ratio of the tether length on the square root of the kite area comes as the second greatest influence factor for true wind angles above 70°. While the drag angle is more influential for the narrower angles. In fact, the most substantial gains are made upwind.

https://onepetro.org/JST/article-pdf/6/01/173/2494516/sname-jst-2021-11.pdf

5-4 Rotors and bubbles: Route-based assessment of innovative technologies to reduce ship fuel consumption and emissions

Authors: Bryan Comer, Ph.D.a; Chen Chen, M.S.a; Doug Stolz, Ph.D.b; Dan Rutherford, Ph.D.a

Date: May 2019

Abstract

This preliminary assessment, which combined hourly AIS and global meteorological data, shows how innovative technologies such as wind-assist and air lubrication can reduce emissions from ships. For the ships and routes modeled, we found that rotor sails can reduce fuel consumption, CO2 emissions, and ship-level carbon-intensity between approximately 1% and 47% (about 1% to 12% per rotor); air lubrication systems can yield savings of between 3% and 13%. Rotor sail performance depends largely on wind speed and direction, and strong winds across the ship's beam generate the most power. In all cases, we found that rotor sails reduced route-level fuel consumption, CO2 emissions, and carbon intensity, although the magnitude depended on the type of ship, route, and associated weather conditions. In the Northern Hemisphere, we observed better performance in the winter months, when wind speeds tend to be stronger. We also saw a clear benefit to using multiple rotor sails, although additional rotors use more deck space. Ship owners who are interested in wind-assist technologies should consider the regions and typical weather conditions in which the ship operates, and should consider installing multiple rotors, when possible. Depending on fuel price, the payback period could be attractive. Air lubrication fuel and emissions reduction potential depends mainly on draught and ship speed. Low draught and high ship speed result in better MALS performance, although faster ship speeds increase absolute route level fuel consumption compared to slower speeds. Air lubrication performance is less sensitive to geography and provides more consistent fuel savings in the cases we modeled. Retrofitting air lubrication systems is uncommon to date, however, and thus this technology may be better suited for newbuilds.

https://theicct.org/sites/default/files/publications/Rotors_and_bubbles_2019_05_12.pdf

5-5 **Study on the Analysis of Market Potentials & Market Barriers for Wind Propulsion Technologies for Ships** (commissioned by European Commission DG Climate Action) Dagmar Nelissen, Jasper Faber, Saliha Ahdour (CE Delft), Michael Traut (Tyndall Centre) Jonathan Köhler (Fraunhofer ISI) Wengang Mao (Chalmers University), Nov 2016 – publicly available Jan 2017

Abstract

The study analyses wind as a renewable energy source for maritime transport and has the following objectives: the identification of barriers to the development and uptake of wind propulsion and possible actions to overcome these barriers, the estimation of the technologies' market and emissions savings potential and the associated economic and social effects. Three key barriers have been identified: 1. (Trusted) information on the technologies. 2. Access to capital for building and testing of full scale demonstrators. 3. Incentives to reduce the ships' CO2 emissions. Possible actions to overcome these barriers are proposed, with the development of a standardized assessment method combined with test cases as an important starting point. Power savings have been calculated for four generic propulsion technologies, six sample vessels, two speed regimes, considering AIS voyage profiles and sample routes. Rotor and wingsail show similar, substantial relative savings, the kite higher (lower) savings for smaller (larger) vessels; savings are lowest for wind turbines. With increased speed absolute savings of rotor and wing sail rise. In 2030, the market potential could amount to around 3,700–10,700 installed systems on bulkers and tankers, associated with approximately 3.5–7.5 Mt CO2 savings and 6,500–8,000 direct and 8,500–10,000 indirect jobs.

https://cedelft.eu/wp-content/uploads/sites/2/2021/04/CE_Delft_7G92_Wind_Propulsion_Technologies_Final_report.pdf