



Fully Automated Wind Tunnel Experiments on a Double Rotor

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Gefördert durch:



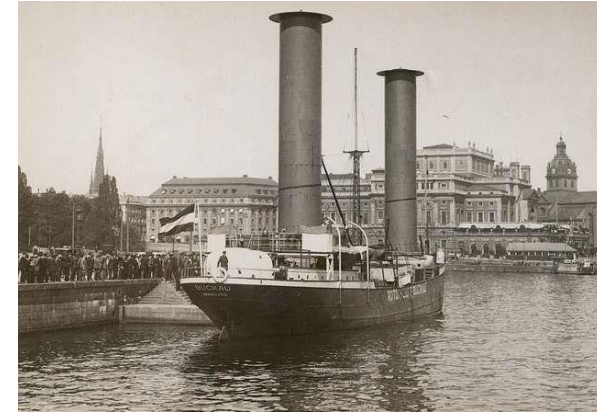
aufgrund eines Beschlusses
des Deutschen Bundestages

Research Questions

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Sustainable Maritime Mobility



- How is overall performance affected when a second Flettner rotor is installed?
- Do the Flettner rotors need to run at maximum speed to generate maximum thrust?
- Does the arrangement of the rotors matter?



Problem: Combinatorics

- 2 Flettner-Rotors with 11 rotational speeds tested in every combination: $11 \times 11 = 121$ Measurements
- With 2 rotors, the symmetry of the problem is lost and we need to test angles of attack from 0° to 180° for every combination: $11 \times 11 \times 14 = 1694$ Measurements
- We also wanted 3 distances between the rotors in every combination: $11 \times 11 \times 14 \times 3 = 5082$ Measurements
- 3 different wind speeds for showing Reynolds Independence... $11 \times 11 \times 14 \times 3 \times 3 = 15246$ Measurements
- In the end „only“ 10164 Measurements were done, because the Reynolds Independence could be cut

Solution to the Combinatorial Explosion

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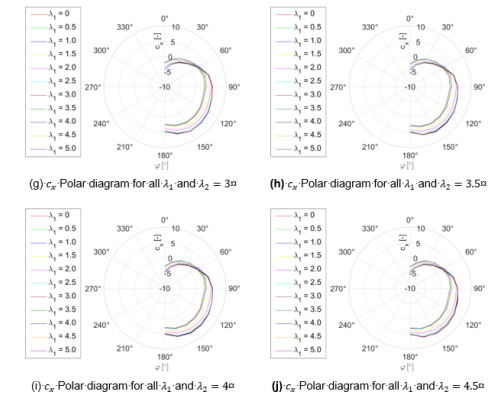
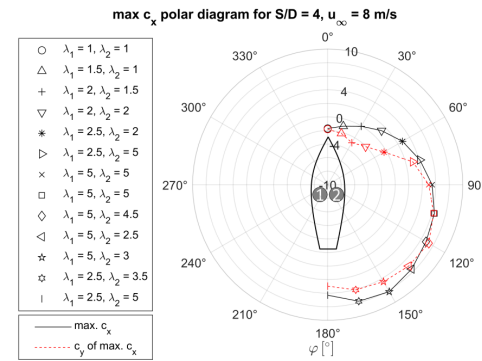
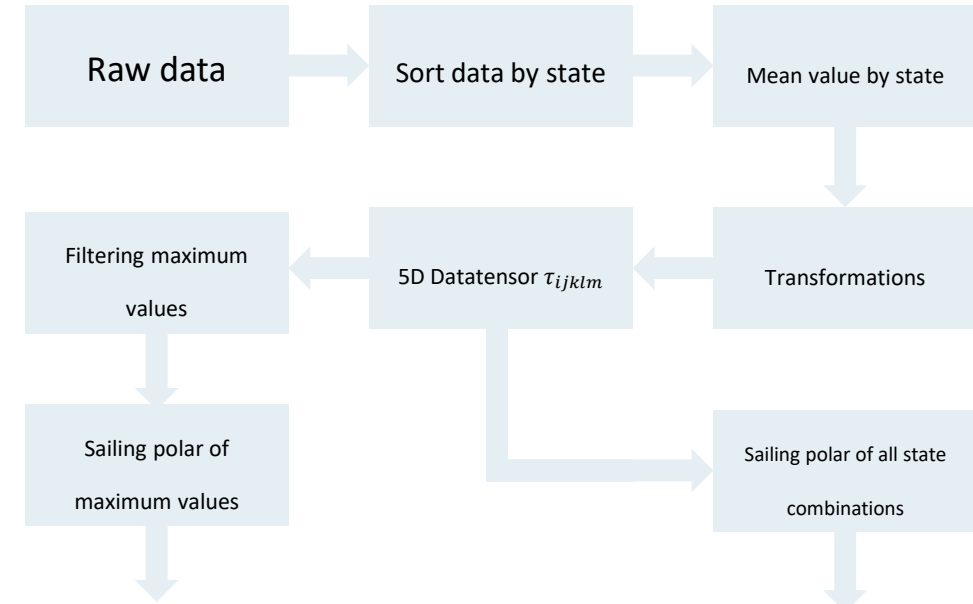


- 10164 Measurements done manually?
 - Assuming 5 minutes per experiment, this would take more than 5 months of non-stop measurements at the wind tunnel
- Solution: Automating the process
 - Our setup allows setting parameters automatically during wind tunnel operation.
 - With 30s measurements per parameter set, all measurements take 3.5 days



Data Reduction Strategy

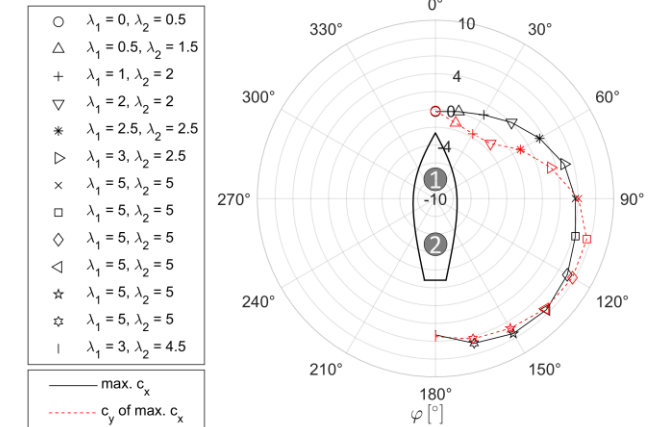
- Huge Dataset
 - 10164 Measurements, 30s at 10Hz, 15 Values recorded
 - 45.738.000 Values
- 5D Tensor structure
 - 84 11x11 matrices
 - Indices define state
 - Matrices contain c_x/c_y values



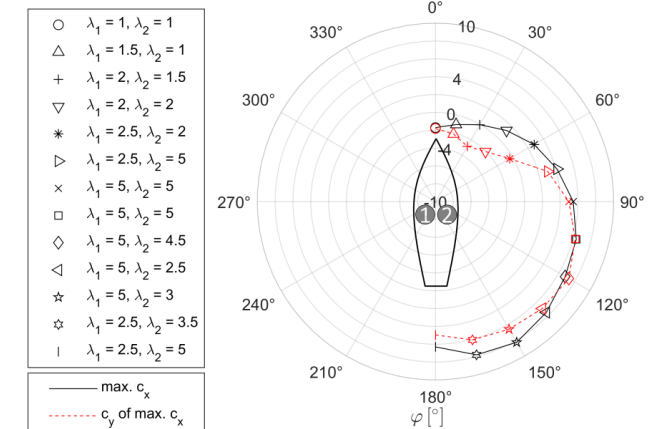
Results

- The rear rotor (in the wind) can rotate up to 50% slower than the front rotor.
- The rear rotor can actually be more powerful when operating in the wake of the front rotor.
- Rotors arranged transversely to the ship's length generate about 10% more thrust than those arranged longitudinally.
- By carefully adjusting rotational speed, spacing, and arrangement, the energy efficiency of ships equipped with Flettner rotors can be significantly increased.

max c_x polar diagram for $S/D = 4$, $u_\infty = 8$ m/s

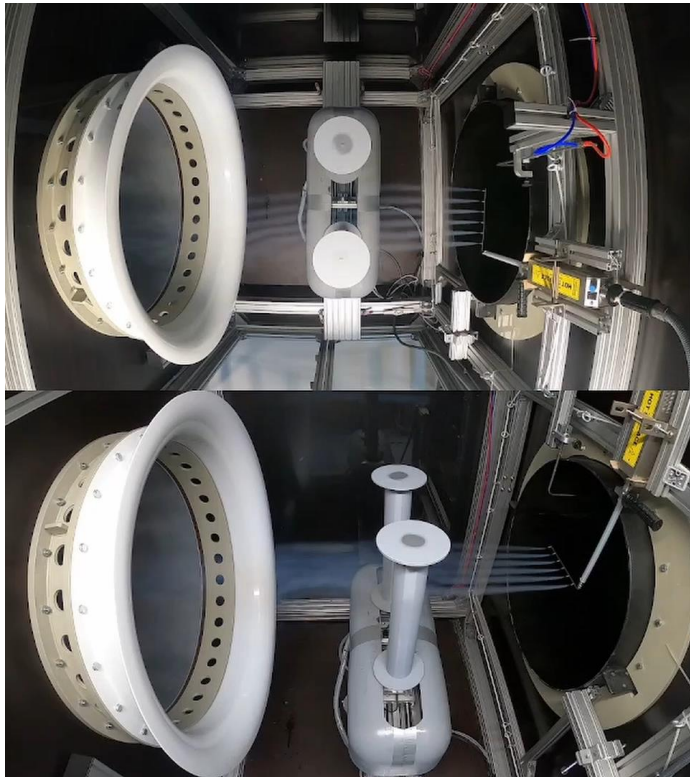


max c_x polar diagram for $S/D = 4$, $u_\infty = 8$ m/s



Results

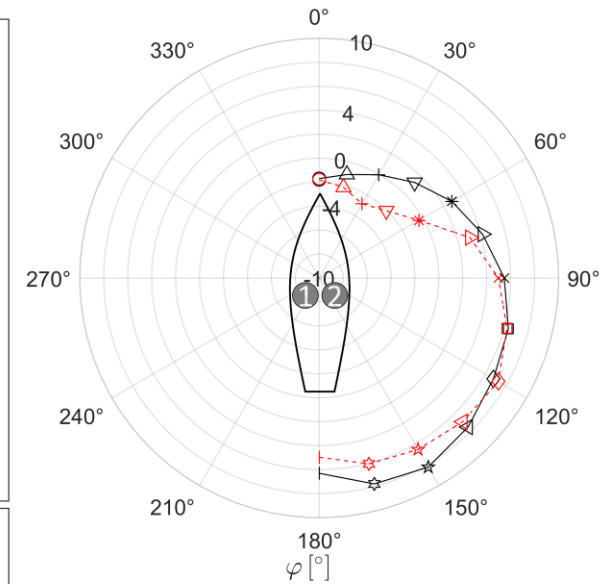
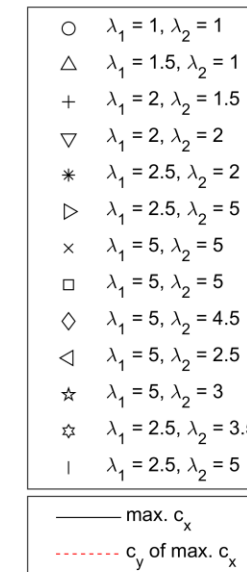
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rotor1 = 30 Hz ($L1 = 1$)
rotor2 = 30 Hz ($L2 = 1$)
angle of attack = 0°
distance = 360 mm ($S/D = 4$)
windspeed = 8 m/s

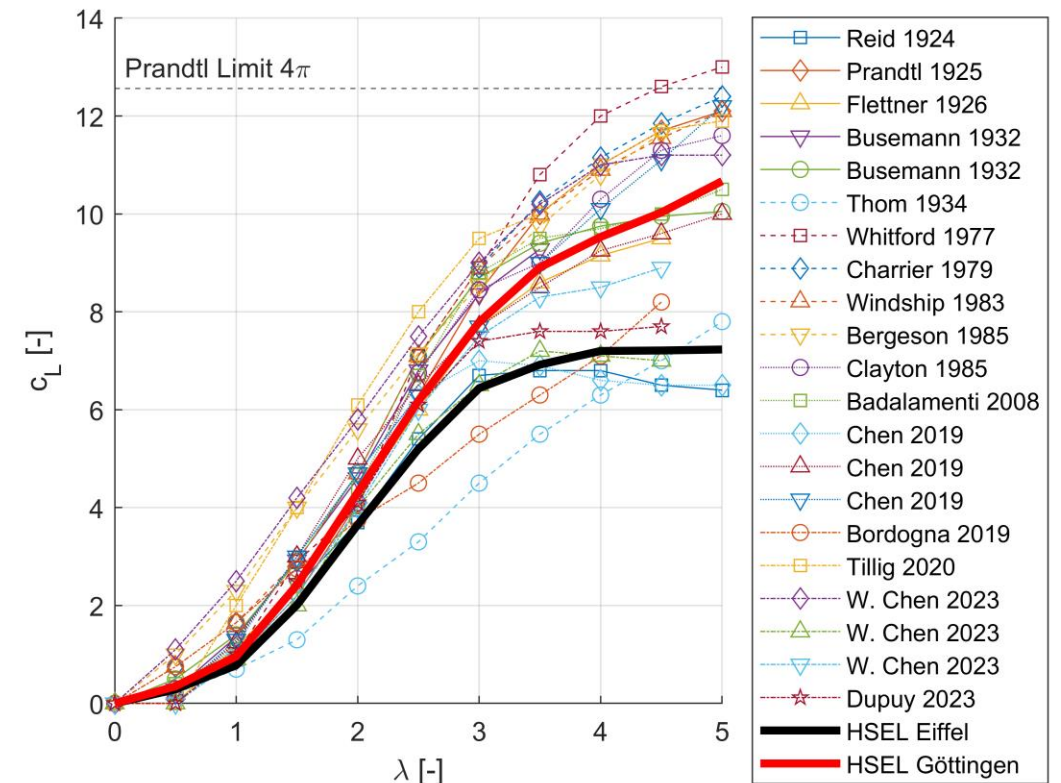


max c_x polar diagram for $S/D = 4$, $u_\infty = 8$ m/s



Further Research

- We observed that the rear rotor performs better than the front rotor in certain conditions
- Hypothesis: Turbulence has a positive effect on the Magnus Effect
- Research question: Where must the turbulence be present for improving the Flettner-Rotor's performance?
- Testing is on-going





Flettner FLEET



Shaping a World of Trust



Thank you for your attention!

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Gefördert durch:



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