XI International Conference on Computational Methods in Marine Engineering

Aerodynamic testing of rotor sails: A scaling challenge

Alberto. F. Rius-Vidales[1*], Supun Pieris [2],
Albert. A. K. Rijkens[1], John. W. Kurelek[2] and Marcus Hultmark[3]

[1] Maritime and Transport Technology Department, Delft University of Technology, Delft, NL
[2] Mechanical and Materials Engineering Department, Queen's University, ON, CA
[3] Mechanical and Aerospace Engineering Department, Princeton University, NJ, USA
[*] Corresponding author email: a.f.riusvidales@tudelft.nl

ABSTRACT

A major challenge when predicting the performance and loads of wind propulsion systems, is the lack of data, numerical or experimental, representative of the full-scale conditions. Figure 1, shows an overview of the $Re_D = (\rho U_\infty D)/\mu$ used in recent experimental (e.g. Bordogna et al., 2019; Chen et al., 2023; Deybach et al., 2024) and numerical (e.g. Jiang et al., 2024; Kwon et al., 2022; Liu et al., 2024; Massaro et al., 2024) rotor sail studies.

In conventional atmospheric wind tunnels the reduced diameter (D) of rotor-sail models makes it difficult to simultaneously match the Reynolds number ($1 \times 10^6 \leq Re_D \leq 6 \times 10^6$) and velocity ratios ($k = U_T/U_\infty$ = 1 to 5) of full-scale conditions. In this work, we propose using a pressurized wind tunnel facility to overcome this limitation.

The advantage of pressurized wind tunnel testing, over a conventional atmospheric tests, lies in the ability to modify the fluid density (ρ) and free-stream velocity (U_∞) to match both Re_D and k. To this end wind tunnel experiments at the High-Reynolds Number Test Facility (HRTF) have been conducted on a rotor-sail model of $AR = 5$ and 6 and endplate sizes $D/De = 1.6$ and 3 in the Re_D range indicated in Figure 1.

With this presentation, we would like to contribute to the invited session in Simulation Methods For Wind Propulsion Of Ships by: 1) Providing an overview of the challenges in experimentally simulating rotor sails, which limit the availability of benchmark experimental data for CFD at representative conditions. 2) Providing a first step toward high-Reynolds number experimental benchmark data for CFD simulations. 3) Provide insight into the Reynolds number dependence of the aerodynamic loads, which can be used to guide future CFD simulations.

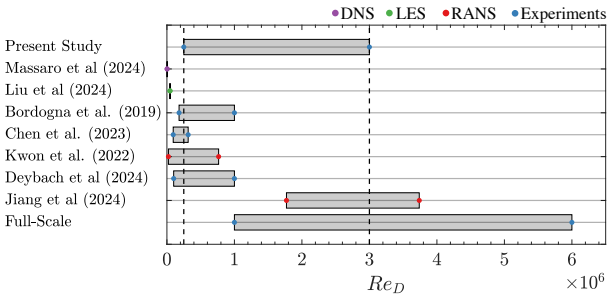

Figure 1: Overview of Re_D in recent experimental and numerical studies.

References

Bordogna, G., Muggiasca, S., Giappino, S., Belloli, M., Keuning, J., Huijsmans, R., and Veer, A. v. . (2019). Experiments on a Flettner rotor at critical and supercritical Reynolds numbers. *Journal of Wind Engineering and Industrial Aerodynamics*, 188:19–29.

Chen, W., Wang, H., and Liu, X. (2023). Experimental investigation of the aerodynamic performance of Flettner rotors for marine applications. *Ocean Engineering*, 281:115006.

Deybach, F., Mudry, M., Robert, C., and Paakkari, V. (2024). Aerodynamics of the Flettner rotor at high Reynolds Number. In *RINA Wind Propulsion Conference*.

Jiang, Y., Liu, K., Zhang, Q., and Zhang, Z. (2024). Lift modeling, load and vibration analysis of Magnus rotors. *Ocean Engineering*.

Kwon, C. S., Yeon, S. M., Kim, Y. C., Kim, Y. G., Kim, Y. H., and Kang, H. J. (2022). A parametric study for a flettner rotor in standalone condition using CFD. *International Journal of Naval Architecture and Ocean Engineering*, 14:100493.

Liu, Q., Gong, S., Lu, H., Tang, F., and Liang, Z. (2024). Coupling impacts of end effects and rotation on the three-dimensional flow around a rapidly rotating circular cylinder with two flat ends. *Physics of Fluids*, 36(11):115106.

Massaro, D., Karp, M., Jansson, N., Markidis, S., and Schlatter, P. (2024). Direct numerical simulation of the turbulent flow around a Flettner rotor. *Scientific Reports*, 14(1):3004.