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Numerical simulation of vertical axis wind turbine in turbulent flow

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Abstract

Vertical axis wind turbines (VAWTs) have recently received increasing attention for their fit in the need for renewable energy solutions and their applicability in urban areas. Therefore, an efficient flow solver was developed to predict and study the aerodynamic performance, by exploiting finite volume and direct forced immersion boundary (DFIB) methods. Convective dynamics (QUICK) schemes are used for discretized spatial terms, second-order central differencing, and second-order quadratic upstream interpolation. Discretization of the time term is done using the Adam-Bashforth scheme. The successive over-relaxation (SOR) method is then used to solve the pressure Poisson equation. The Smagorinsky-Lilly turbulence model flow is used in large eddy simulations (LES) to resolve turbulent scales.

Problem description

Schematic diagram of computational domain for rotating Savonius rotor.
The computational domain for the rotor as well as the relevant distances is illustrated. The boundary conditions used in the simulation are described as follows. At the inlet, a wind velocity of 7 m/s and a pressure gradient of 0 were set. The Neumann boundary conditions for pressure and velocity were used at the outlet.

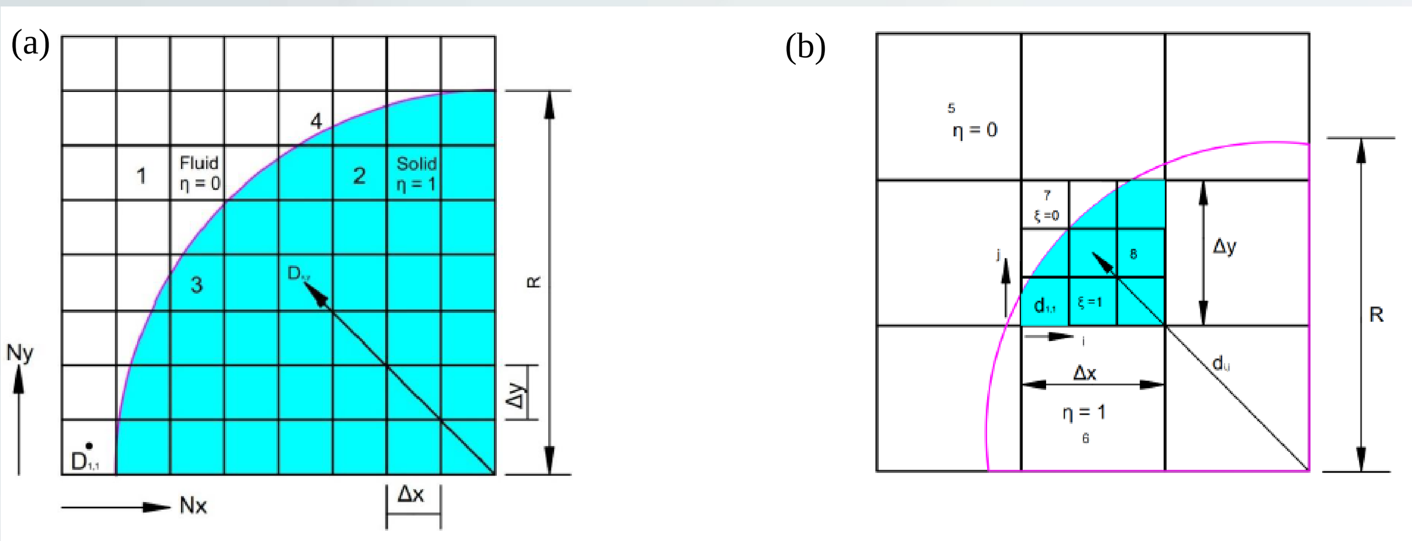


Fig. (a)grid cell schematic representation for defining etaη; (b) demonstration of subgrid cells used to define ξ.

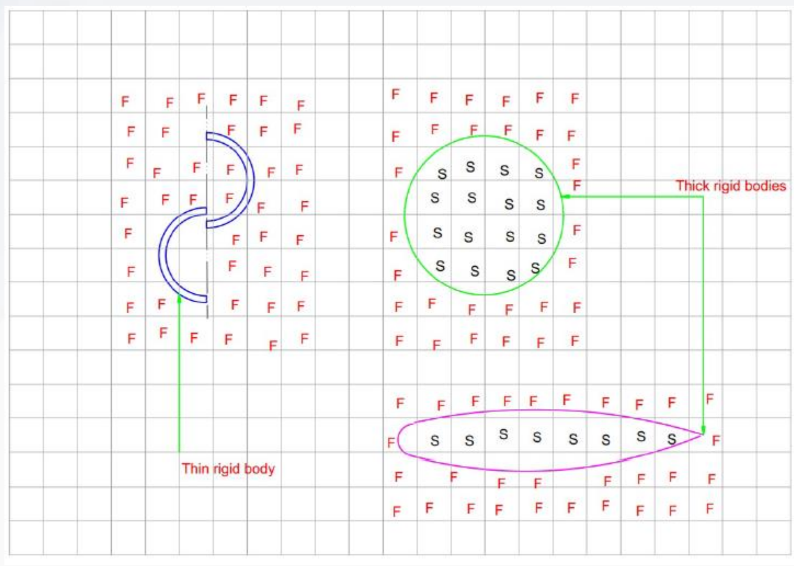


Fig. llustration DFIB method application for thick and thin rigid bodies. In a particular figure, F represents the fluid grid cell, and S is solid grid cell.

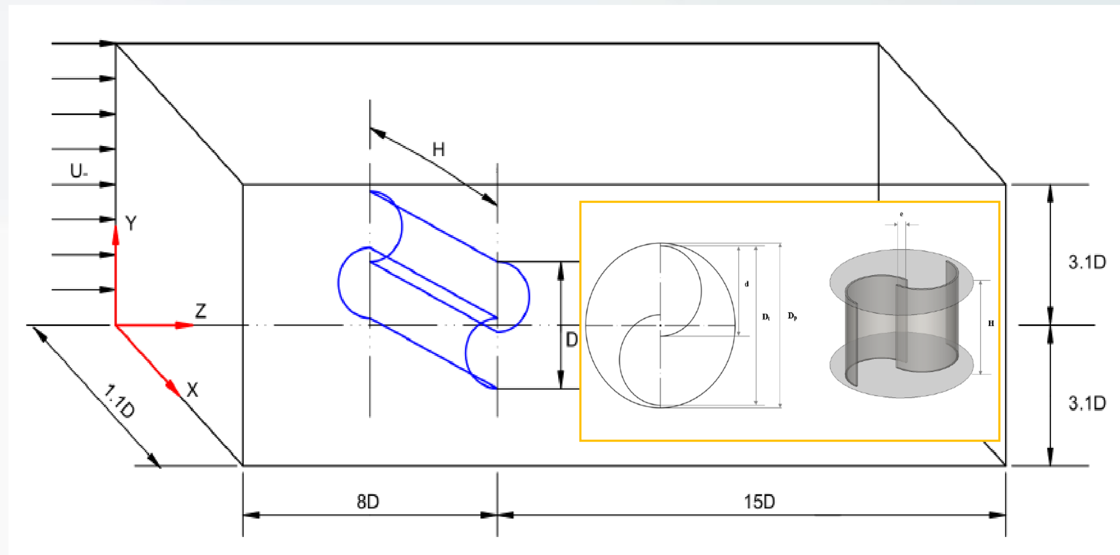


Fig. Description of the computational domain.

Results and discussion

The vorticity field, instantaneous pressure, and torque were used to study the interaction between the fluid and the rotor. The intensities of vortices generated at the blade tip were then related to the power coefficient value.

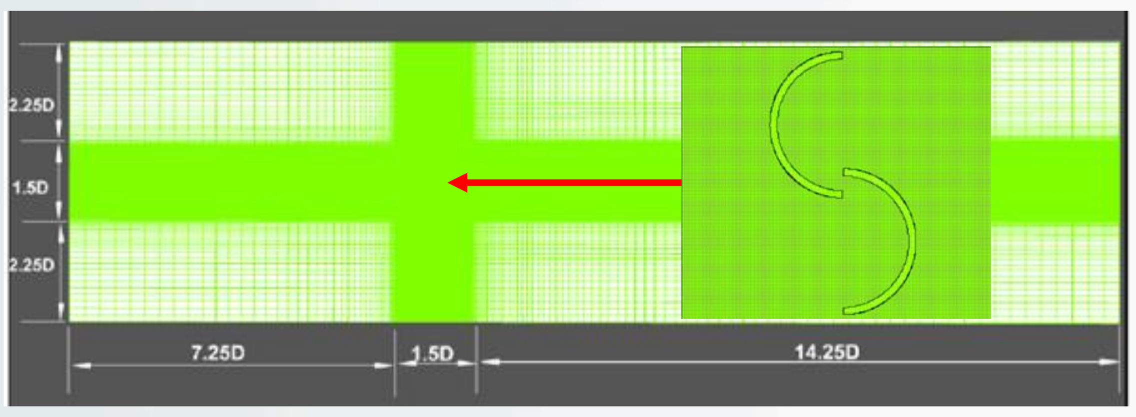
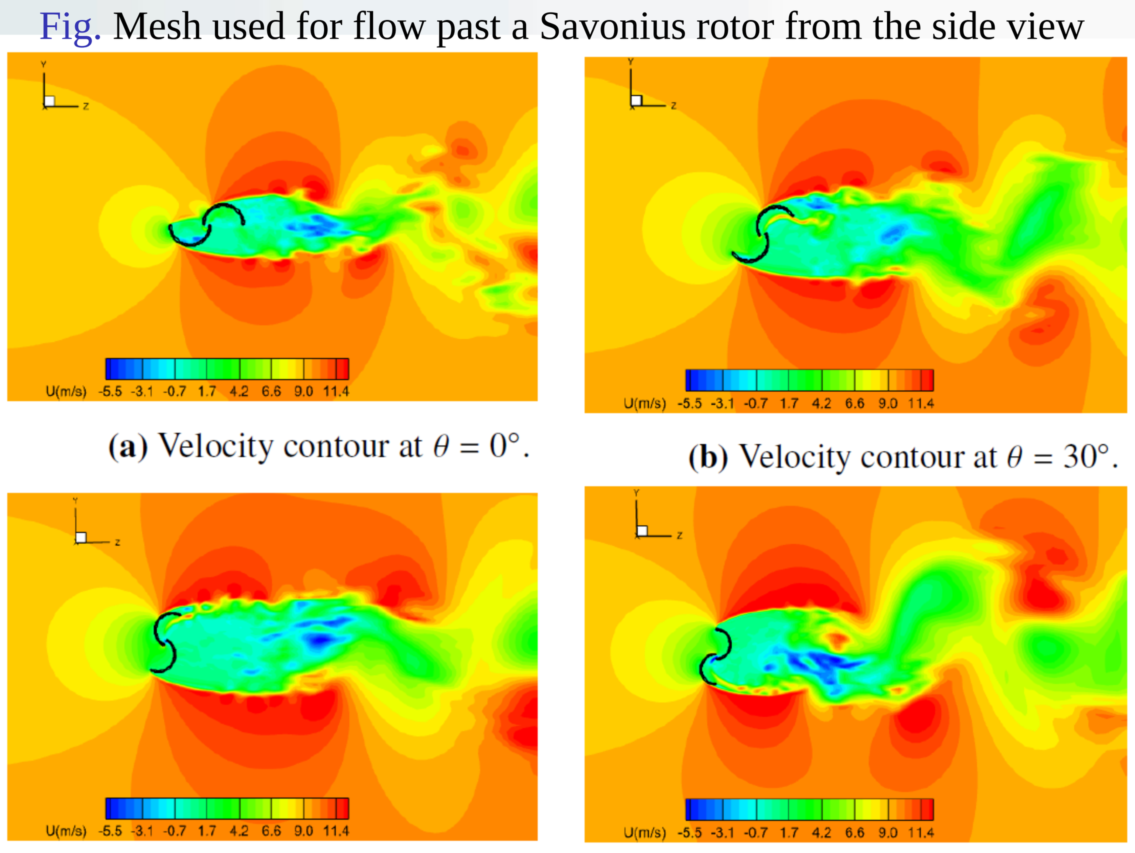
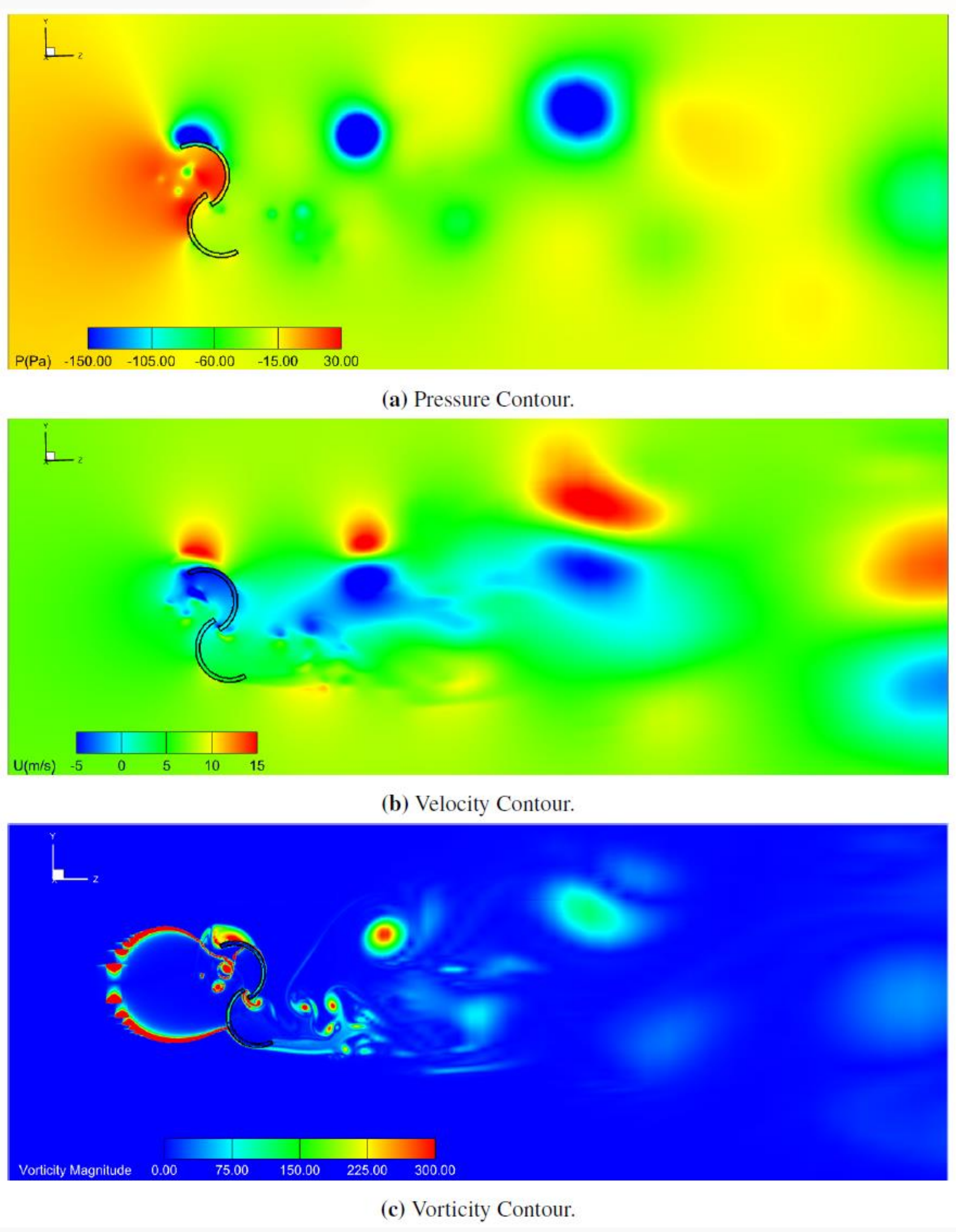


Fig. Mesh used for flow past a Savonius rotor from the side view



(a) Velocity contour at $\theta = 0°$.
(b) Velocity contour at $\theta = 30°$.
(c) Velocity contour at $\theta = 60°$.
(d) Velocity contour at $\theta = 90°$.

Fig. Side-view of velocity field for the Savonius rotor at angular position of 0◦, 30◦, 60◦ and 90◦.



(a) Pressure Contour.
(b) Velocity Contour.
(c) Vorticity Contour.

Fig. The pressure, velocity, and vorticity field in 2D plane.

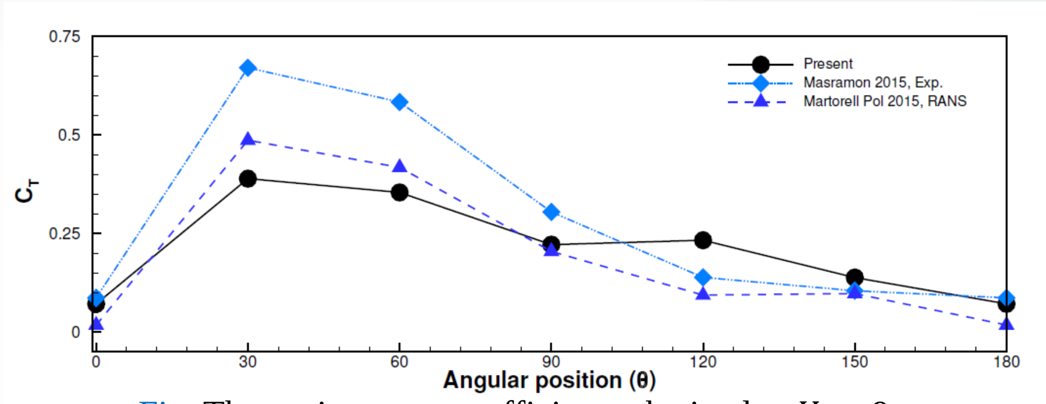


Fig. The static torque coefficients obtained at $U_\infty = 9$ m

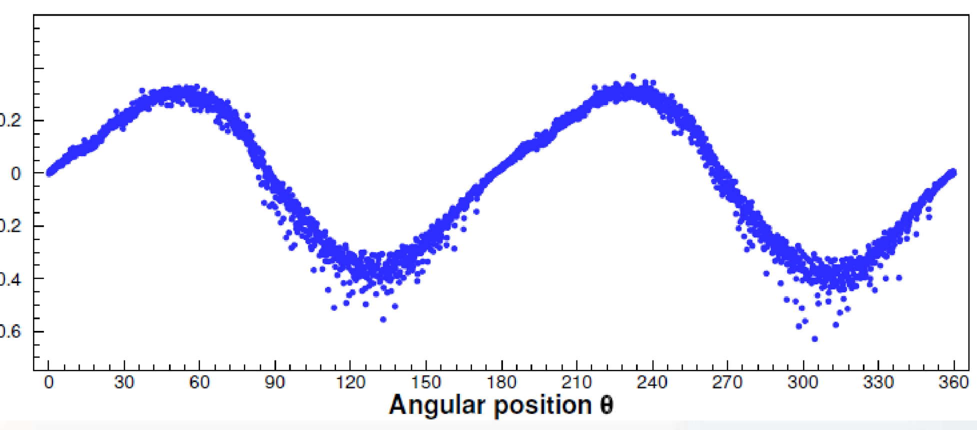


Fig. Instantaneous power coefficient versus angular position of the blades

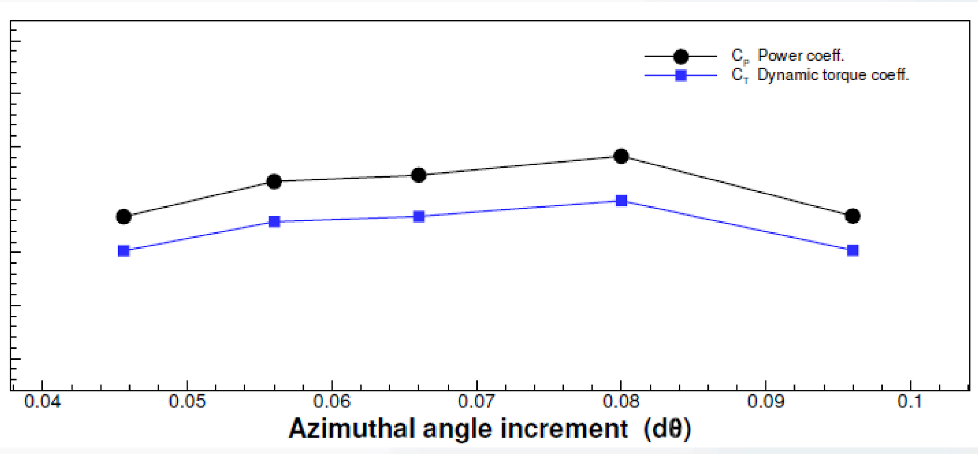


Fig. Mean power and dynamic torque coefficients for various azimuthal angle increments ($d\theta$) at $\lambda = 0.8$

Conclusions

The DFIB method coupled with the GA successfully simulated rotating VAWT blades in flow fields and noticeably improved the performance of the optimized blades of the VAWT. The new algorithm developed using a DFIB method successfully simulated the interaction of the fluid with volumeless and thin, rigid structures. The minimum number of turbine rotations rquired to maintain a statistically steady state in the simulations determined.

References

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Acknowledgements

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