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Optimizing Flat Plate Orientation as Passive Flow Control in a Magnus Effect VAWT: A Numerical Investigation

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Abstract

The Magnus effect VAWT utilizes the "Magnus effect" principle [1] in combination with a vertical axis orientation. This allows the Magnus VAWT to control power generation amidst varying wind speeds and directions. The proposed method involved installing a flat plate near each rotating cylinder to generate a net torque while minimizing the energy input. A direct-forcing immersed boundary (DFIB) numerical model was used to simulate the flow past a rotating cylinder with a flat plate at several positions, and then the optimal flat plate orientation was determined by the highest torque produced.

Problem description

- One of the challenges in the Magnus effect VAWT is how to produce a high net torque while minimising the energy input. One effort that can be done is by maintaining a constant cylinder rotation speed.
- In this study, a flat plate was placed in such a way at a certain gap to the cylinder without being dependent on cylinder rotation. The plate moves to follow the movement of the cylinder as it revolves around the rotor axis (Fig. 2).
- The position of the flat plate is expected to change the flow pattern and the Magnus force, resulting in a unidirectional torque at each position of the blade.
- The investigation was done at Re=5,000 and a constant spin ratio (α)=2 [2]. For this purpose, a 3D numerical simulation was carried out by implementing the direct-forcing immersed boundary (DFIB) method with the LES turbulence model.

$$\text{spin ratio } (\alpha) = \frac{\text{Cylinder's surface velocity}}{\text{Free stream velocity}}$$

Fig. 1. Challenergy, Inc.'s Magnus effect VAWT. https://edition.cnn.com/style/article/typhoon-catchers-japan-challenergy/index.html

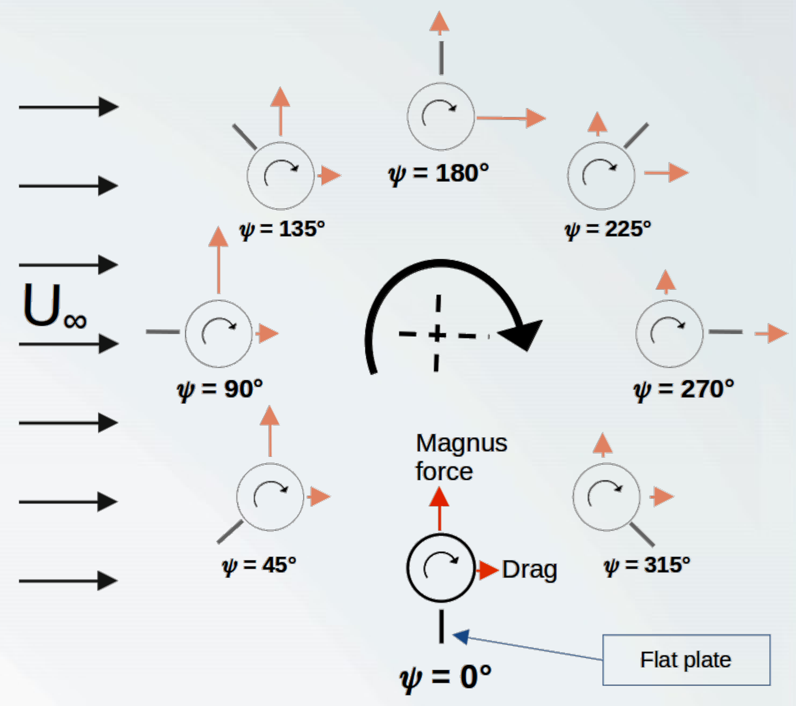

Fig. 2. The trajectory and forces illustration of a single bladed Magnus effect VAWT with a flat plate. (ψ is the azimuth angle).

Results and discussion

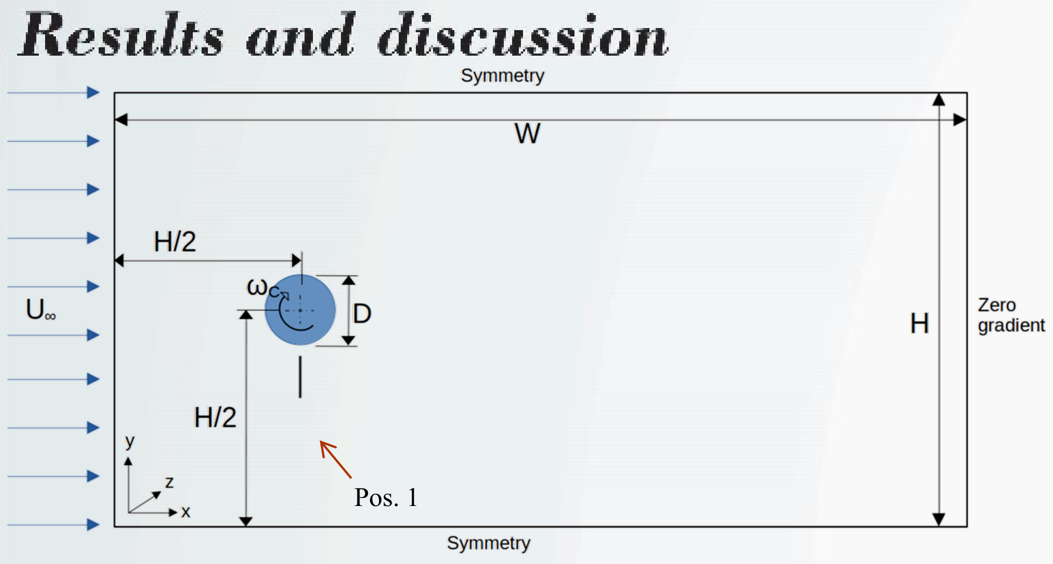

Fig. 3. Simulation domain and boundary conditions.

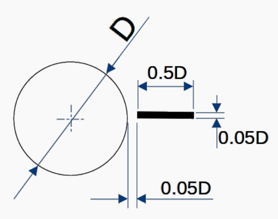

Fig. 4. The flat plate geometry.

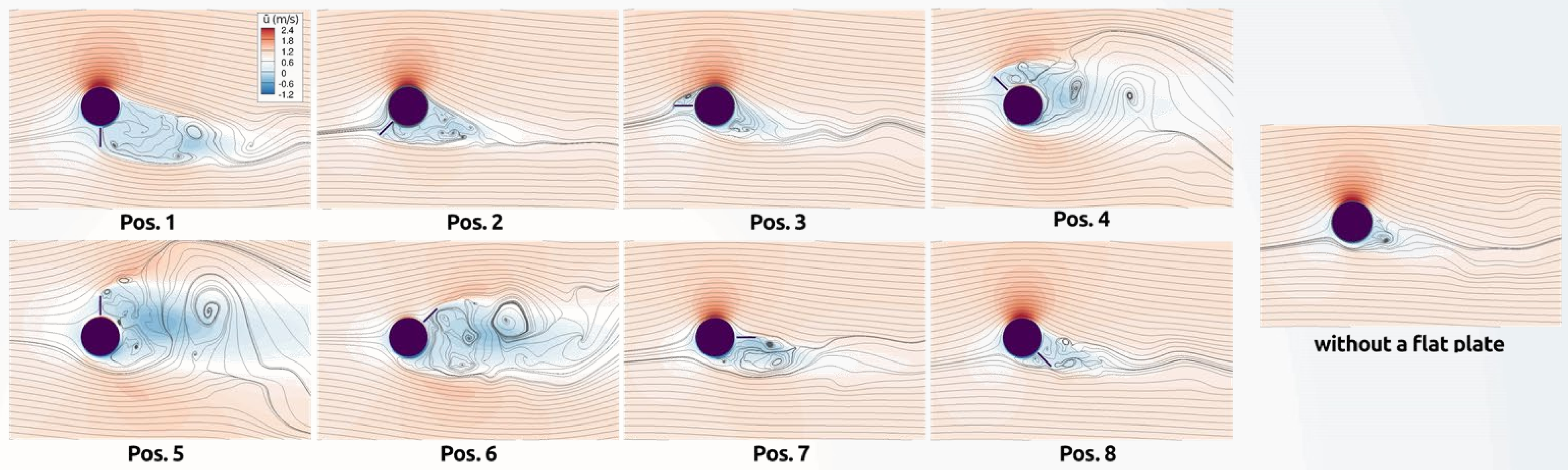

Fig. 5. Streamlines and $\bar{u}$-velocity contours at different flat plate positions. (Pos. 1 - 8)

Table 1. The calculated average torque in one cycle at different flat plate orientations.

Initial position (at $\psi = 0°$)	Average torque in one cycle
Pos. 1	3.301
Pos. 2	−1.013
Pos. 3	−4.733
Pos. 4	−5.681
Pos. 5	−3.301
Pos. 6	1.013
Pos. 7	4.733
Pos. 8	5.681

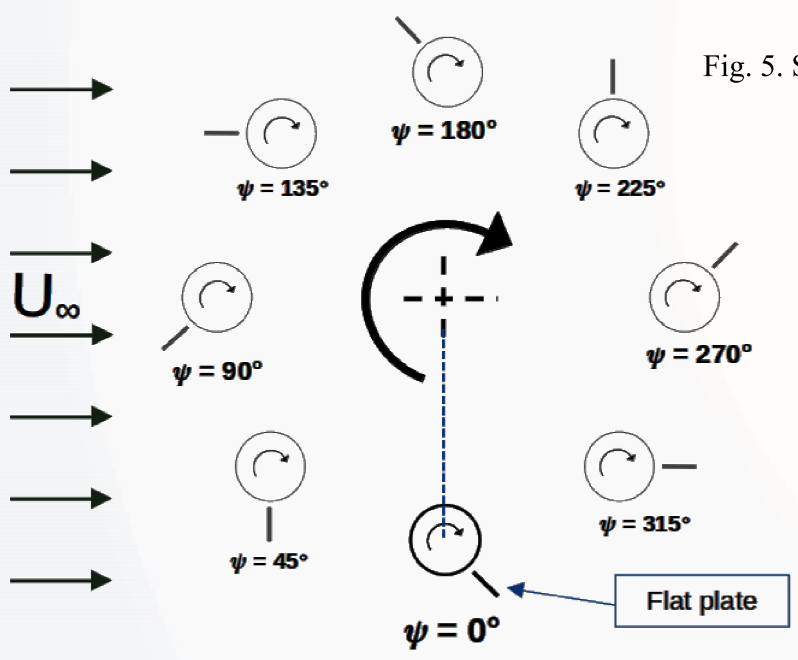

Fig. 6. The trajectory of a single blade with an optimized flat plate position. (Pos. 8 at $\psi = 0$)

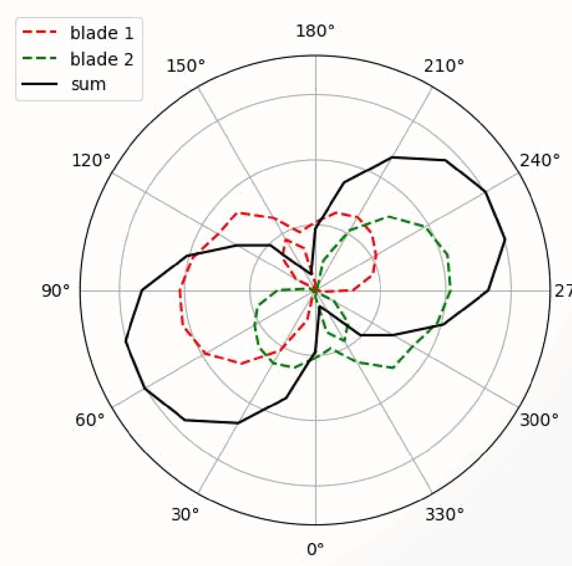

Fig. 7. Instantaneous torque coefficient distribution of a 2-bladed Magnus rotor at the optimized flat plate position.

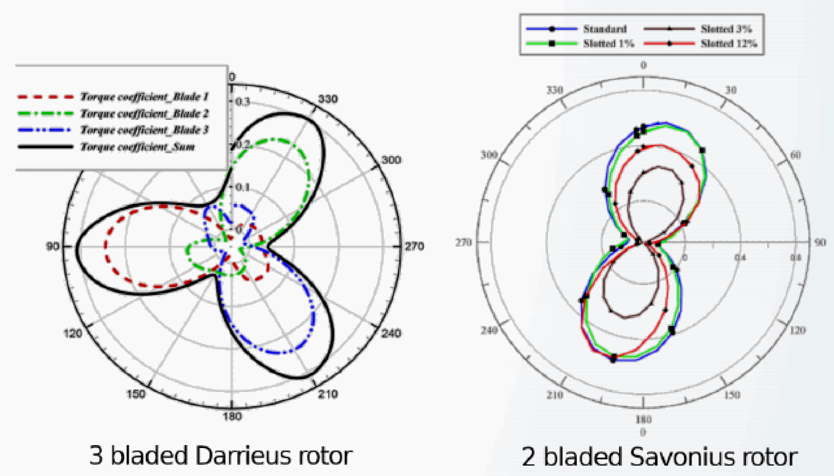

Fig. 8. Typical torque distributions for other types of VAWTs. [3-4] (as a comparison)

- The Magnus force and the drag change with the flat plate position. (Fig. 5)
- The highest average torque produced by the rotor was achieved by setting the flat plate Pos. 8 as the initial position at $\psi = 0$. (Table 1). An illustration of the flat plate movement in one rotor cycle is given in Fig. 6.
- A single-blade Magnus effect turbine could generate torque over a wider range of azimuth angles than a typical Darrieus or Savonius type VAWT. (Figs. 7-8)

Acknowledgement
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Conclusions

- The use of a flat plate as the passive flow control in a Magnus effect VAWT has been numerically investigated.
- The optimal flat plate orientation has been determined by maximizing the resulting torque.
- The Magnus effect VAWT exhibits the potential to produce a comparable amount of power to other VAWT designs, through the utilization of a flat plate as a means of passive flow control.

References

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