Experimental 2D simplified analysis of the wake velocity profile of a flat plate solar tracker in a defence position immersed in a uniform flow

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SUMMARY:
The wake speed profile of a solar tracker is studied by analysing the wake deflection and dynamic pressure loss in the streamlines at a fixed distance downwind from the axis of the solar tracker. The defence angle is modified to analyse its influence on the tracker wake speed profile.

Keywords: Solar tracker, wake deflection, dynamic pressure loss.

1. INTRODUCTION

Satisfying the growing demand for electricity requires the development of new energy sources, such as solar energy. A solar tracker has 10 to 30% higher efficiency than a fixed solar panel (Zhang et al 2023). The structures that support these trackers are becoming less rigid and lighter to save cost. Therefore, they are more sensitive to aeroelastic instabilities whose effects lead to structural deterioration (Rodríguez-Casado et al 2024, Cárdenas-Rondón et al 2024).

Solar trackers are installed in multiple rows of trackers fields. For this reason, upstream trackers influence the aeroelastic behaviour of others downstream. The incoming flow of a tracker is the wake of another one upstream (Wang et al 2021).

The objective of this work is to experimentally characterise the wake of a solar tracker modelled as a flat plate for different defence angle positions at a certain position downstream. The selection of this position is based on the most popular distance between tracker rows in the industry.

2. EXPERIMENTAL SETUP

The model consists of a wooden flat plate with a chord $B = 40$ cm, set at a fixed angle, with a wooden false floor. The height between the model axis and the floor is $H/B = 0.5$. Tests have been performed in the IDR/UPM AB6 wind tunnel, located in Montegancedo campus premises of the Universidad Politécnica de Madrid. It is a two-dimensional closed-circuit wind tunnel, which has a 2.5m × 0.5m closed test section, 4m length, with a 4.5:1 contraction ratio. The maximum wind speed inside the test chamber is 35 ms^{-1}. For the instrumentation, a two-component hot-wire probe Dantec 55P61 has been used to measure the velocity at different heights z. To change the height of the hot wire, a Zaber guide has been placed under the false floor of the wind tunnel, attached to the tunnel wall, which moved an "L"-shaped metal support structure probe holder holding the hot wire probe on top of it, as shown in Figure 1. This velocity has been characterised with its both components: horizontal u and vertical w.

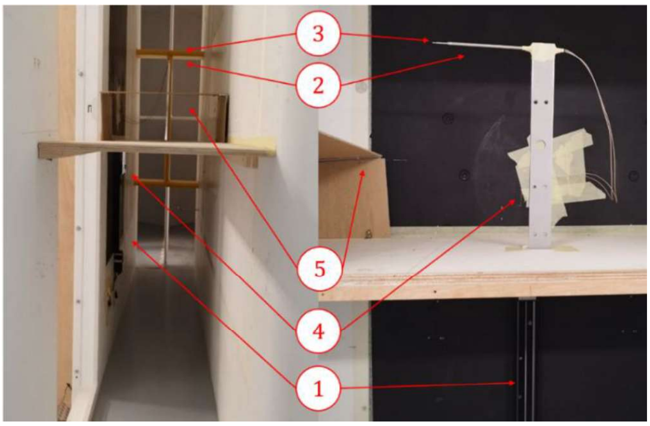

Figure 1. Experimental set-up inside the test chamber. Labels: (1) ZABER Guide (2) Probe holder; (3) Wire probe; (4) Metallic structure; (5) Solar tracker model.

The tests have been repeated for several values of the defence angle α_d = 5°, 10°, 15°, 20° and 30°. For each configuration, the flow velocity has been U_∞ = 5 ms^{-1}, 10 ms^{-1} and 15 ms^{-1}. Finally, in each test the height where wind speed has been measured between $z/B = 0.1$ and $z/B = 1$, in 40 evenly spaced points at a position $d/B = 0.75$. The height between the model axis and the floor is $H/B = 0.5$. A sketch of this experimental set-up is shown in Figure 2.

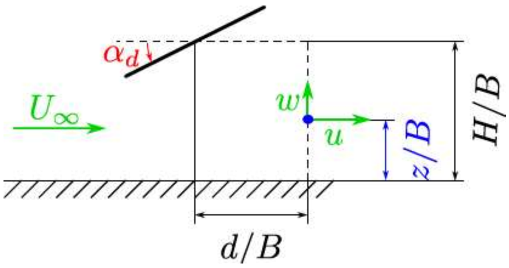

Figure 2. Sketch of the studied parameters: the defence angle α_d, flow velocity U_∞, measurement points height z/B, distance between the measurement position and the tracker axis d/B, axis tracker height H/B, horizontal u and vertical w wake speed components.

3. RESULTS

The behaviour of the streamlines in the wake is analysed: their modulus (dynamic pressure loss $\eta = (u^2 + w^2)/U_\infty^2 = |\vec{v}|^2/U_\infty^2$) and direction (wake deflection ε), vary with α_d. The mean non-dimensional wake velocity profile for each α_d is shown in Figure 3. It has been calculated with the mean for all tested U_∞ for each α_d, since it is almost identical for each U_∞. In each graph, there is a continuous line at z/B = 0.5, corresponding to the tracker axis height, and two dashed lines, one at a lower and one at a higher height, corresponding to the model leading and trailing edge height, respectively. The medium wake height is called wake axis (red dotted line in Figure 3).

For α_d = 5°, the streamlines show hardly any deflection, and a slight dynamic pressure loss. The maximum pressure loss is $\eta = 0.74$ and the maximum deflection is $\varepsilon = 0.80°$. In this case, the wake axis height is practically coincident with the leading edge height.

For α_d = 10°, the streamlines show more deflection than for α_d = 5°, and the dynamic pressure loss is also higher. The maximum dynamic pressure loss is $\eta = 0.53$ and the maximum deflection is $\varepsilon = 4°$. In this case, the wake axis height is close to the leading edge height, but closer to the tracker axis height than the wake axis height for α_d = 5°.

For α_d = 15°, the streamlines show a similar deflection as for α_d = 10°, and the dynamic pressure loss is also higher. The maximum dynamic pressure loss is $\eta = 0.29$ and the maximum deflection is $\varepsilon = 6°$. In this case, the wake axis height is approximately at the midpoint between the tracker axis height and the leading edge height.

For α_d = 20°, the streamlines show a behaviour analogous to that of α_d = 15°, with a slightly higher dynamic pressure loss. The maximum dynamic pressure loss is $\eta = 0.23$ and the maximum deflection is $\varepsilon = 7°$. In this case, the wake axis height is closer to the wake axis height than to the leading edge height.

For α_d = 30°, the streamlines show the highest dynamic pressure loss of the cases studied although they do not show a higher deflection, but lower. The maximum dynamic pressure loss is $\eta = 0.16$ and the maximum deflection is $\varepsilon = 5°$. In this case, the wake axis height practically corresponds to the height of the tracker axis. The wake is similar to a bluff body wake (Wang et al 2021).

It should be noted that in all cases, the streamlines above those of the wake show an increase in velocity, especially appreciable for α_d = 30°.

4. CONCLUSIONS

The wake axis height moves closer to the tracker axis height and away from the leading edge height if the defence angle increases.

The streamlines deflection and the dynamic pressure loss increase with defence angle. It occurs if the defence angle is smaller than a value between 20° and 30°.

The dynamic pressure loss is bigger than 1 above the wake height if α_d > 20°.

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REFERENCES

Zhang, Xiaobin, Wenyong Ma, Xiaohan Kang et al. 2023. Parametric Analysis of Self-Excited Aeroelastic Instability of An Isolated Single-Axis Two-Dimensional Flat Solar Tracker. Journal of Wind Engineering and Industrial Aerodynamics 240, page 105.486.
Juan A. Cárdenas-Rondón, Mikel Ogueta-Gutiérrez, Sebastián Franchini, Raul Manzanares-Bercial 2024. Stability analysis of two-dimensional flat solar trackers using aerodynamic derivatives at different heights above ground. Journal of Wind Engineering and Industrial Aerodynamics 243, page 105.606.
Carlos Rodríguez-Casado, Eva Martínez-García, Raúl Manzanares-Bercial, José Luis Ruiz-Moral, Eduardo Blanco-Miragorta and Atonio Navarro-Manso. Journal of Wind Engineering and Industrial Aerodynamics 253, page 105.838.
Chaoqun Wang, Xugang Hua, Zhiwen Huang and Qing Wen 2021. Aerodynamic Characteristics of Coupled Twin Circular Bridge Hangers with Near Wake Interference. Applied Sciences 11, page 4.189.

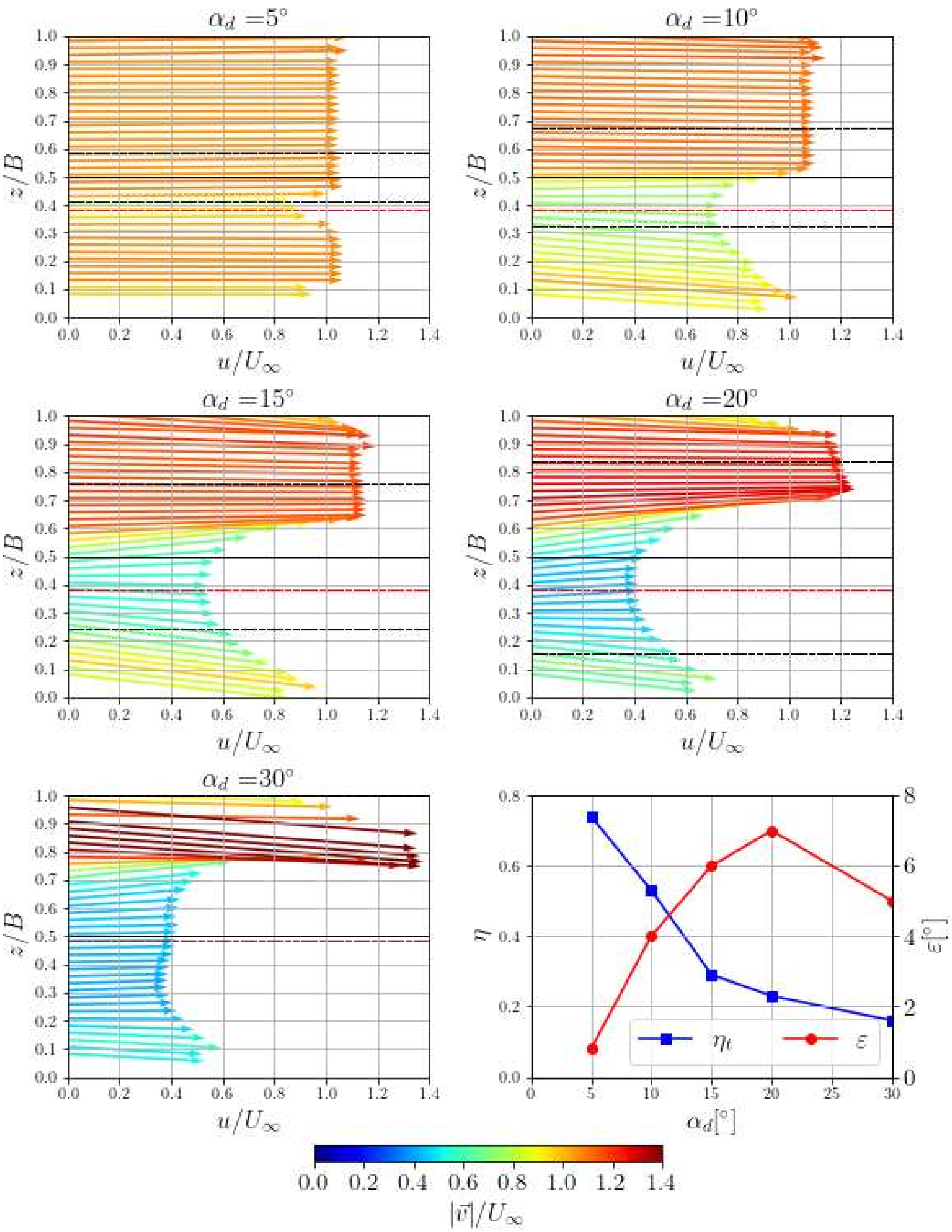

Figure 3. Mean non dimensional tracker wake velocity profile.