Low Reynolds number propellers under non uniform inflow conditions

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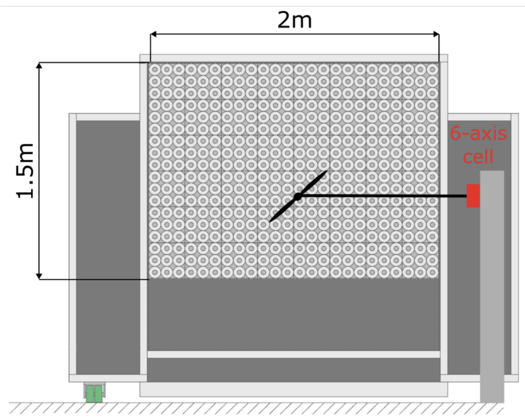
The future of air mobility is closely tied to the advancement of unmanned aerial vehicles (UAVs), which are poised to play a pivotal role in urban settings. This raises important questions about how UAVs perform under non-ideal conditions, such as the complex and turbulent flow environments typical of dense cityscapes. These challenging conditions can drastically reduce efficiency, often leading to overoptimistic performance predictions. Understanding how factors like efficiency and flow characteristics are affected when propellers encounter non-uniform conditions, such as gusts or shear flows, is a critical step toward driving meaningful advancements in drone technology.

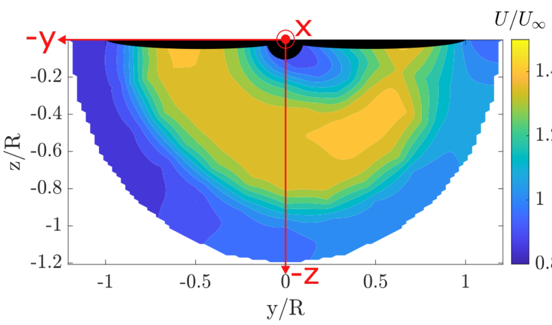
In this study, an experimental campaign is conducted using the indoor flight arena at Politecnico di Torino, featuring a WindShaper with dimensions of $2\,\mathrm{m} \times 1.5\,\mathrm{m}$. The performance of a drone propeller with a radius of 19 cm and a Reynolds number based on the 75% of the chord of about $1 \cdot 10^4$, placed 1 m downstream the fan array, is analyzed under various operating conditions, including uniform inflow, gusty flows, and shear flows.

To evaluate the performance, measurements are carried out using a six-axis load cell, capable of capturing the three force components and the three torque components associated with the propeller. The performance under ideal conditions (uniform flow) are compared with critical cases (gusty flow and shear flow, both with varying characteristics) in order to evaluate the changes in the propeller's efficiency. Flow field measurements are also performed in the wake of the propeller using a five-hole probe, which provides the three velocity components for the time-averaged results, and a hot wire anemometer for the time-varying cases, which are mounted on a 3D traversing system that allows the scan of several planes in the wake region.

We will show how the wake topology is affected by the non-uniform inflows and how this is reflected into the global quantities such as the thrust and torque of the propeller.



(a)



(b)

Figure 1: (a) Front view of the experimental setup. (b) Colormap of the normalized streamwise velocity component, measured at $x/R = 2$ downstream the propeller (i.e. in the wake region), for a case with a shear rate.

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