Experimental investigation of the coupling of wake-to-structure dynamics exposed to free-stream turbulence

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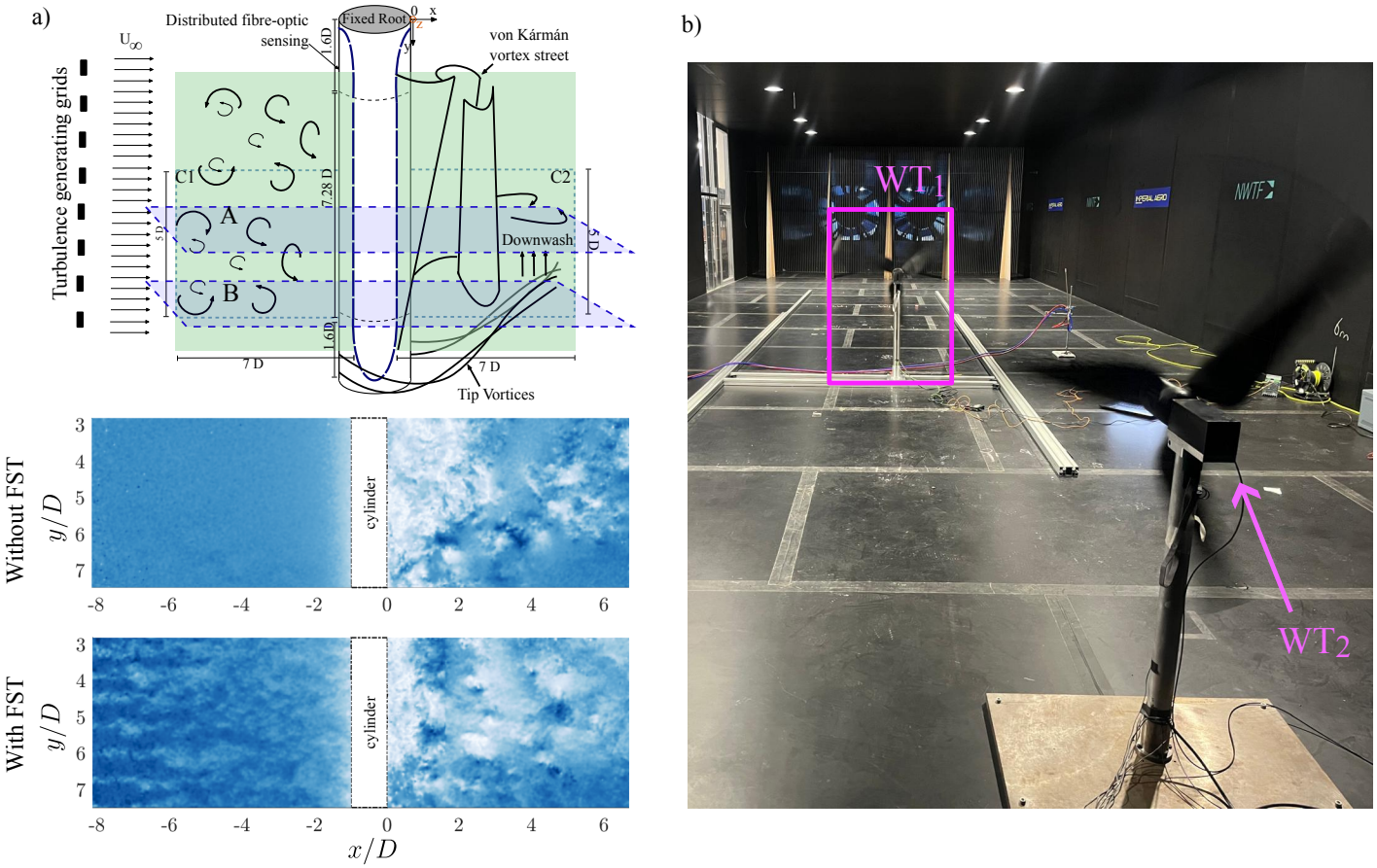
Fluid-structure interaction plays a central role in determining the dynamic response and fatigue life of structures operating in turbulent environments, such as wind turbines, marine risers and overhead transmission lines. In such systems, free-stream turbulence and wake interactions introduce multi-scale, unsteady inflow conditions whose impact on distributed structural loading remains poorly understood. This seminar presents a novel experimental framework for the simultaneous, spatially resolved measurement of flow dynamics and structural response. The approach combines time-resolved flow measurements with distributed fibre-optic strain sensing based on Rayleigh backscattering, enabling continuous, minimally intrusive measurements of strain along slender structures. The methodology is applied to a range of canonical and applied configurations, including a cantilevered circular cylinder in turbulent cross-flow and a wind-turbine model operating under varying inflow conditions (exploring the influence of free-stream turbulence and "waked" inflow conditions). These measurements provide direct insight into how turbulence intensity, inflow structure, and coherent wake dynamics influence the spatial and temporal evolution of flow-induced structural dynamics. A new experimental methodology for linking flow physics to distributed structural response is established, advancing understanding of load generation mechanisms and informing the design and operation of structures in complex turbulent flows.



a) Cantilevered cylinder campaigns experimental schematic (top panel); and representative PIV velocity fields (from C1 and C2 in the bottom panel) for different inflow conditions.

b) "Waked" wind turbine experiment by exposed the instrumented wind turbine (WT2) to different inflow "waked" conditions.