An insight on FOWT wake development through high-fidelity simulations of a pitching rotor

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OBJECTIVE – understand the effect of rotor motion & inflow turbulence on FOWT wake development

Floating Offshore Wind Turbines (FOWTs) add rotor motion to an already complex multi-physics problem. Understanding how **rotor motion** interacts with the **inflow turbulence** and influences **wake development** is of paramount importance.

METHODS

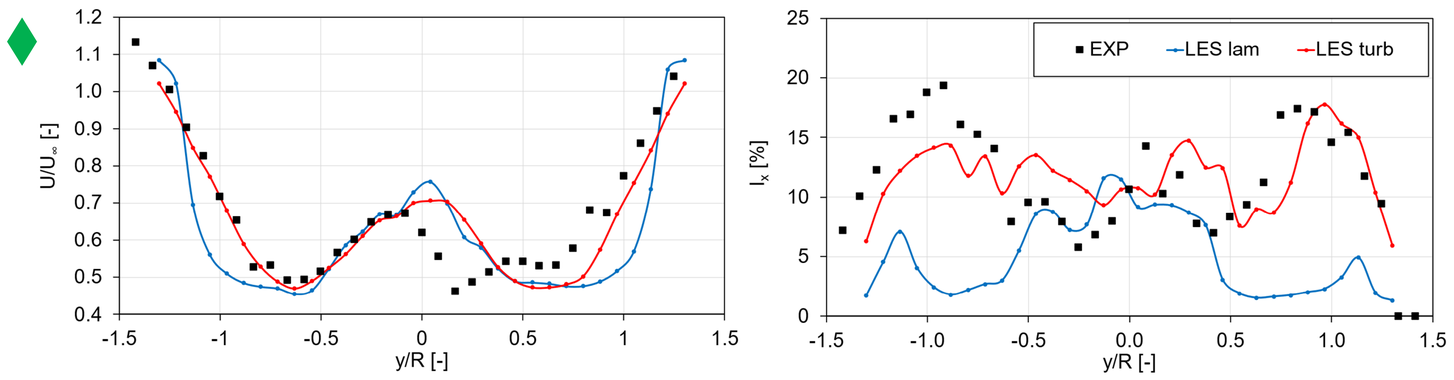
High-fidelity **Actuator Line** (ALM) **Large Eddy Simulations** (LES) are performed. A tota cell count of $120*10^6$ was used to ensure adequate resolution of the turbulent spectrum in the wake. Simulations mirror an experimental campaign that was run in parallel and feature a **still and pitching rotor** as well as **laminar and turbulent inflow** conditions. Each simulation ran for approximately 120000 core-hours.

Table 1: Main specification of 1:75 scale rotor

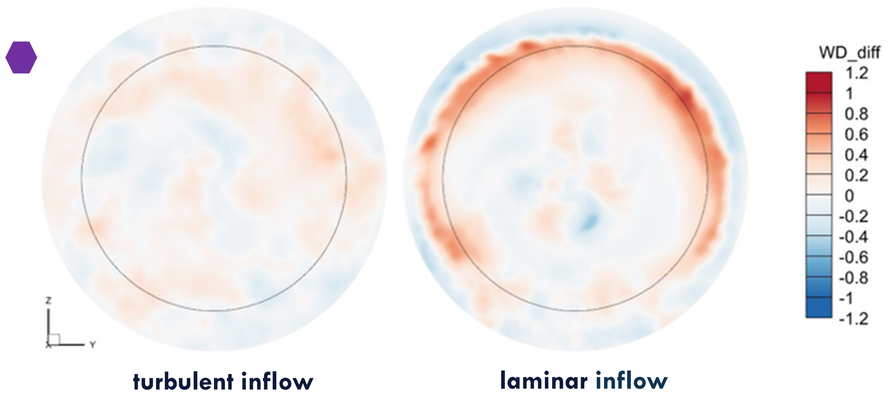
Parameter	Value
Rotor diameter [m]	2.38
Blade length [m]	1.10
Tilt angle [°]	0
Tower length [m]	1.4
Tower base offset [m]	0.73

Parameter	fixed case	pitching case
Inflow speed	4 m/s	4 m/s
Rotor speed	240 rpm	240 rpm
Blade pitch	0°	0°
Pitch amplitude	n/a	1.3°
Pitching frequency	n/a	1 Hz
Strouhal number	0	0.595

Influence of turbulence on mean velocity profiles & turbulence intensity 3 diameters (3D) downstream the rotor



Influence of turbulence & rotor motion on mean velocity in the wake @3D

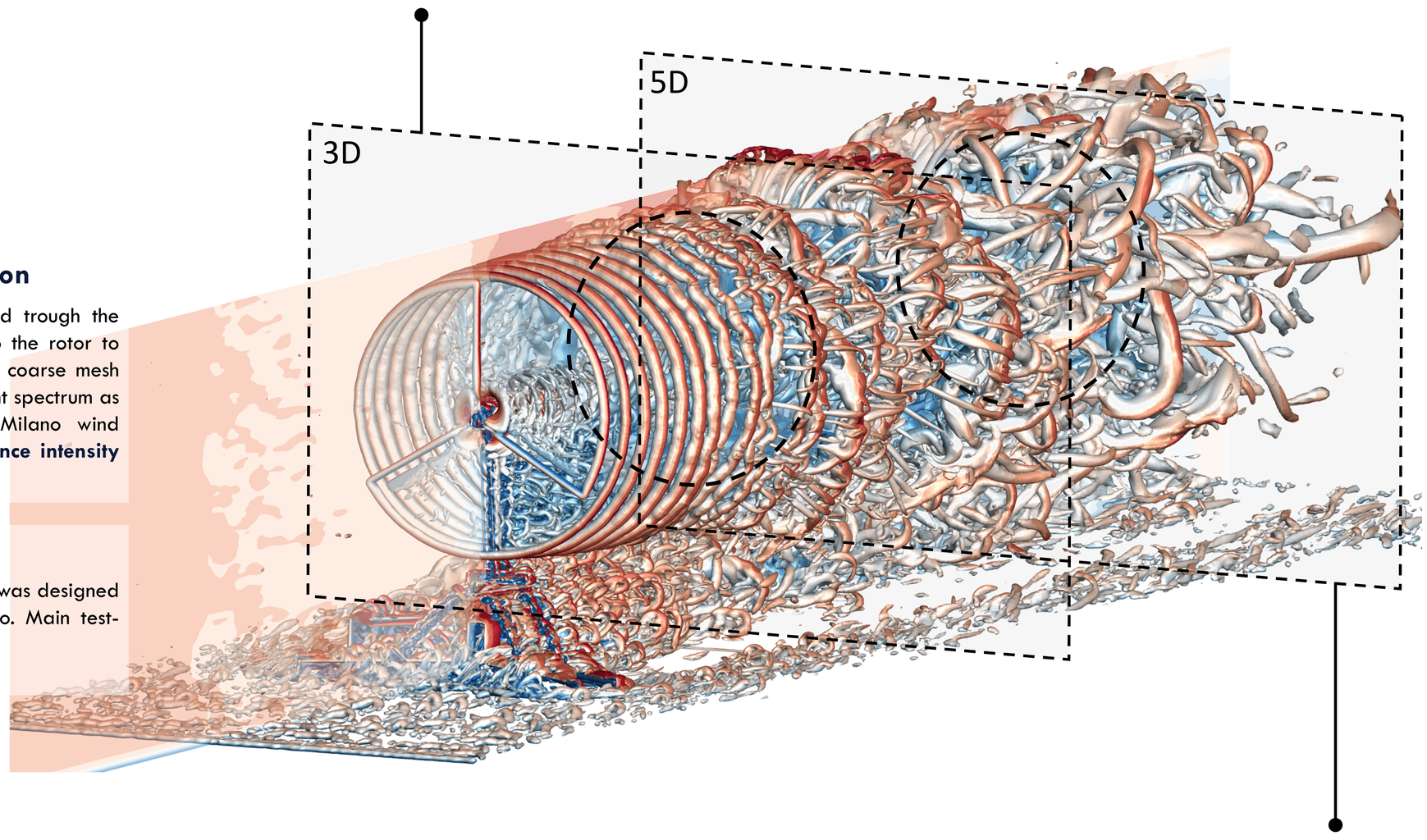


Turbulent inflow generation

Velocity fluctuations are generated trough the insertion of volume forces close to the rotor to avoid numerical diffusion from the coarse mesh far upstream the rotor. The turbulent spectrum as measured in the Politecnico di Milano wind tunnel is used, featuring a **turbulence intensity (TI) of 1.5%**.

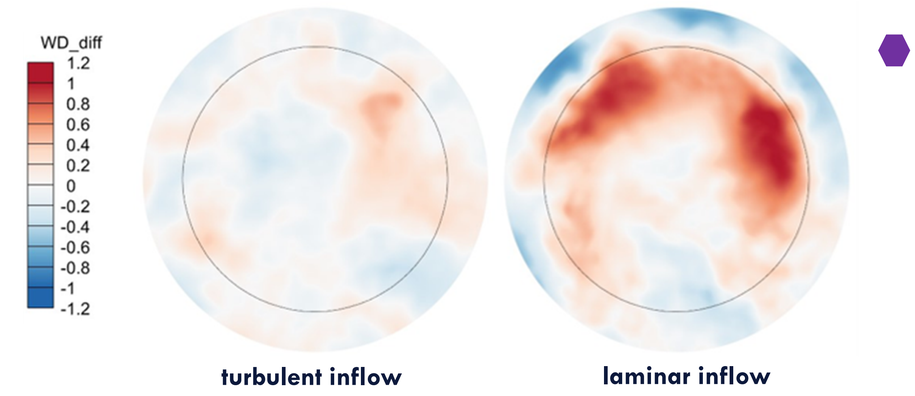
1:75 scale rotor

1:75 scale DTU 10MW rotor which was designed and tested by Politecnico di Milano. Main test-case specification in **table 1**

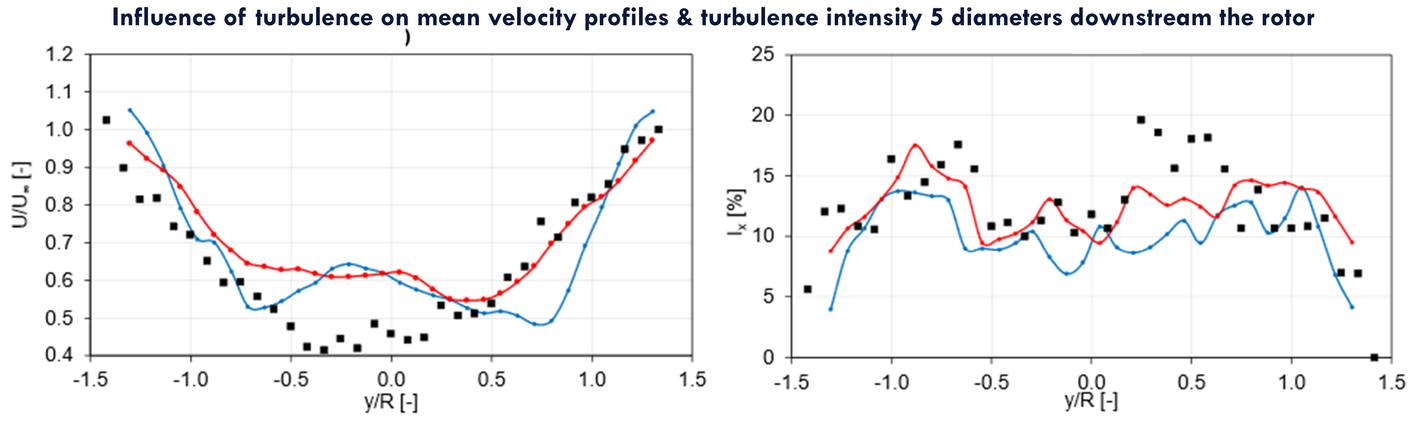


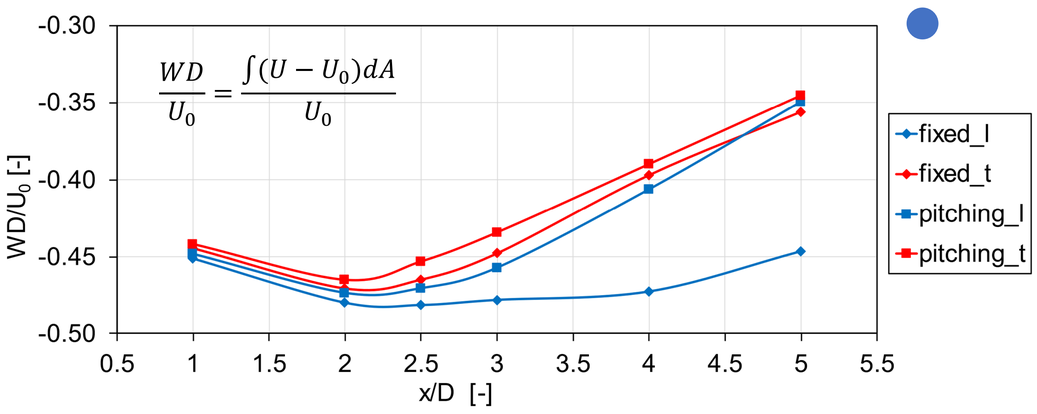
$$WD_{diff} = \overline{U_{pitch}} - \overline{U_{static}}$$

Influence of turbulence & rotor motion on mean velocity in the wake @5D



Influence of turbulence on mean velocity profiles & turbulence intensity 5 diameters downstream the rotor





RESULTS

The relatively low inflow turbulence of 1.5% significantly affects both mean velocity profiles in the wake as well as turbulence intensity, bringing the LES simulations much more in line with experiments (◆). Rotor pitching motion, despite the significant amplitude and frequency, significantly affects wake recovery only in laminar conditions (●) . In turbulent conditions very little additional recovery is noted when rotor pitching motion is simulated. In fact, increased mixing in the wake shear layer due to pitching motion can be noted 3D downstream the rotor in laminar conditions (⬢), leading to areas of the wake with increased recovery also downstream at 5D. The increased mixing is almost absent in turbulent inflow conditions (⬢).

KEY TAKE-AWAYS

- A relatively low 1.5% TI significantly affects rotor wake. Good agreement between experimental and numerical results if inflow turbulence is considered
- Both inflow turbulence and rotor pitching increase wake breakdown & recovery. Combining the two effects doesn't result in significant additional recovery.
- The effect of inflow turbulence length scale on FOWT wakes reains to be studied

CURIOUS ABOUT EXPERIMENTS?

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