Experimental investigation on the hydroelastic response of a spar-supported Floating Offshore Wind Turbine

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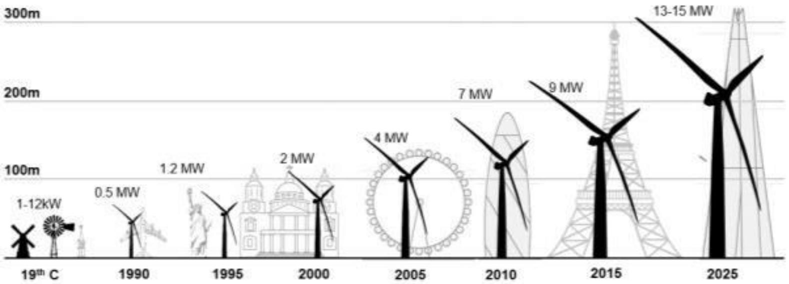
Context

Hydroelasticity of large FWT platforms

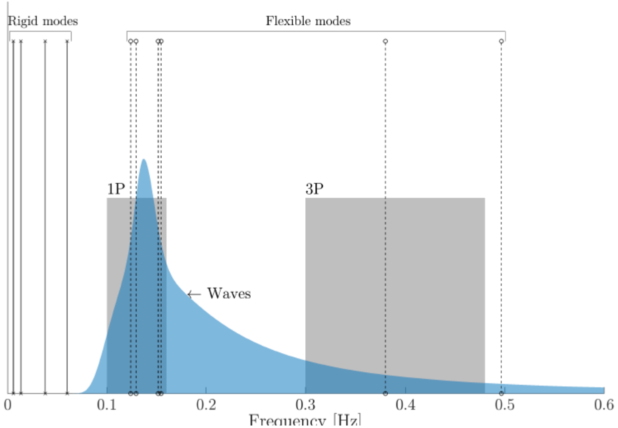


(source: Bloomberg New Energy Finance)

Increasing size of Offshore Wind Turbines and substructures

In complex environmental conditions

- Irregular and steep sea-states (NL effects)
- Turbulent wind
- Oscillating loads (3p, wind turbine motions)



(Borg et al., 2017)

Triple-Spar concept
(Lemmer et al., 2016)

Project HeloFOW

Hydroelasticity of large FWT platforms

Financed by WEAMEC
Centrale Nantes LHEEA (France) / NTNU IMT (Norway)

Floatgen FWT ©Centrale Nantes/Above All

Numerical

> How to account for hydro-elastic coupling in FOWT simulation?

→ Develop a coupling between non-linear potential flow solver and a FEM “beam” model

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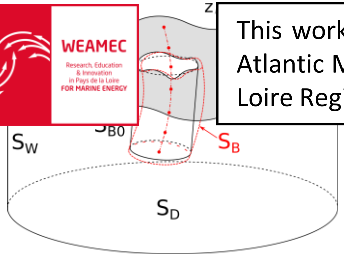


This work was carried out within the framework of the WEAMEC, West Atlantic Marine Energy Community, and with funding from the Pays de la Loire Region and Europe (European Regional Development Fund)

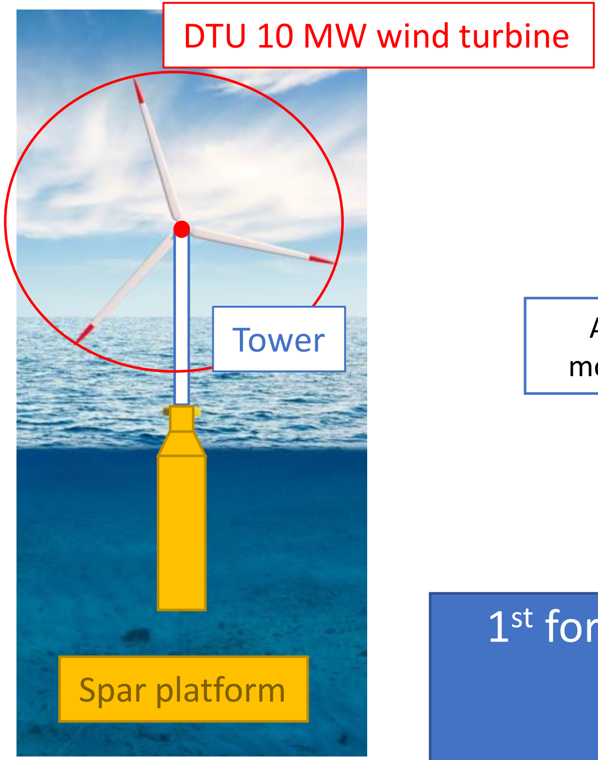
Experimental

> Experimental testing of flexible platform models

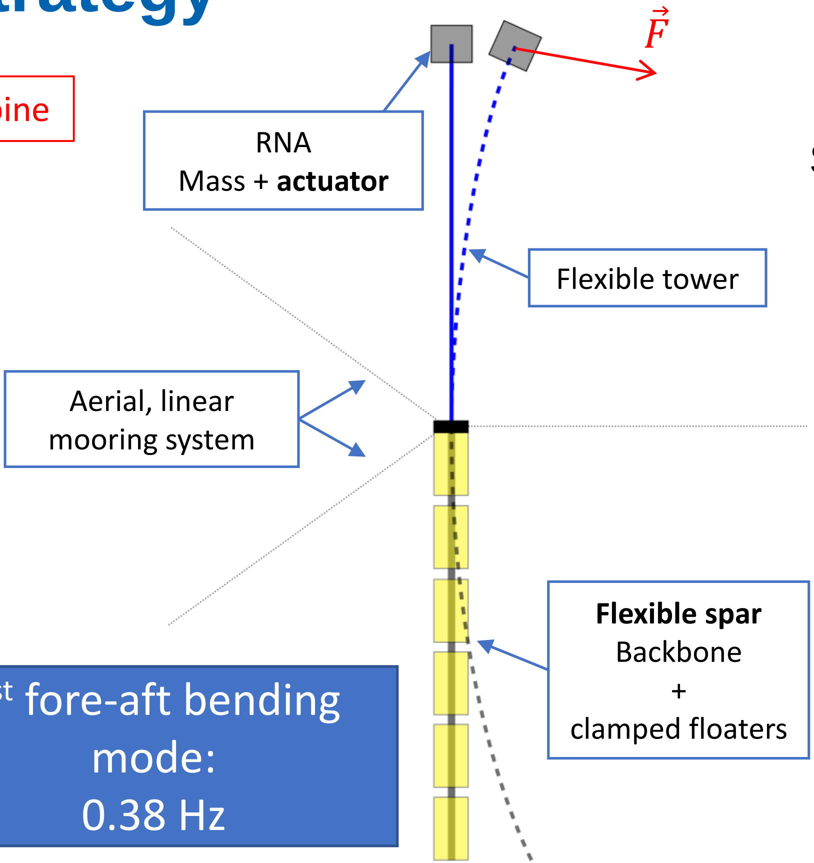
> In the Hydrodynamic and Ocean Engineering Tank of Centrale Nantes

(50 m length x 30 m width x 5 m depth)

Modelling strategy



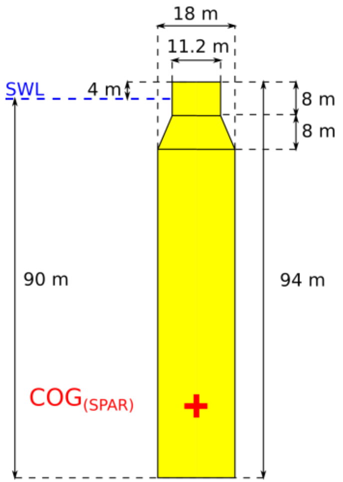
Credits: Green Girafe



1st fore-aft bending mode:
0.38 Hz

Spar platform, scale 1:40

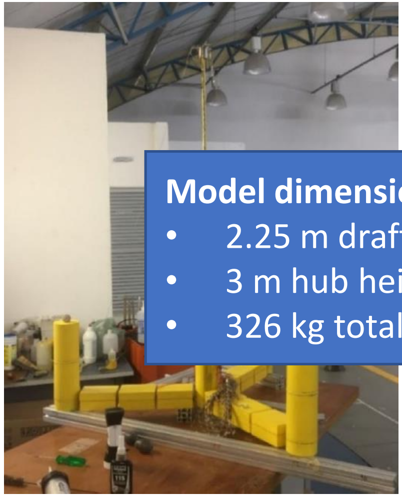
- In-house design (Centrale Nantes)
- Same dimensions as a rigid model (Arnal, 2020)



Modelling strategy

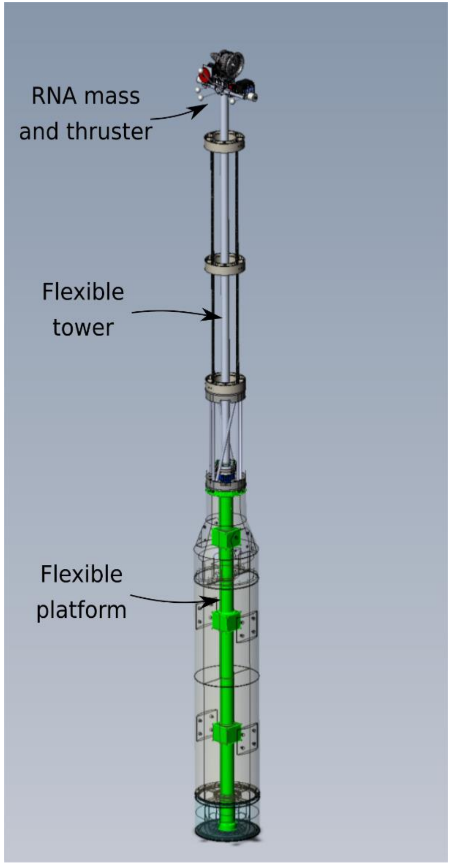
> Aim:

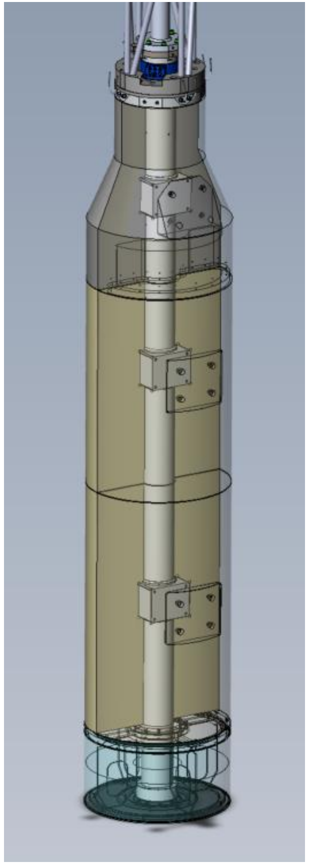
- Assessing to sectional loads
- Modelling froude-scaled hydroelasticity: Froude-Scaled first bending mode frequency



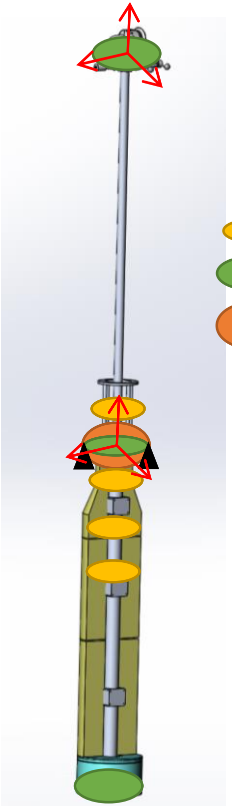
Model dimensions:
- 2.25 m draft
- 3 m hub height
- 326 kg total mass

(Suzuki et al., 2019)

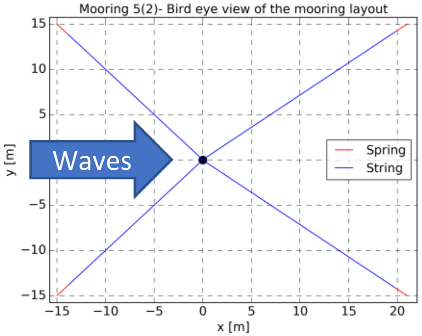




Installation and sensors



> System installed with 4 aerial mooring lines (linear)



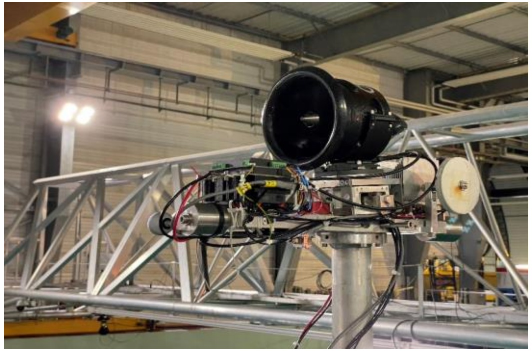
> Measurements

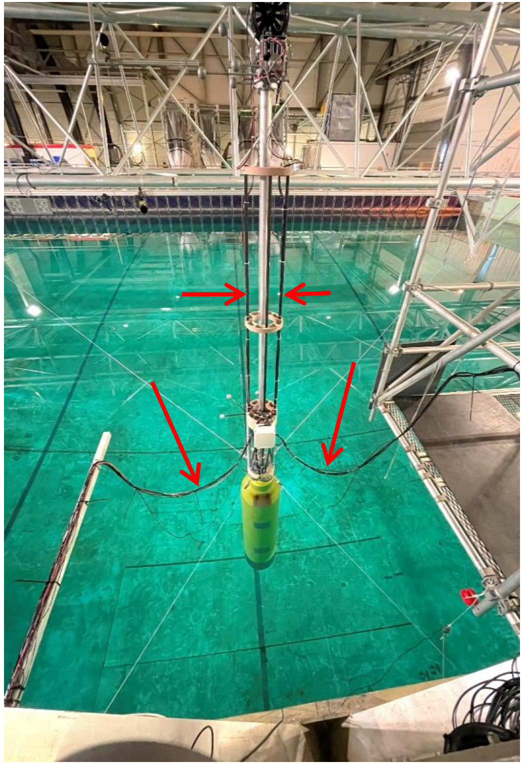
- Strain gauges
- Accelerometers
- 6 component load cell
- Mooring load 1D sensor
- 6DOF tracking

> RNA actuator (Arnal, 2020)

- **SoftWind project**
- Constant thrust
- Can include FAST + SIL

> Cables linked to the central bridge (catenary)





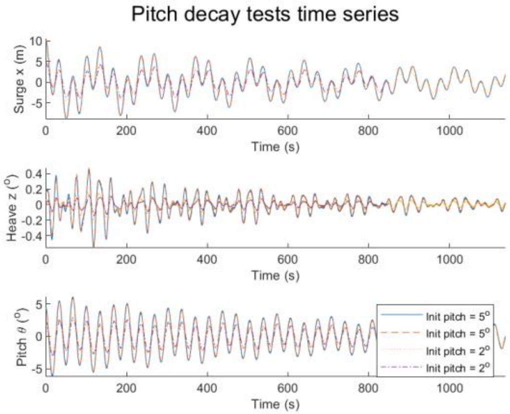
Decay tests

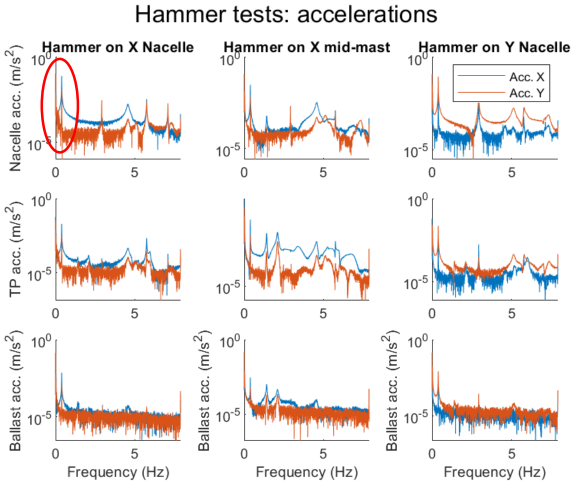
> Decay tests: natural modes / natural periods

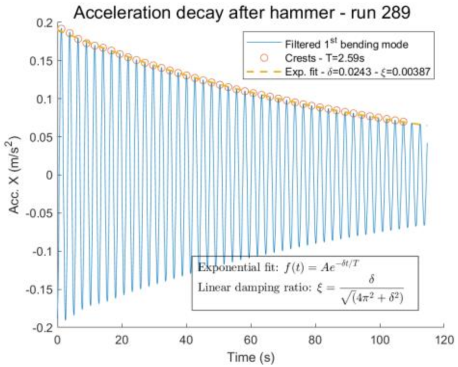
• Heave:	30.7 s	(Full scale)
• Pitch:	33.6 s	
• Roll:	35.4 s	
• Yaw:	25.9 s	
• Surge:	132.8 s	

> Hammer tests: flexible modes frequencies

- 1st bending mode : 2.45 Hz / 0.39 Hz Full scale



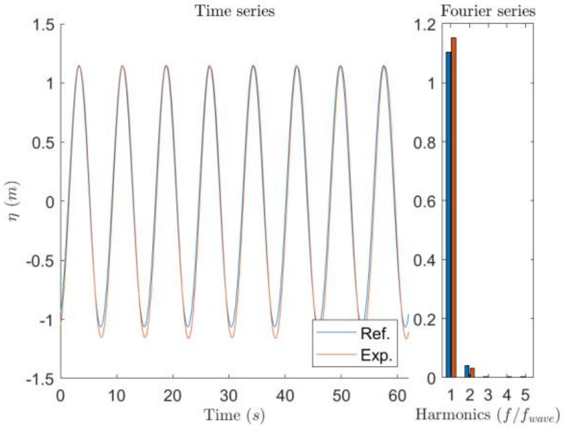




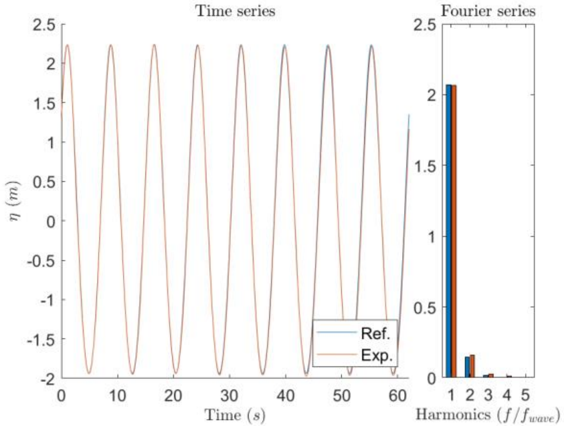
Regular waves

> Regular waves

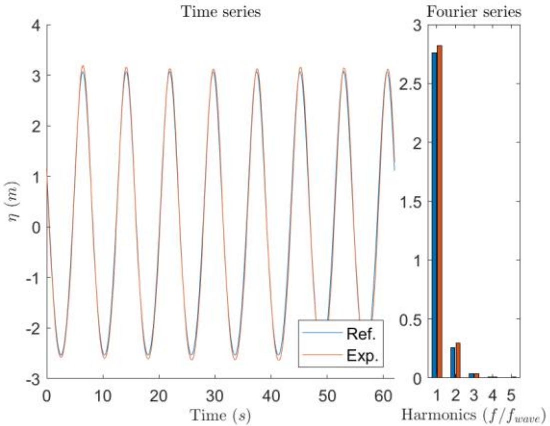
- Wave steepness: $\frac{H}{\lambda} = 2\%, 4\%\ 6\%$
- Wave periods: $5\ s$ to $19\ s$
- Aerodynamic constant force: 0, 53 % and 67 % of DTU 10MW rated thrust



$$T = 7.75\ s, \frac{H}{\lambda} = 2\ \%$$



$$T = 7.75\ s, \frac{H}{\lambda} = 4\ \%$$

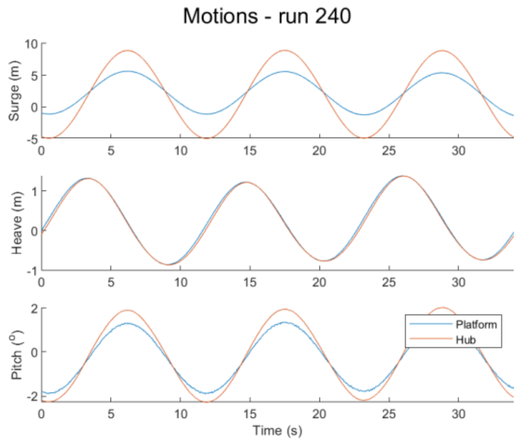


$$T = 7.75\ s, \frac{H}{\lambda} = 6\ \%$$

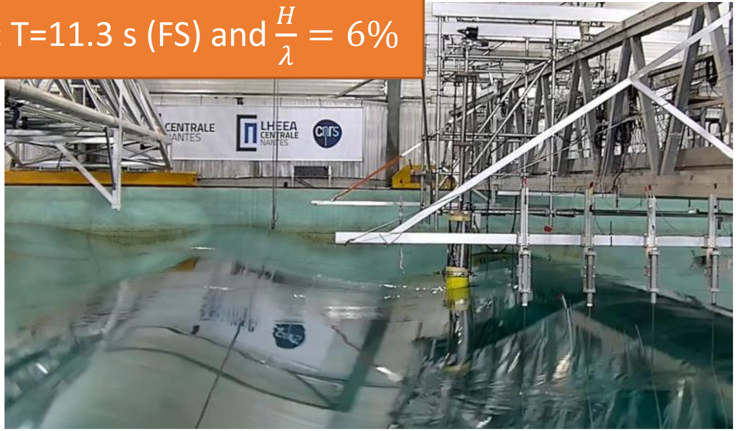
Regular waves

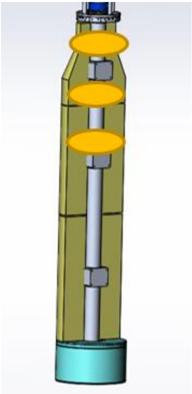
> Regular waves

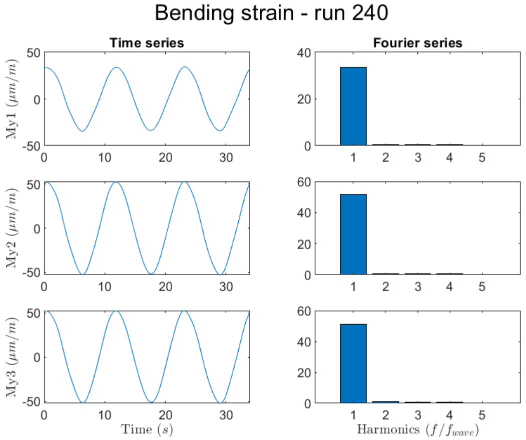
- Wave steepness: $\frac{H}{\lambda} = 2\%, 4\%\ 6\%$
- Wave periods: $5\ s$ to $19\ s$
- Aerodynamic constant force: 0, 53 % and 67 % of DTU 10MW rated thrust



Here: T=11.3 s (FS) and $\frac{H}{\lambda} = 6\%$







Regular waves

- > Decay tests: natural modes / natural frequencies
- > Hammer tests: flexible modes frequencies
- > Regular waves

> Here : $\frac{H}{\lambda} = 6\ \%$

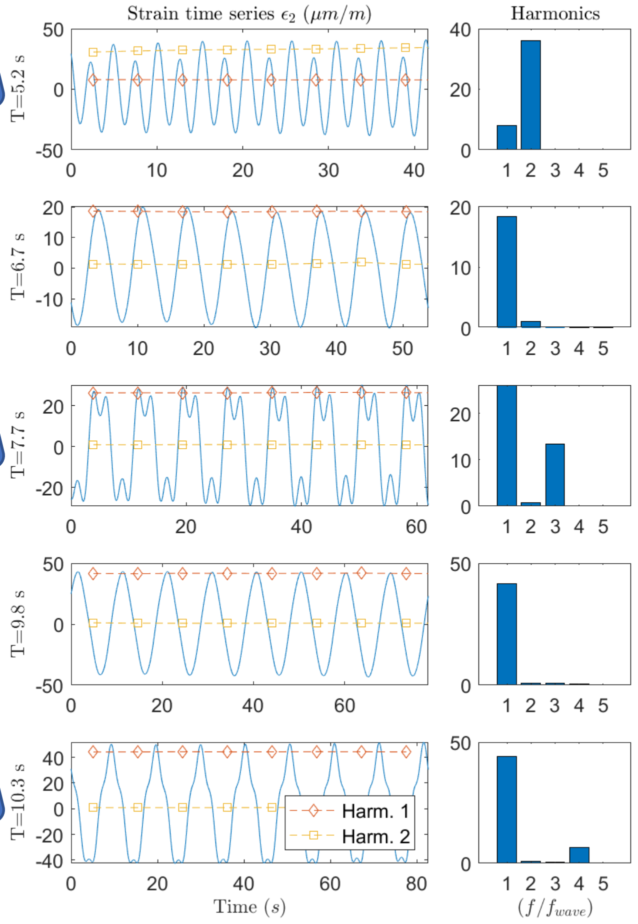
The bending mode can be triggered by 2nd, 3rd or 4th order hydrodynamic loads

→ Necessity of ***non-linear hydroelastic*** modelling

$T_{wave} = 2T_{ben}$

$T_{wave} = 3T_{ben}$

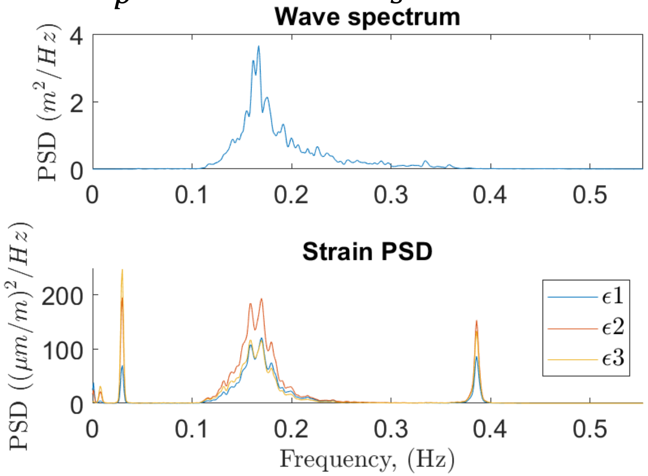
$T_{wave} = 4T_{ben}$



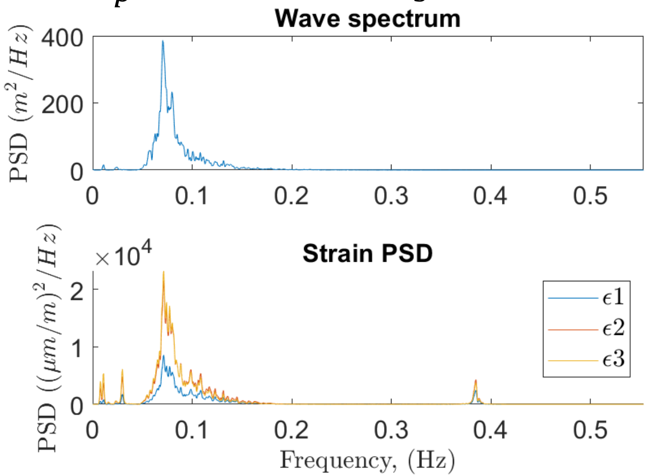
Irregular waves

> Irregular waves (*no directional spreading*): Gulf of Maine (Gomez et al. 2015, *Lifes50+ project*)
  - With/without aerodynamic constant force
  - Including extreme sea states (5, 10 and 50-year return period)

$T_p = 6.0\ s$ and $H_s = 1.50\ m$

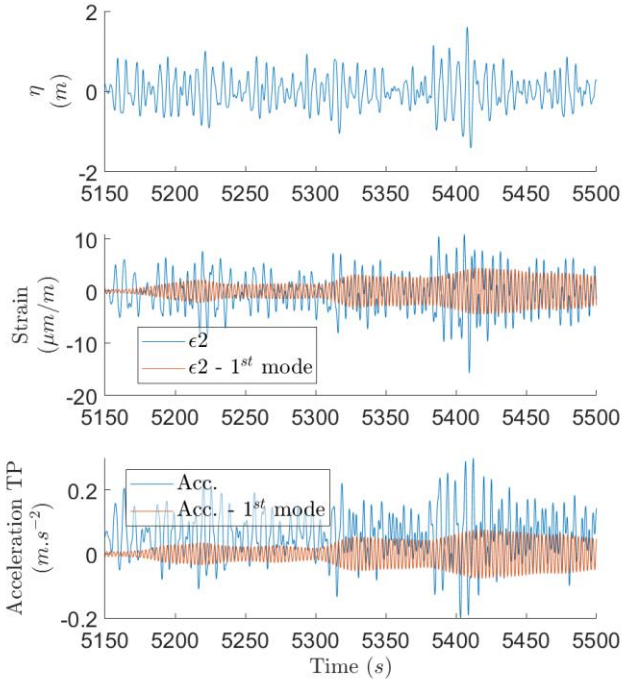


$T_p = 13.8\ s$ and $H_s = 10.9\ m$

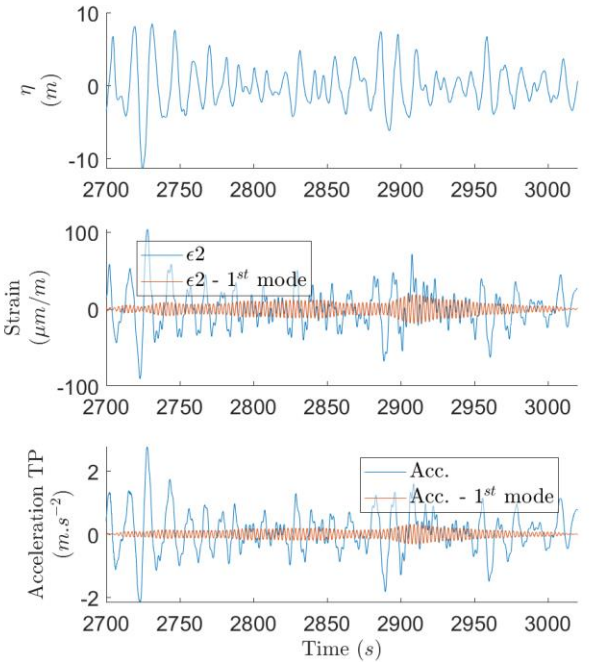


Irregular waves

$T_p = 6.0\ s$ and $H_s = 1.50\ m$



$T_p = 13.8\ s$ and $H_s = 10.9\ m$



Conclusions

> Experimental investigation on the hydroelastic response of a spar-supported FOWT

> Flexible 1/40 scaled model

- Froude-scaled hydrodynamic loads
- Froude-scaled first bending mode frequency

> Various regular waves and irregular sea-states, including constant aerodynamic force

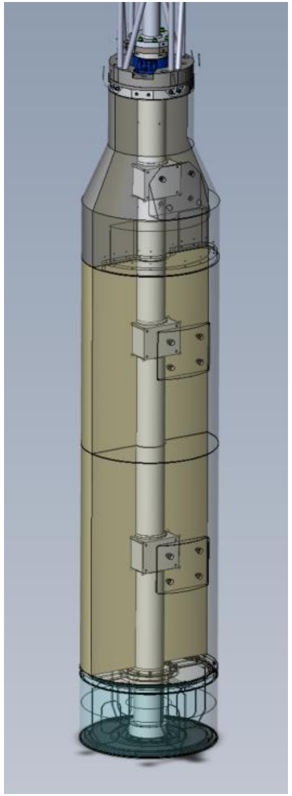
> Deeper analysis to come soon, with comparison with numerical models

> Simulation tool validation database

- Contact: vincent.leroy@ec-nantes.fr

> Video available on YouTube:

« Les essais HeLoFOW aux bassins, pour l'étude du comportement élastique des éoliennes flottantes » → https://www.youtube.com/watch?v=xpHZn2NGzlM



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Thank you for your attention

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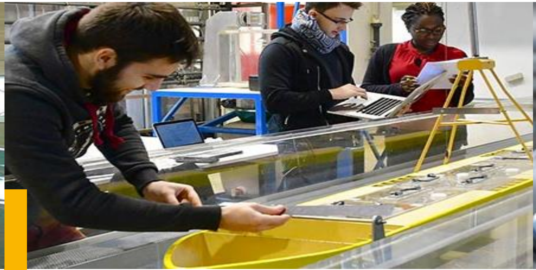

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