DIMPACT

FRANCE ENERGIES MARINES

anr

FRANCE 2030

WAVES & FOWT DESIGN

Impacts of energetic steep and breaking waves on the design of floating wind turbines

Webinar to present the main results of the DIMPACT R&D project.

FRANCE ENERGIES MARINES · Cerema · DNV·GL · EDF · ENSTA BRETAGNE · EOLFI · Ifremer · CNR ISMAR · Sercel · OCEAN INNOVATION · RWE · SAIPEM · SHOM · TotalEnergies · UNITECH · École des Ponts ParisTech

AGENDA

10:30 - 10:40	**Introduction (10')**

- Context of the project and links between the various work packages
  Jean-François FILIPOT, France Energies Marines

10:40 - 11:40	**Focus on the main project results (60')**

- Motion and attitude of floating offshore wind turbine in high seas (15')
  Christophe PEYRARD, EDF R&D
- Wave tank experiment and load severity (15')
  Florian HULIN, France Energies Marines, Ifremer and ENSTA Bretagne
- Hydrodynamics loads on floating wind turbine (15')
  Paul RENAUD, France Energies Marines
- Implementation of engineering methods from DIMPACT project in OpenFAST tool (15')
  Camil MATOUG, France Energies Marines

11:40 - 12:25	**Interactive Q&A session (45')**

12:25 - 12:30	**Conclusion & Wrap up (5')**

The DIMPACT project

Objective : incorporate slamming loads model in FOWT coupled models

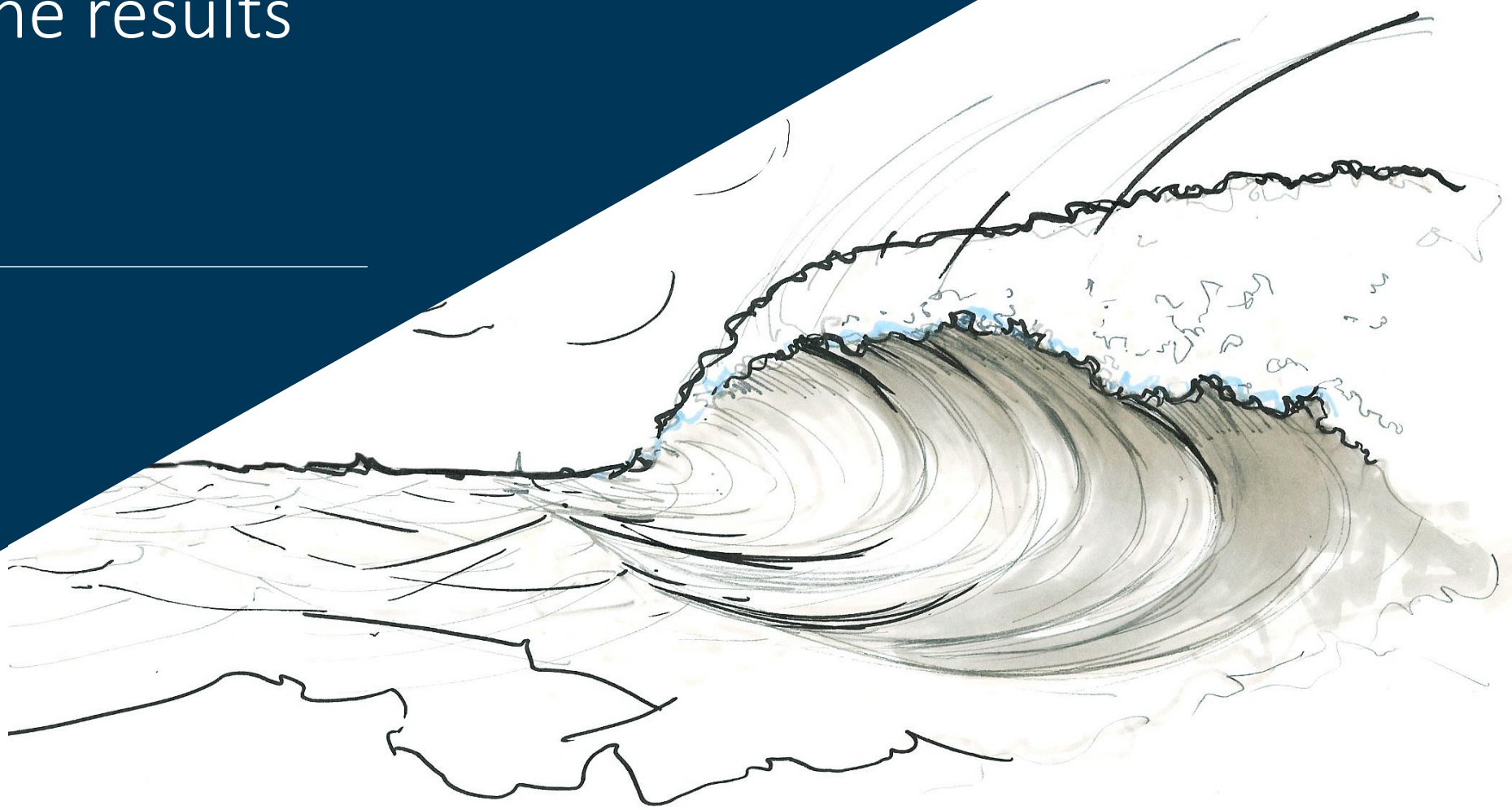
Duration : May 2, 2020 – October 12, 2023

Budget : 2.6M€

Funding : France2030, project partners, France Energies Marines

DIMPACT

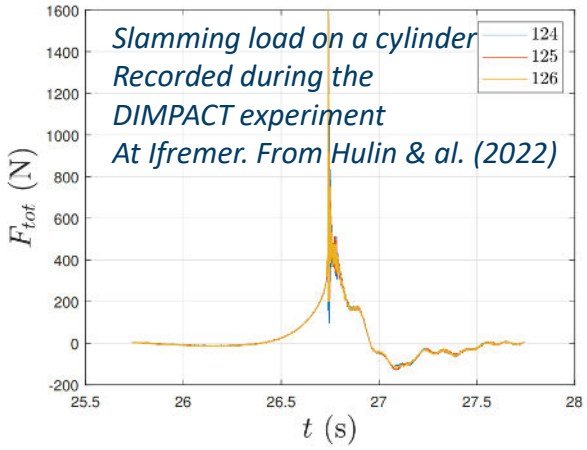
Summary of the results



The « slamming » loads

Slamming loads :

- due to breaking waves
- Severe and impulsive
- Difficult to measure and model



→Slamming loads are similar to what you experience when:

1) you enter water at a beach exposed to breaking waves,

2) or during a ”belly flop” at the swimming pool

Figure: Top panels : A massive wave slamming La Jument lighthouse. Credit : Air, Vide et Eau. Bottom panel : 2 kids experiencing a slamming load

Why do we need to assess them for the design of OWT?

Effects on Offshore Wind Turbines :

- Local structural damage
- Mode excitation of the tower up to the nacelle
- Run-up : water climbing up along the
- foundation (bottom-fixed or spar type floating OWT)
- Green water : submersion of the substructure

Specifity of Floating Offshore Wind Turbines :

- Floater motion (surge)
- Floater-turbine tilt

→ May affect slamming loads

→ Need fully aero-hydro-elastic-servo models

(See Derisk project for slamming loads on bottom-fixed OWT)

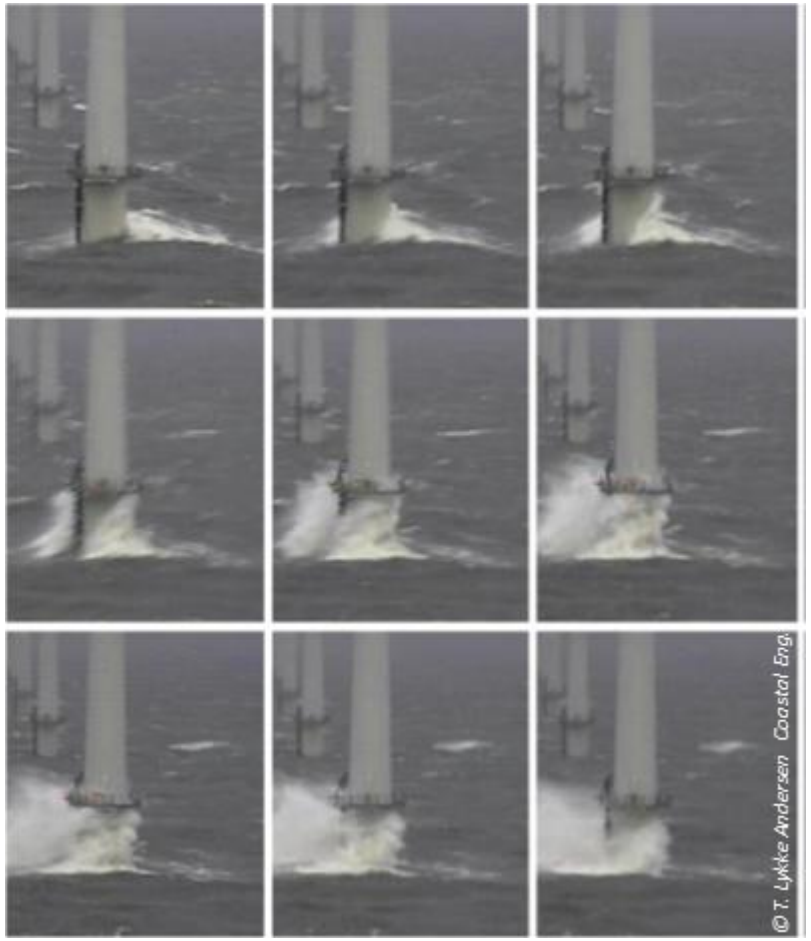
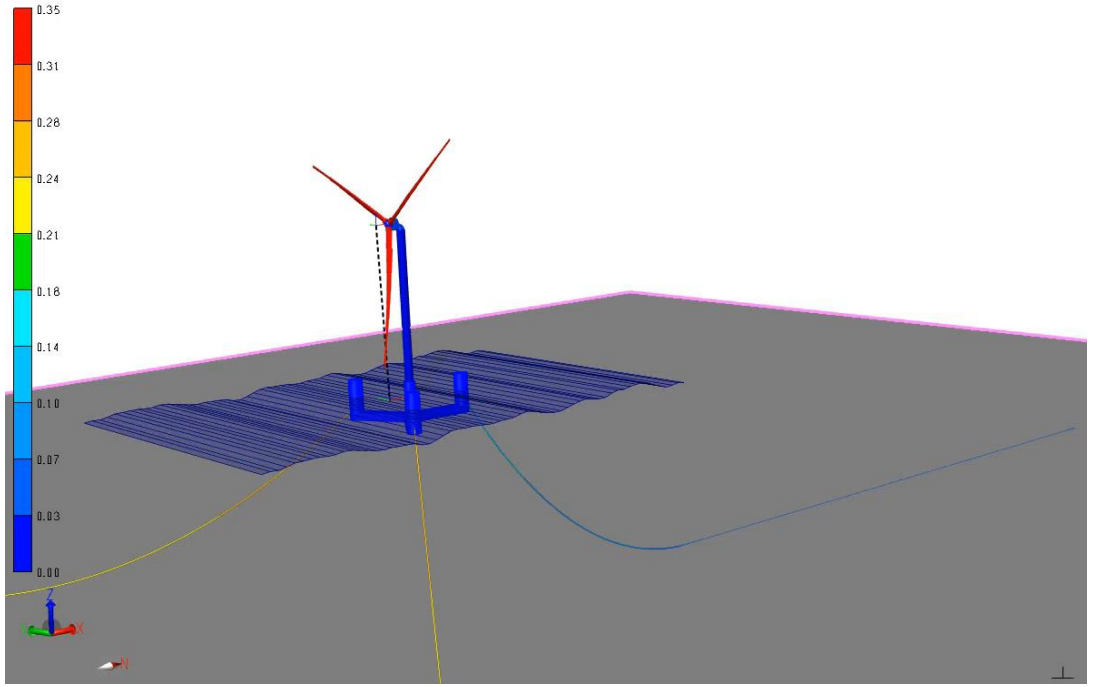


Figure: A breaking wave impacting an OWT on the Horns Reef 1 wind farm, Denmark. From Lykke Andersen et al. [2011].

Slamming loads in fully coupled FOWT model

The windFloat Atlantic FOWT from Principle Power Inc.

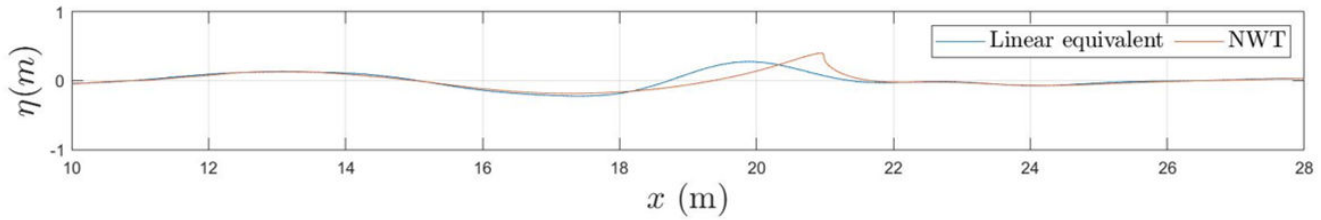


A numerical simulation of a FOWT in high sea, (T. Coquio, FEM)


Oc

How to incorporate slamming loads in FOWT models ? Scientific questions

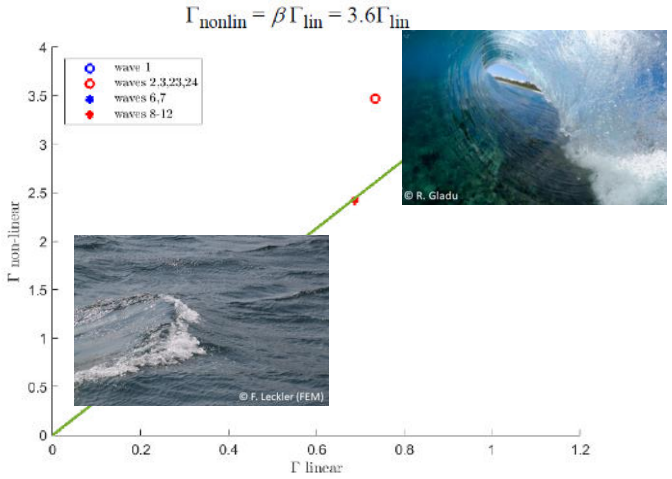
1. Would we be able to detect the breaking wave in the linear sea state?

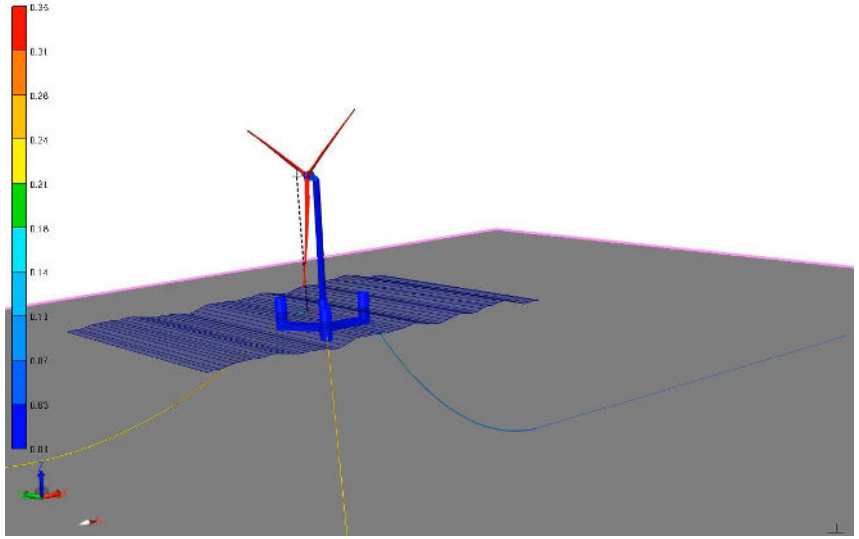


Nonlinear criterion u/c = 0.85 → linear criterion u/c = 0.34

2. Would we be able to assess the breaking severity from the linear wave properties?

$$\Gamma = T_b \left. \frac{\mathrm{d}(u/c)}{\mathrm{d}t} \right|_{u/c\,=\,0.85}$$





Results from Hulin et al. (2024a) and Prevosto & al. (2024)

Associated scientific breakthroughs

New wave loads models
→ Renaud & al. (OE2023)

Linear wave breaking onset definition
→ Hulin & al. (2024a)

Vibration corrections in hydrodynamic loads
→ Tassin & Hulin (JSV2023)

CFD model for slamming loads
→ Batlle & al. (ISOPE2022)
→ Batlle & al. (CE2023)

Design sea states with breaking waves
→ Prevosto & al. (OE2024)

Relation between breaking severity and load
→ Hulin & al. (2024b)

Wave loads on a moving/tilted FOWT
→ Renaud & al. (OMAE2023)
→ Hulin et al. (JH2022)

Slamming loads from linear waves
→ Renaud & al. (OE2024)

Full methodology & FOWT coupled model
→ Filipot & al. (OE2024)

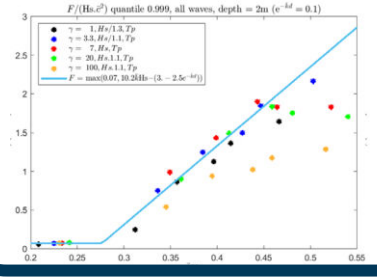
→ will be referred to in the 2024 update of DNV recommended practice

DIMPACT method to assess design wave load using global FOWT models

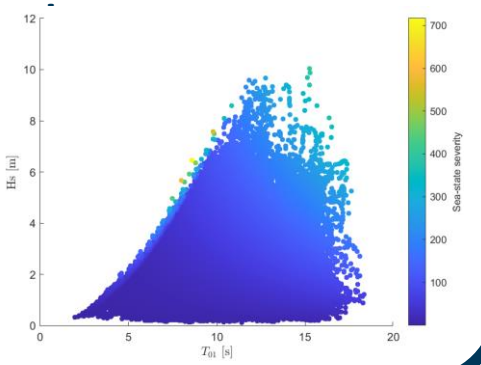
FRANCE ENERGIES MARINES

Total force model

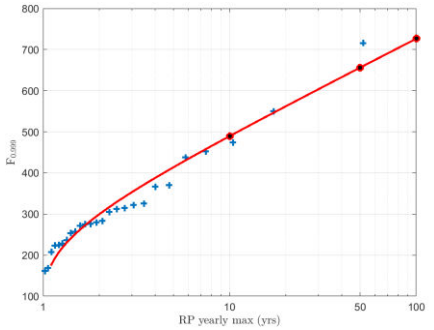
$$F_{0.999}/(Hs.c_{01}^2) = \max(0.07\ ,\ 10.2k_{01}Hs - (3.-2.5e^{-k_{01}d}))$$



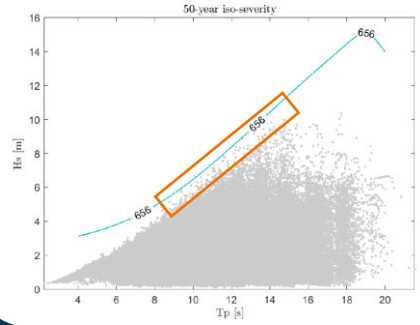
Application to site



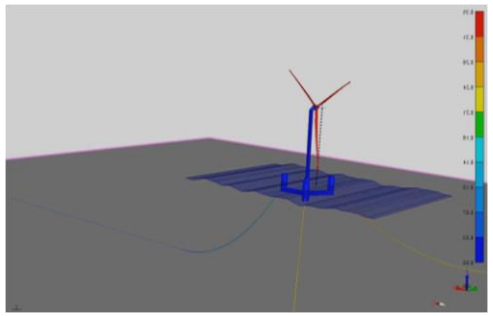
50-year $F_{0.999}$



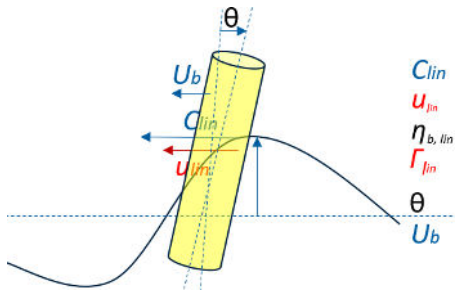
Design sea states candidates



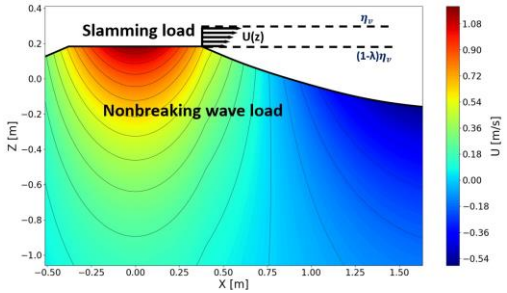
FOWT modeling



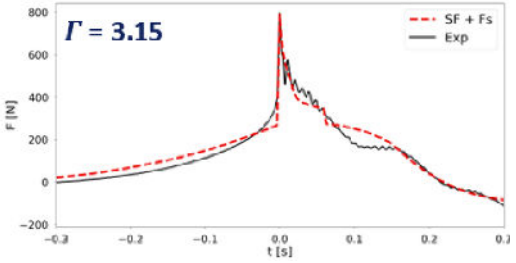
wave-FOWT information



Load model



Design Load



Applicability of the results

Technologies :

- Any floating substructure made of vertical cylinders
- Any bottom-fixed substructure made of vertical cylinders

Site conditions :

- Any water depth wave
- Any wave conditions

(best with breaking waves!)

- Strong bottom slopes

could be an issue

Publications

1. Hulin, F., Tassin, A., Filipot, JF., and Jacques N. . Experimental investigation of the hydrodynamic loads induced by breaking wave impacts on a spar-type floating offshore wind turbine substructure. In 18ème Journées de l'Hydrodynamique, Poitiers, France, 2022
2. Martin, M. B., Harris, J. C., Renaud, P., Hulin, F., & Filipot, J. F. (2022, June). Numerical investigation of slamming loads on floating offshore wind turbines. In *ISOPE International Ocean and Polar Engineering Conference* (pp. ISOPE-I). ISOPE.
3. Renaud P., Hulin F. , Batlle M., Scolan, Y.M., Tassin, A., Jacques N., Harris J., and Filipot JF. Semi-analytical load models accounting for the tilt and motion of a cylinder impacted by a plunging breaking wave. In Proceedings of the ASME 42nd International Conference on Ocean, Offshore and Arctic Engineering (OMAE2023), 2023
4. Renaud P., Batlle Martin, M., Hulin F., Harris, J., Filipot JF, and Scolan, Y.M. Semi-analytical load models describing the progressive immersion of a fixed vertical cylinder in a breaking wave. Ocean Engineering, 276:114116, 2023
5. Batlle Martin, M., Harris J., Filipot J.F., Florian Hulin, Alan Tassin, and Paul Renaud. Deep water focused breaking wave loads on a fixed cylinder. Coastal Engineering, 2023, 186, 104397
6. Tassin, A., Hulin F., Jacques N., A direct multimode method for the reduction of vibration induced oscillations on force signals during "pseudo-rigid" water impact experiments, *submitted to Journal of Sound and Vibration*
7. Hulin F. & al. Numerical and physical generation of intermediate water depth breaking waves to characterize the breaking intensity and the breaking probability (in preparation)
8. Hulin F. & al. Experimental investigations of slamming loads on a moving and tilted cyclinder (in preparation)
9. Renaud & al. Breaking wave loads from linear wave properties (in preparation)
10. Prevosto & al. A method to define the design sea state candidates in presence of breaking waves (in preparation)
11. Filipot & al. A method to assess extreme wave loads on offshore wind turbine (in preparation)