PERFORMANCE AND MOORING QUALIFICATION IN FLOATGEN : THE FIRST FRENCH OFFSHORE WIND TURBINE PROJECT

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SUMMARY: A new floating foundation, now known as the Damping Pool ® concept was presented at Grand Renewable energy 2014. Since then, the floating wind turbine has been built, tested in port and is about to be deployed offshore in France. Due to the fundamentally innovative nature of the project, several new concepts were introduced and tested. This paper describes how the main innovations introduced are validated step by step to mitigate risks and increase the learning effect of the project. The floating wind turbine includes a 2MW Vestas V80 turbine installed on top of a concrete hull, moored by means of polyamide mooring lines. We will focus here on the validation of the hydrodynamic concept, wind turbine coupling, mooring system and concrete material used.

Keywords: offshore, wind, floating, mooring, qualification

INTRODUCTION

Beyond the purpose of demonstrating floating wind turbine technology, the Floatgen project also aims at demonstrating that it makes economic sense.

This drove the project to select a wind turbine size representative of offshore wind turbines, and to take into consideration factors of importance for the successful implementation of commercial scale project:

- Scalability of the wind turbines,
- Maximum local content,
- Minimum environmental impact.

A surface floater was designed as described in [1] with a hull made out of concrete, a small-footprint mooring system. The main dimensions of the demonstrator are the following:

Table 1. Floatgen demonstrator dimensions

Hull width	Breadth overall	Depth	Draft	Turbine power
36m	40.2m	9.5m	7.0m	2MW

These dimensions are not so much smaller than those of a 6 to 8MW unit [2]

The main principle used to identify qualification of the system was to use hazard identification techniques that enabled to evaluate the risks related to each component. These points are then qualified step-by-step to prevent risky situations to happen during the lifetime of the project. We will present the main innovative features of the floater hydrodynamics and mooring system, and how they were evaluated during the course of the project to ensure the safety of the wind turbine.

DAMPING POOL VALIDATION

Principle

The principles of the damping pool is that the water entrapped within the hull can oscillate under the effects of the floater motion, but also of incoming waves. The water mass behaves as a mass-spring system. The phenomenon can well be described by perfect fluid models [3], but it could be argued that the sharp edges of the hull create vortex shedding that is not well represented by simulations.

The approach selected was to combine perfect fluid simulations, wave tank testing and Computational Fluid Dynamics simulations to assess the effects of downscaling prior to launching the platform before going at sea.

Model testing

As in any new type of floating structure wave tank tests are necessary to confirm its behaviour. In the case of the Floatgen project, model tests were done at a scale of 1/30th. This enabled to adjust simulation models by the model-of-the-model method, and safely design all components. The water depth was scaled down to account for shallow water effects.

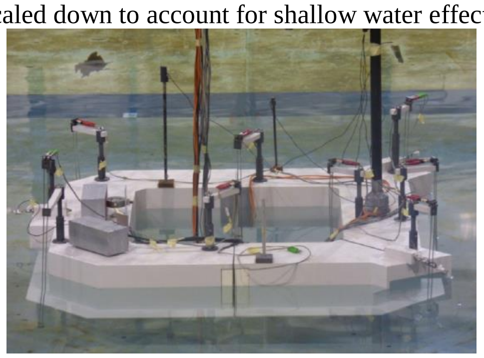

Figure 1. Model tests set-up

Tests were then reproduced in simulations to confirm the adequacy of physical models as well as adjust physical parameters Modelling techniques presented in [1] were confirmed as adequate, with the following summary results:

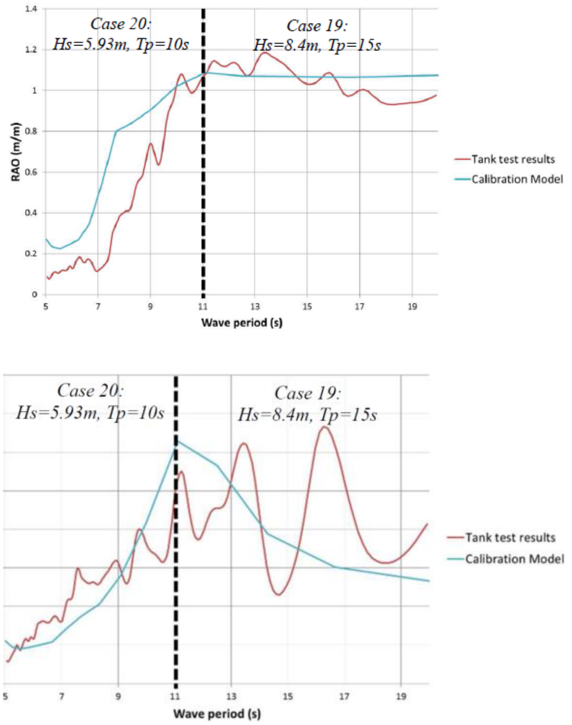

Figure 2. Comparison of motion RAOs from simulations (in blue) to tests (in red) – Heave (top) Pitch (bottom)

The models show good agreement with the model tests. The wriggles at large periods are caused by processing artefacts and wave tank reflections. It will be shown in the next subsections that the RAOs measured on site are actually closer to those simulated.

Upscaling to full scale

Then, to make sure that the scale effect of the floater was evaluated accurately, CFD simulations were performed by the University of Stuttgart [4]. They confirmed that the effect of the upscaling was negligible.

The simulations consisted in running regular wave cases using a numerical wave tank. The simulations were done at model scale and full scale. The pitch motion derived from these are compared to model tests in the curve below:

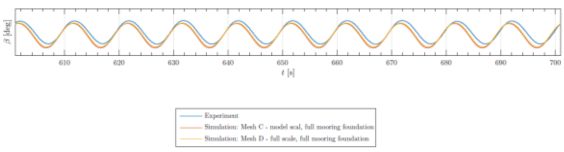

Figure 3. Comparison of pitch motion, model scale and full scale from CFD simulations

Validation during construction

After construction, we performed tests in the same way as in model tests: inclining test to check the metacentric height, free-decay test by loading / unloading the wind turbine to identify the natural frequencies of the floating foundation and confirm its added inertia.

As the floater dimensions are reasonably small, the complete floating wind turbine can be assembled in the port, and put to its operating draught when moored alongside. The wind turbine could be tested up to 25% of its power production capacity. Figure 4 shows the wind turbine moored in the port of St Nazaire in the same condition as during tests. Figure 5 compares simulated and measured natural frequencies of the dynamically prevailing natural frequencies.

Figure 4. View of the floating wind turbine in port

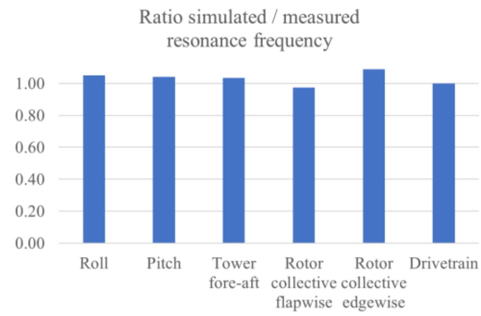

Figure 5. Comparison of natural frequencies as measured during power tests in port to simulations

More details on the modelling techniques and results can be found in [6]. The models used Bladed as the main software. Results of simulations and measurements frequencies are within a few percent, which is in line with the fabrication tolerances.

At sea measurements

During the first days of deployment of the floating wind turbine, it encountered waves sufficiently large (significant wave height of 3m and broad energy spectrum) to confirm the seakeeping performance of the wind turbine.

Wave data were measured by a wave buoy and motion data of the floating wind turbine was recorded using a high-accuracy motion reference unit. It was chosen to compare response amplitude operators of motion rather than the statistics or time histories due to difficulty to represent accurately in simulations in the same time wave directional and frequency-spreading.

To do so, motions were calculated in time domain on a sea-state with the same frequency spectrum and average wave direction. This enabled to derive motion RAOs from both simulations which can be compared to measurements (Figure 6). The curves presented show normalised values, that is divided by the maximum measured value.

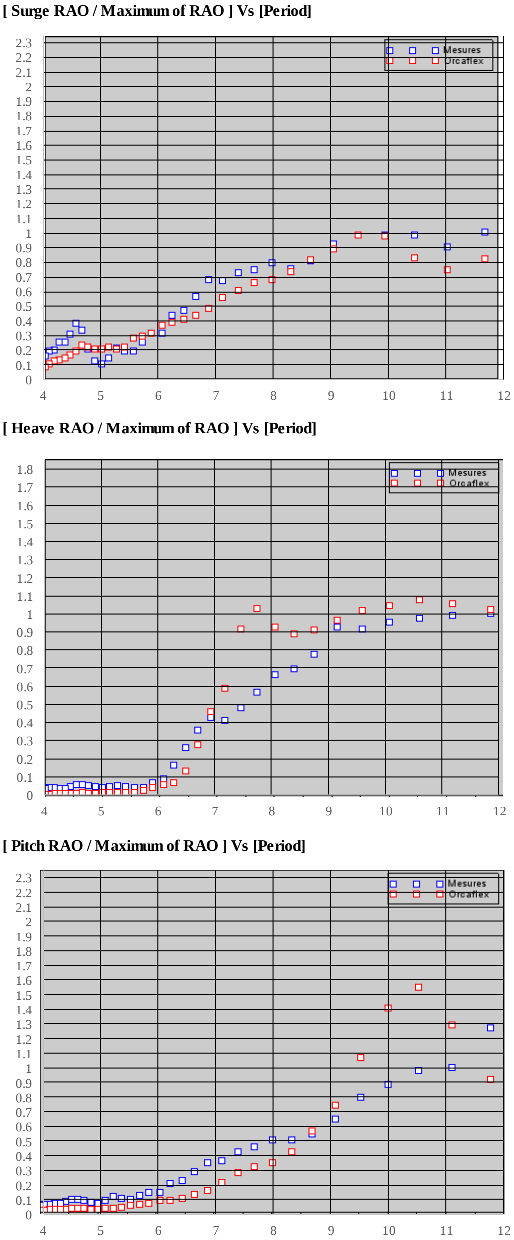

Figure 6. Comparison of measured and calculated Surge (Top), heave (middle) and pitch (bottom) RAO Amplitudes are scaled to the maximum of the measured value.

It comes as a consequence of the validity of models calibrated in wave tank applied to full scale, that the Froude scaling law is valid for this family of floaters.

The combination of the size of the breadth of the hull (36m) and the design significant wave height (9.0m) hence makes the demonstrator representative of a 10MW unit subject to 14m significant wave height.

MOORING LINE MATERIAL

Description and specification

The mooring system was designed to have the shortest length of line on the seabed to minimize chafing degradation of the seabed, and to be soft enough for the mooring radius to be as compact as possible. This was made possible by using polyamide mooring lines suspended to buoys to keep the lines off the seabed, and kept under tension between chains and weights.

Pre-existing research had already quantified the good fatigue performance of nylon ropes [5]. The mooring system was in addition validated by an independent analysis done by Lloyd’s Register.

The validation steps included laboratory tests to assess the stiffness and stretching force needed to avoid retensioning the lines during the life of the floating wind turbine. Tests also enabled to quantify accurately the stiffness of the lines and its evolution over time in the specific loading context of the project.

Behaviour at high loads

During offshore installation, the lines were stretched up to the maximum storm force which enables to embed the anchors and in the same time stretch the ropes so that their length remains constant over the life of the floating wind turbine.

By definition, the load is representative of the storm conditions, and enables to validate onsite the behaviour of individual lines. This is a necessary step toward the confirmation of the behaviour of the moored floating wind turbine.

Figure 7 is an example of a stretching cycle compared to tests, which shows that the measurements are within 10% of the predictions, which is within design margins.

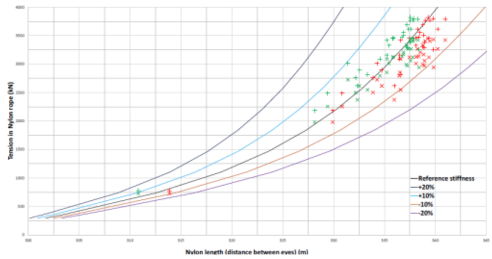

Figure 7. Pull-in test load/extension curve during installation

Behaviour at low loads

In addition to the stiffness of ropes at high loads, the applicability of the rope creep measured in laboratory and the stiffness at low loads can also be ascertained during the mooring lines installation.

During the mooring lines connection phase, load / extension tests were performed under tension around the hook-up tension. This enables to confirm the stiffness of the rope and the length at low load.

After these tests, the ropes can safely be cut at the wanted length and connected to the wind turbine.

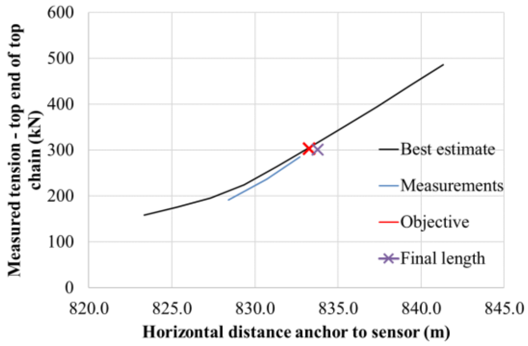

Figure 8. Load/extension curve during hook-up

The tests revealed that the stiffness at low load was within 5% of the expectations, as derived from laboratory tests. The length of the lines is within 0.2% of predictions, which corresponds to the positions measurement accuracy of the anchor. It was then considered to use the theoretical values.

CONCLUDING REMARKS

The Floatgen project constituted a unique opportunity offered to test innovative systems as well as develop methods before commercial scale projects development. Academic and industrial collaboration was instrumental to reaching the ambitious objectives of the project.

As this article is being written, the wind turbine is not yet fully commissioned. The elementary verifications made in laboratory, during installation and construction enabled to validate the behaviour of the mooring lines, floater behaviour and floating wind turbine dynamics. This consequently limits the risks during power production at sea, to the combination of wind and wave events.

The approach of risk mitigation and narrowing during development also enables the project execution teams to focus primarily on their own performance, without being disturbed by lengthy validation steps.

References

[1] T. Choisnet,M. Favré, M. Lyubimova, E. Rogier “A robust floating wind turbine foundation for worldwide application” *Grand Renewable* 2014, Tokyo, Japan

[2] T.Choisnet, B. Geschier, G. Vetrano “Initial comparison of concrete and steel hulls in the case of Ideol’s square ring floating substructure” presented at *WWEC conference*, 2016, Tokyo, Japan

[3] B. Molin ‘On the piston and sloshing modes in moonpools’ *Journal of Fluid mechanics* 2001

[4] F. Borisade, T. Choisnet, PW Chen “Design study and full-scale MBS-CFD simulation of the IDEOL floating offshore wind turbines foundation” presented at *Torque conference* 2016, Hamburg

[5] IML Ridge, SJ Banfield, J Mc Kay, etc. ‘Nylon fibre rope moorings for wave energy converters’ 2010

[6] R. Buils Urbano, M. de Battista, A. Alexandre, E. Norton, Y. Percher, M. Favré ‘Control retro-fit for the Floatgen floating wind turbine: from paper into reality’ presented at FOWT 2018 conference, Marseille

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