Brief by IUML

N°6 | December 2024

OCEANEXT 2024

SESSION 9

Environmental integration of Marine Renewable Energies

OCEANEXT 2024

IUML FR CNRS 3473

Influence of biofouling on the mooring tension of the COAST-HF Iroise monitoring buoy

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Introduction

Offshore artificial structures are quickly colonized by marine organisms, which can affect the local environment, but also the reliability of the structure (Schoefs and Tran 2022) and its behavior (Marty et al 2021). This problem is especially of importance for the design and maintenance of marine renewable energy structures such as floating offshore wind turbine mooring systems (want and porter 2018).

The presence of biofouling can have a great impact on mooring lines responses: it adds weight, restricts line's movements, initiate corrosion, materials ageing and increases hydrodynamic loads (Shun-Han Yang, September 2016) (Benjamin Decurey, 2020). Indeed, biofouling can decrease the fatigue life of the lines by approximately 20 % (Shun-Han Yang, September 2016), because of fluctuating hydrodynamic loads (A. Marty, September 2021). In comparison to a smooth cylinder, the hydrodynamics coefficients (drag, inertia) is likely to be 1.5 to 4 times higher. This changes if drag is linked to the change of rugosity, but also to the distribution of biofouling along the line, the species of biofouling and aggregation (Franck Schoefs, 2022).

Taking into account the biofouling during design process is hard because of its uncertain estimation (A. Marty, September 2021) (Benjamin Decurey, 2020). Its geometry along the line is complex with probabilistic distributions of deep and peak of hard, soft and log flapping biofouling (Franck Schoefs, 2022), which have not been extensively studied. Several modeling efforts, alongside trials in wave and current circulating tanks (Shun-Han Yang, September 2016) (A. Marty, September 2021), have identified a significant correlation between hydrodynamic loads and surface roughness, particularly regarding hydrodynamic coefficients in relation to wave and current conditions (A. Marty, September 2021). Comparing these results to in situ mooring tension measurements with and without fouling under various forcing (wind, waves, and currents) appears to be of interest.

The COAST-HF_Marel-Iroise station is a scientific floating platform in the Ifremer in situ test site of Sainte Anne du Portzic equipped with various sensors to monitor the local metocean conditions (Trasch Martin, 2023). It provides a rich array of input data for field campaign on mooring line tension of this station, both with and without the presence of biofouling.

The experimental set-up used for this campaign are firstly presented, followed by the temporal and spectral presentation of some results, along with the metocean data. It will enable to establish mooring tension transfer functions, and to study the influence of the biofouling on the hydrodynamic responses of the lines.

I. Experimental set-up

I.1. Marel-Iroise buoy mooring line measurement protocol

Figure 1: The MAREL-Iroise scientific buoy in Sainte-Anne du Portzic ©Ifremer (2014)

The COAST-HF-MAREL-Iroise buoy is a scientific platform that monitors since 2000 the physical, chemical and biological characteristics of the coastal marine environment of the Bay of Brest (Figure 1). This buoy is a part of the national observation network COAST-HF - Coastal OceAn observing SysTem-High Frequency (CNRS/Ifremer, 2019) from the ILICO Research Infrastructure.

Measuring 4 meters in diameter and weighing 10 tons, the COAST-HF-MAREL-Iroise buoy is moored in the Sainte-Anne du Portzic observation site (48°21'48 N, 4°33'33 W), at the interface between the Bay of Brest and the Iroise Sea (Rimmelin-Maury Peggy, 2023).

The buoy is placed 8m above seabed at lowest astronomical tide, while the tidal range is about 7.5m. The site is sheltered from the Northerly and Easterly conditions, and is open to wind, waves and current coming from the Iroise Sea in the South-West. These various metocean conditions provide a rich panel of input data (Trasch Martin, 2023).

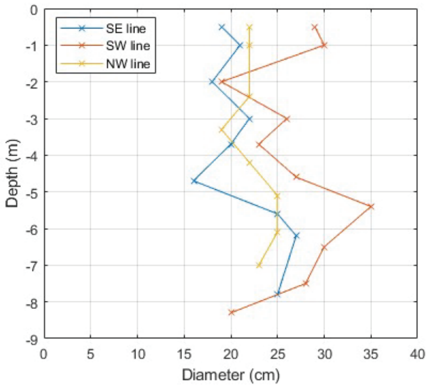
Figure 2: Load sensor set-up in one of the mooring lines ©Ifremer (2023).

The mooring system is made of three 55m-long catenary steel chains of diameter 33mm linked to 10t concrete blocks. The lines are oriented approximately at respectively 62° (NE), 185° (SW) and 300° (NW).

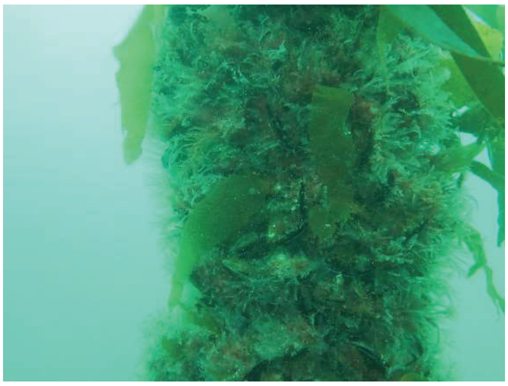
The tension is measured by an autonomous SF5 force sensor from NKE installed on a by-pass of each mooring line as shown in figure 2. According to the manufacturer, the load range of the sensor is up to 5t, its resolution is 2,2kg and it has an accuracy of 25kg.

The loggers are programmed to do 10-minutes recording every hour, at a sampling period of 0,3s. Measurements are available from June 8th to October 4th, 2023. However, the load sensor placed on the SW line seems to be malfunctioning between August 2nd and August 30th, 2023.

Approximately at the middle of the measurement campaign, the fouling on each line has been measured and then removed, in order to assess its influence on the mooring line tension. Therefore, on August 30th 2023, on each line and for each linear metre of chain, starting from the surface and working downwards, divers measured the depth and the diameter of the biofouling cluster around the chain using a measuring tape. Results are presented in Figure 3.



(a)



(b)

Figure 3: (a) Diameter of biofouling measured along the lines. (b) Picture of bioufouling around one of the mooring lines ©Ifremer (2023).

II.2 Metocean measurements

The tidal level is monitored by a Krohne BM100 Reflex Radar in Brest, which is part of the REFMAR tide gauge network operated by the French Naval Hydrographic and Oceanographic Service (SHOM, 2023). There is a light time fluctuation of a few minutes with the tidal level in the Sainte-Anne, which is considered not significant.

Deployment of a Nortek Signature 1000 ADCP took place from June 27th to July 13th 2023, on the Marel-Iroise eastern chain, in the vicinity of point: 4.550607 W, 48.357803 N. Average current speeds of up to 1 m/s were measured. The current is south-westerly/north-easterly. It is positive towards the east when the tide goes out: it goes in the opposite direction to the tide. This phenomenon is explained by the presence of a gyre in Ste Anne Bay.

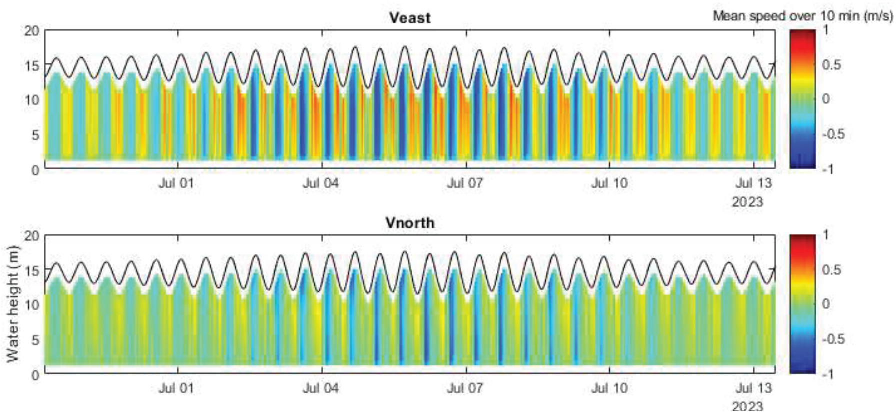


Figure 4: Mean current speed over 10 minutes in the East and North direction in the water column measured during the ADCP campaign

The wind measurement is performed by a CV3 anemometer placed on a lattice mast 3.75 m above the ground, which is 10.0 m above the lowest astronomical tide level. It can measure wind speed up to 41 m/s, with a precision of 0.13 m/s and the direction from 0 to 359° with a precision of 1.5°. The sampling frequency is 1.88 Hz.

Wave monitoring has been performed with a Spoondrift Spotter buoy moored next to the South-West anchor of the Marel-Iroise buoy. The wave monitoring buoy diameter is 42 cm and its weight is 5.4 kg. It is equipped with a 3-axis displacement measurement system using GNSS positioning data (Raghukumar, 2019). The measurement sampling frequency is 2.5 Hz. Waves with a significant height up to 2 m have been measured. Peaks periods are most of the time about 8-9s. Open sea swell enters through the strait of Brest Bay, so most of the waves comes from the South-South-West.

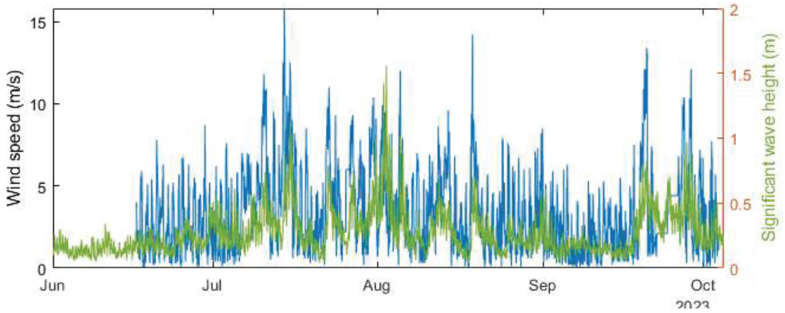


Figure 5: Mean wind speed over 10 minutes and significant wave height

III. Presentation of the results

Field measurement campaign of the SF sensors lasted for four months. The average over the 10 minutes window measured per hour are plotted in Figure 6. The Sud Ouest sensor had a dysfunction during July and August. For the study, the result has been cleaned to ignore the measurement during this period for this particular sensor. The three sensors follow the same trend. There is a periodic behavior induced by the superposition of sinusoidal waves at different frequency and amplitude, following the local tidal level. There are also local peaks that are likely governed by punctual meteorological conditions .

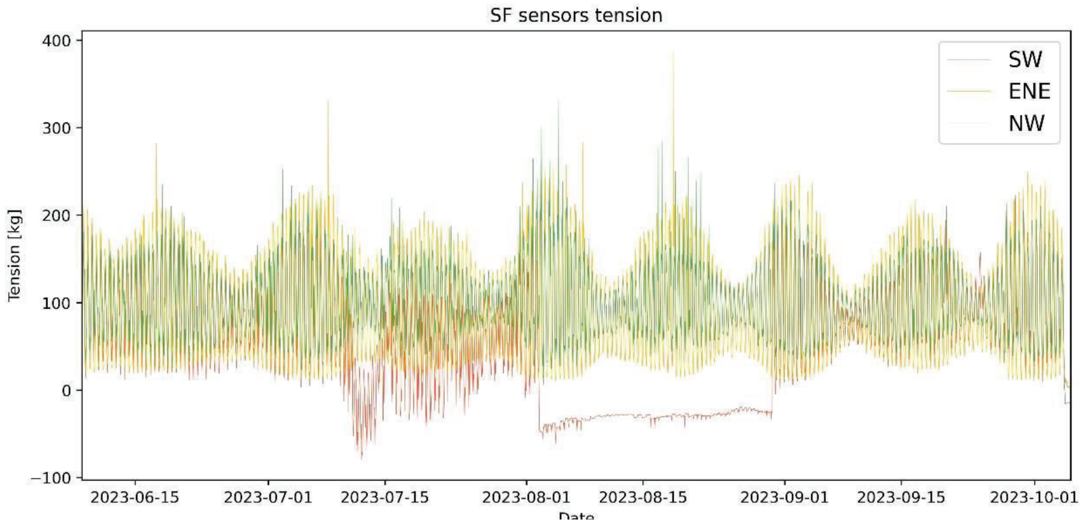
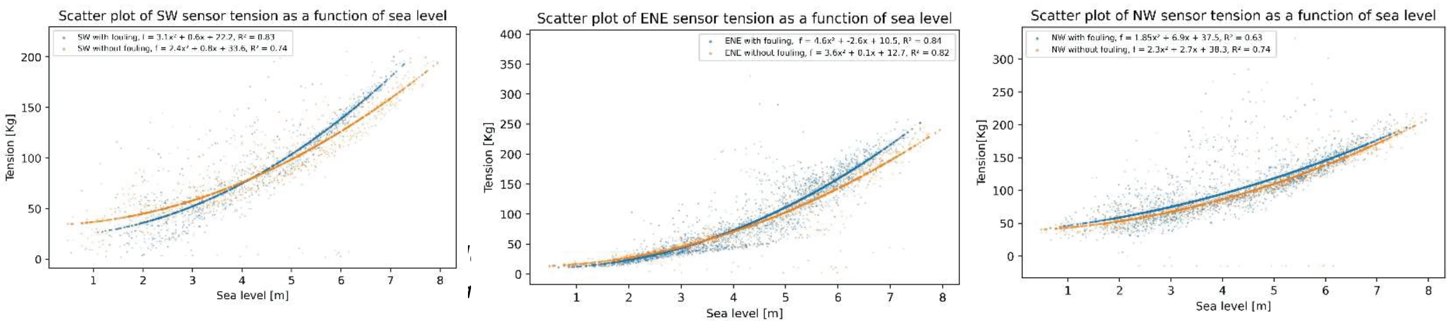


Figure 7: 10-min average of the mooring tension every hour during the measurement campaign

The sea level variation is studied first as the most obvious and the most impactful forcing. Sainte-Anne du Portzic observation site is subject to great tidal influence causing currents and variation of sea level. The COAST-HF-Marel-Iroise buoy being moored by catenary lines, a greater portion of them is lifted off the ground at high tide, resulting in additional tension in the chain due to its own weight. By plotting the scatter plot of cable tension as a function of sea level, a second order polynomial relation can be found (Figure 8).



For each sensor, two trend curves had been calculated by the least square method. Indeed, the cleaning of the anchor lines creates a discontinuity in the tension measurement which induces a distinction between with (AF) and without (SF) biofouling for the polynomial calculation. There is however some dispersion of the values that prevent to identify any significant influence of the biofo²uling on the relation between the tidal level and the average load. This dispersion is probably due to others forcing has wind, current. In order to assess the difference in the current-induced load caused by the presence of biofouling, Figure 9 focuses on three tidal range to cover situation of neap tide, mean tide and spring tide. The selected tidal window were chosen taking only into account days when wind was below 5 knots of wind (2.57 m/s). One must note the measurement for the 73 tidal coefficient were carried out the last day of the campaign, wich explain the zero value in tension after 20 hours.

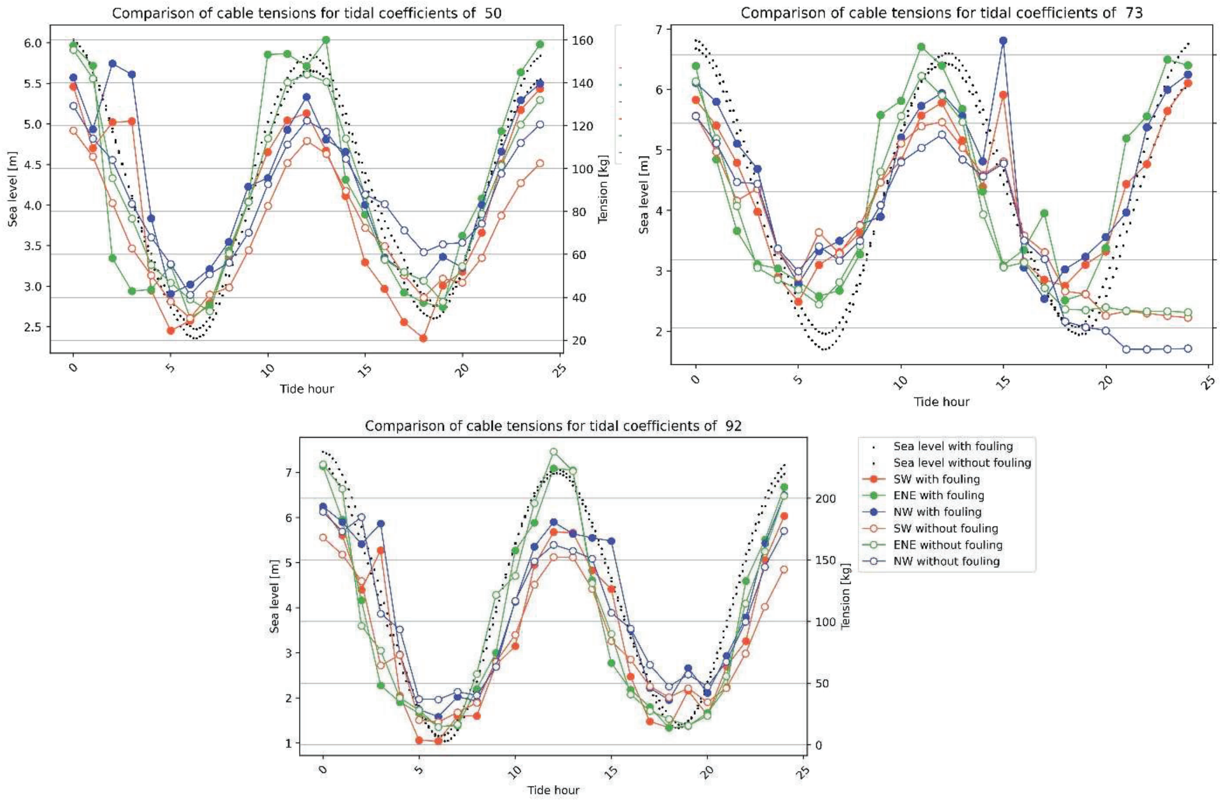


Figure 9: Comparison of mean load during similar tidal condition in the three mooring lines with and without biofouling

On these graph, the load signal follows sea level, but there are peaks which can't be explain by the tide level. For the NE line the peaks appear during the flood, whereas for the SW and NW they appear with the ebb. This suggests that these peaks are generated by the tidal current in Sainte-Anne site. For the selected tidal periods (50, 73 and 92 tidal coefficient), the peaks are greater for the line with fouling (AF) than without (SF). The biofouling cleary seems to have a influence on the loading of the anchor line. More generally, the mean tension is lower for the three sensors. The anchor line behaviour can not be considered the same with and without fouling. However, the presence of peaks is not systematic but recurrent, and their amplitude is not solely influenced by the current speed. Indeed other forcing (wind and waves) can have effect on these peaks, that is why days with light wind where selected.

In order to assess the influence of biofouling on the dynamic response of the mooring line to wave forcing, power spectral density (PSD) of the load have been calculated and compared for measurement windows with similar wave conditions. PSD of the surface elevation and the load signals have been calculated using Welsh estimate with Hanning window on 512 points and 50% overlap. Table 1 presents the experimental conditions for an example of window comparison with and without presence of biofouling, and Figure 10 presents the results of the PSD with and without the presence of biofouling. We can notice a more energetic response of the mooring line in a frequency range around 0.2 Hz.

Table 1: Experimental conditions during the measurement windows used for the spectral comparison

Date	Hs	Tp	Htide	Wind speed	Wind direction
11-Jul-2023 01h50	0.66 m	8.5 s	3.8 m	9.6 m/s	320°
20-Sep-2023 11h20	0.67 m	8.2 s	3.0 m	11.9 m/s	310°

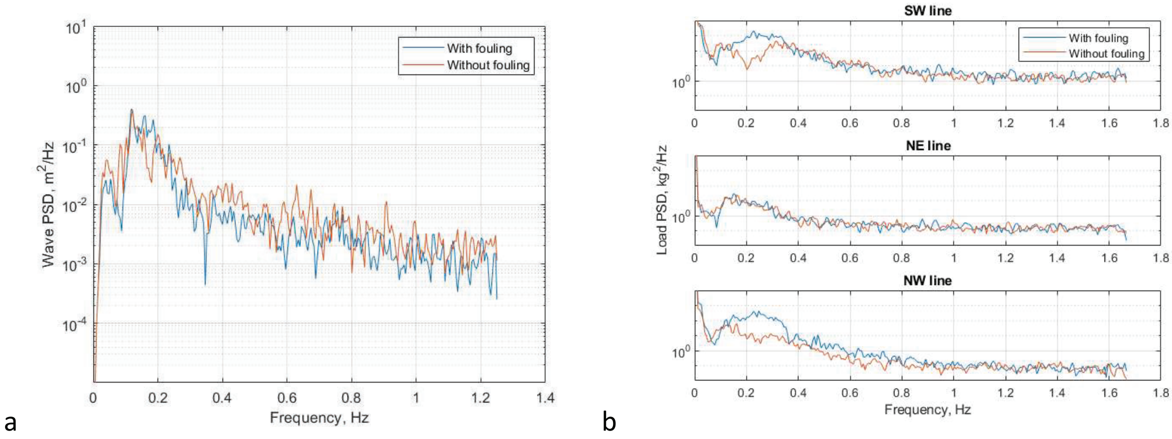


Figure 10: (a) PSD of the surface elevation and (b) PSD of the load signals for similar experimental conditions with and without the presence of biofouling

IV. Conclusions and perspectives

An experimental protocol has been presented to assess the additional loads caused by the presence of biofouling on mooring lines. Preliminary results seem to show a significant influence of biofouling on the response of anchors to current and wave forcing.

Further analysis will be carried out on these results to estimate the hydrodynamic coefficients of the lines with and without biofouling. A comparison with a numerical model will also be carried out.

These tests enabled to generate a database of field measurements that will be useful when compared with the existing literature and the assumptions commonly used in the design of offshore structures, MRE or oceanographic station. The measurement protocol can also be replicated and improved in the future to obtain more data at different locations and on different types of mooring.

V. References

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