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Fatigue Load Ranges of Mooring Lines of Floating Offshore Renewable Energy Platforms

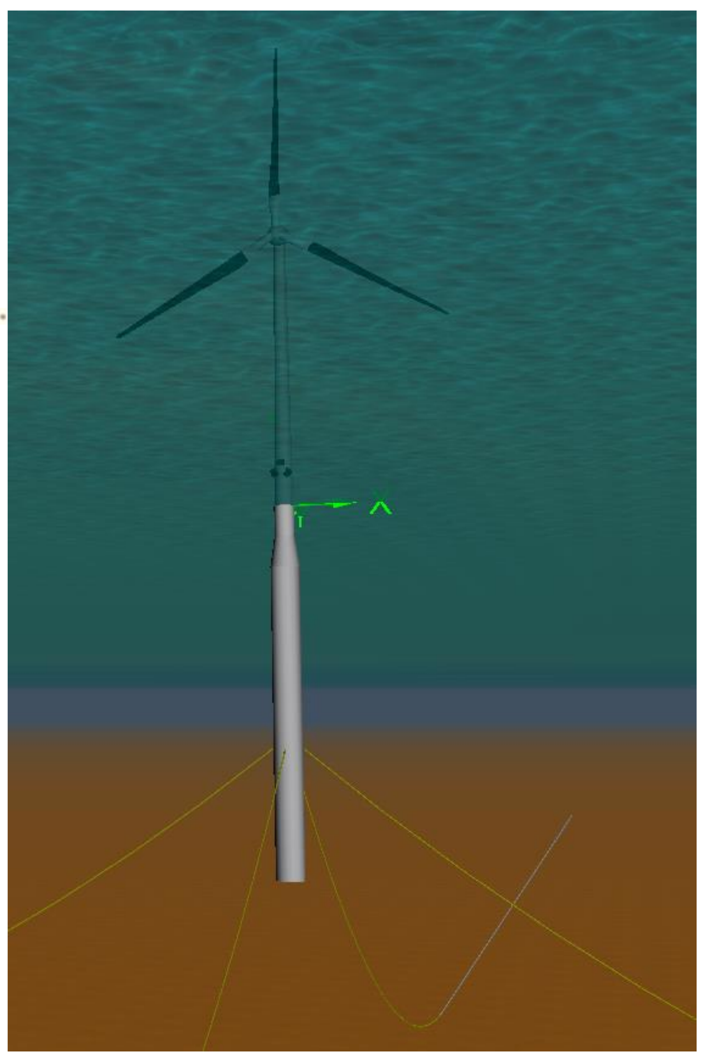
Imanol Touzón[1,2], Javier Lopez-Queija[2], Vincenzo Nava[1,3], Victor Petuya[2]

[1]Tecnalia Research and Innovation
[2]Department of Mechanical Engineering, University of the Basque Country UPV/EHU
[3]Basque Center for Applied Mathematics - BCAM

INTRODUCTION

Offshore floating structures are subject to environmental loading such as wave, wind and current loads. It is commonly considered that current and wind loads only contribute to the mean line tension of mooring systems, together with mean drift forces. However, wave loading are cyclic loads which directly impact on mooring line tension. Additionally, slowly varying drift forces, which are non-linear forces, have a non-neglectable contribution on the cyclic loading of mooring systems. This non-linearity, along with the drag terms and the geometric stiffness of catenary lines, make challenging accurate estimations in the frequency domain of tension range distributions and, therefore, fatigue damage. In this work several non-linear time domain simulations have been carried out and its tension range distribution is obtained by means of the Rainflow cycle counting method. Considerations about impact on annual damage of mean correction methods as well as statistical distributions based on PSDs of line tensions are made. Finally, range estimation models are proposed to compute the fatigue damage based on frequency domain linearized simulations.

NUMERICAL SIMULATIONS AND METHODOLOGY



Fully non-linear time domain simulations carried out of a spar FOWT [1] with a 4 line mooring system:

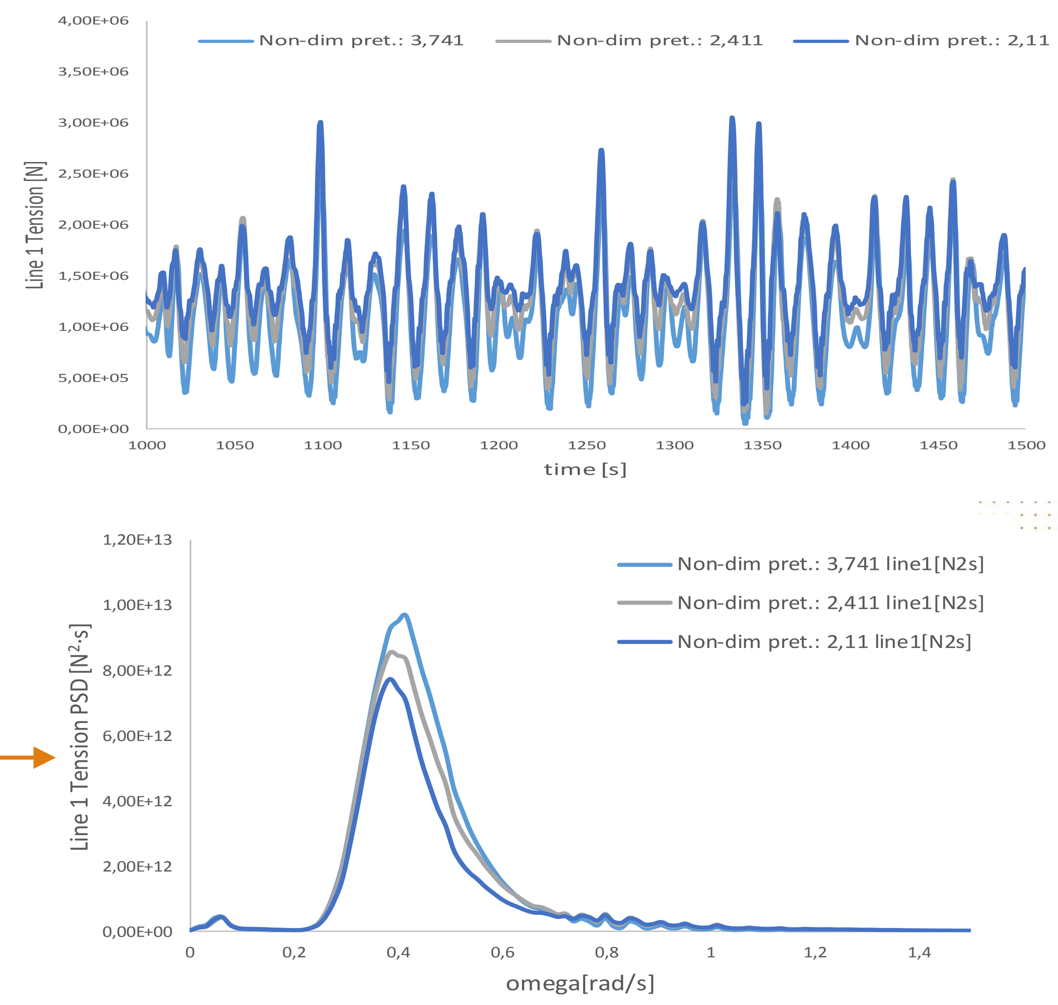
10-3 hour simulations to reproduce both Low and Wave frequency motions of 15 cases.

Different non-dimensional pretensions and linear masses are reproduced covering suitable ranges for the platform based on methodology presented in [2].

PSDs provide frequency domain like results for cycle number estimation and comparison.

Most loaded line (Line 1) tension range distribution estimated by the Rainflow cycle counting method and to be compared with Rayleigh distributed tension ranges.

Non dimensional pretension	Linear mass [kg/m]
3,741	110
3,090	160
2,746	210
2,525	260
2,365	310
3,495	110
2,806	160
2,411	210
2,249	260
2,105	310
3,734	110
2,920	160
2,504	210
2,263	260
2,110	310



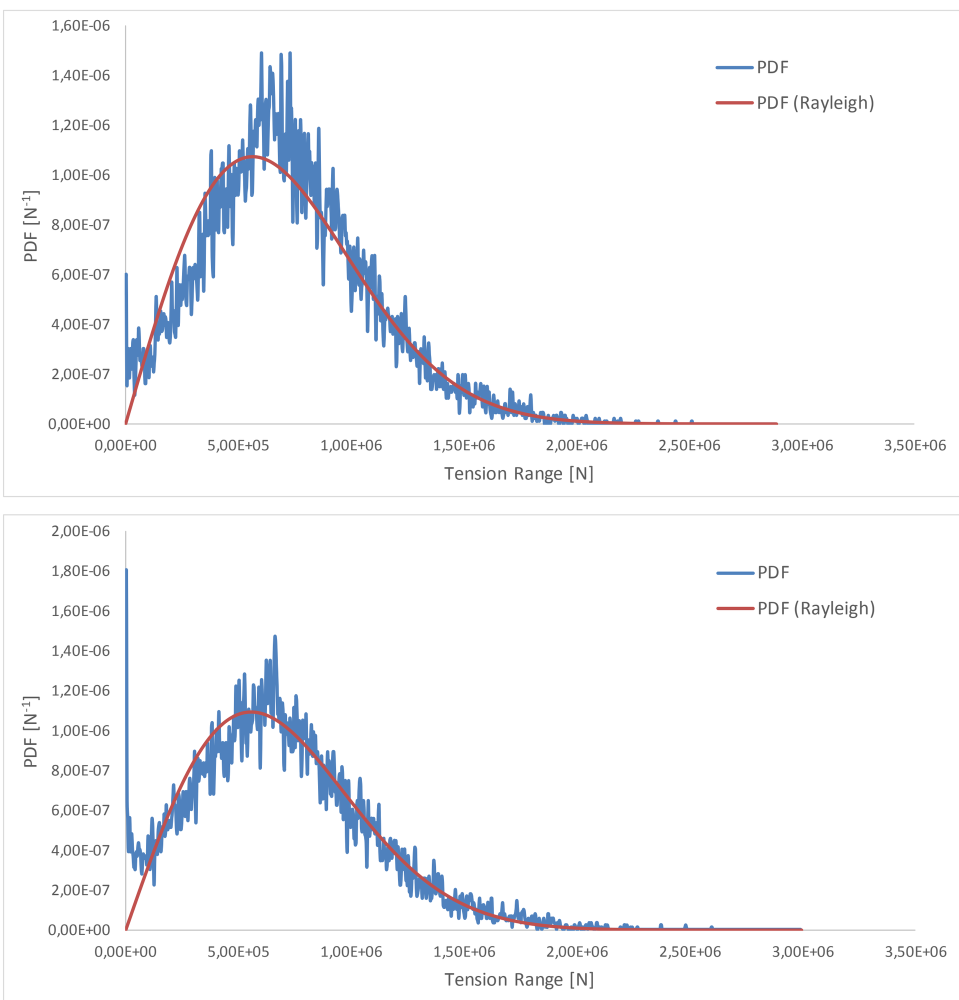
Most Loaded line (Line 1) tension time series and its corresponding PSDs for 3 non-dimensional pretensions

RESULTS

Tension Range Distribution:

- Range distribution estimated from both the time series and the PSD.
- Rainflow cycle counting method is used for time series and Rayleigh distribution is assumed from PSD standard deviation
- Vanmarcke bandwidth parameter [3]:
  - δ → 0: Narrow Band
  - δ → 1: Wide Band

$$\delta = \sqrt{1 - \frac{m_1^2}{m_0 \cdot m_2}}$$

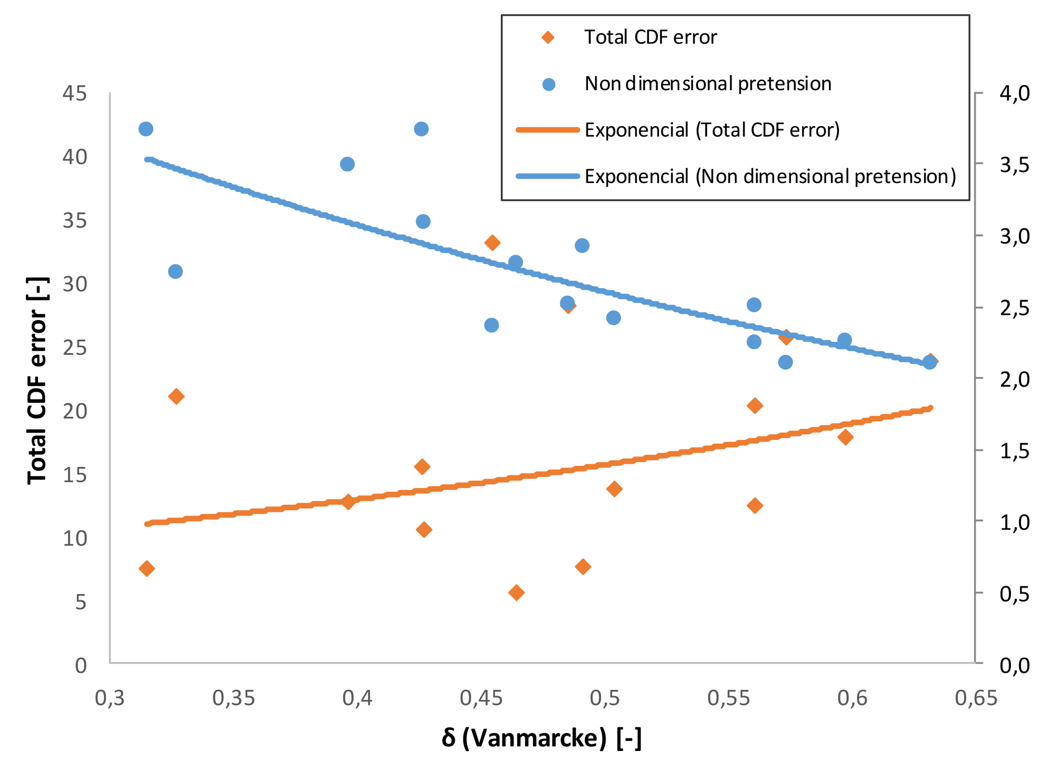


PDF comparisons for non-dimensional pretensions of 3,741 (top) and 3,734 (bottom)

Bandwidth considerations:

- Obtained bandwidth parameters are in the range of 0,3-0,7.
- Total errors of CDFs are calculated for Rayleigh tension distribution with respect to Rainflow cycle tension distributions.
- Larger δ leads to larger errors in range estimations.
- Lower non-dimensional pretension leads to higher Vanmarcke factors.

A method to account for wideband processes tension range distributions is to be proposed to accurately predict fatigue damage on mooring lines.



Error in range estimations as function of Vanmarcke bandwidth parameter and Vanmarcke parameter dependency on non-dimensional pretension

CONCLUSIONS

Distribution of cycle ranges is necessary to obtain an appropriate estimation of the fatigue damage in mooring lines. A set of fully non-linear time domain cases has been simulated in an energetic sea state. These cases represent different combinations of mooring line characteristics varying its pretension and linear mass. Rainflow cycle counting method has been applied to time series and a Rayleigh distribution is assumed from its power spectral density. Since two frequency ranges are excited the Vanmarcke bandwidth parameter has been applied. The more close to zero the more narrow banded is the process. It has been observed that lower non-dimensional pretensions provide larger bandwidth parameters.

Obtained errors of CDFs tend to be higher for larger bandwidth parameters, as expected, and methods to account for wideband processes are to be considered.

Initially, Gaussian processes can be assumed for Frequency Domain fatigue assessment. Different approaches for wide band processes will be considered in order to obtain a good correlation of tension ranges with the Rainflow cycle counting. One alternative is the Jiao-Moan method that estimates the Total Fatigue Damage as a sum of the Wave Frequency fatigue damage and the damage due to a process which is the sum of the Low Frequency process and the envelope of the Wave Frequency process. This approach has the potential to be extended also to non-Gaussian processes.

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TECNALIA
Parque Científico y Tecnológico de Gipuzkoa
Mikeletegi Pasealekua, 2
E-20009 Donostia-San Sebastián - Gipuzkoa (Spain)
www.tecnalia.com

Contact Information:
Imanol Touzon
Tel.: +34 671 749 481
imanol.touzon@tecnalia.com

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