tecnalia Inspiring Business

www.tecnalia.com

FATIGUE ANALYSIS OF MOORING LINES IN TIME AND FREQUENCY DOMAINS FOR WAVE ENERGY CONVERTERS

Javier Lopez Queija[1,2], Imanol Touzón[1,2], 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 renewable energy devices, such as wave energy, is on its way to reach full scale demonstration. The income of such devices is demonstrated not to be enough to plan single device installations. Therefore, the technology is being deeply analyzed to find suitable sizes in terms of power of individual device as well as number of devices to make up arrays which may justify its commercial development. Mooring analysis requires time consuming simulations which need to be carried out for different limit states and most times makes optimization routines too slow. Offshore floating structures are subject to environmental loads produced by waves, wind and current. Generally, current and mean wind forces only affect to the mean line tension of mooring systems, along with mean drift loads. Nevertheless, wave loads are cyclic which has direct impact on mooring line tension. Moreover, slowly varying drift forces, which are non-linear, also contribute on the cyclic loading of mooring systems. This non-linearity, together with the drag terms and the geometric stiffness of catenary lines make challenging estimations of fatigue damage in the frequency domain. In this work several non-linear time domain simulations have been carried out in the operational mode and its tension range is obtained applying the Rainflow Method. Based on the statistical distributions of the counted ranges a fatigue damage value is calculated. The Palmgren-Miner rule is applied to estimate the fatigue damage for all cases.

NUMERICAL SIMULATIONS AND METHODOLOGY

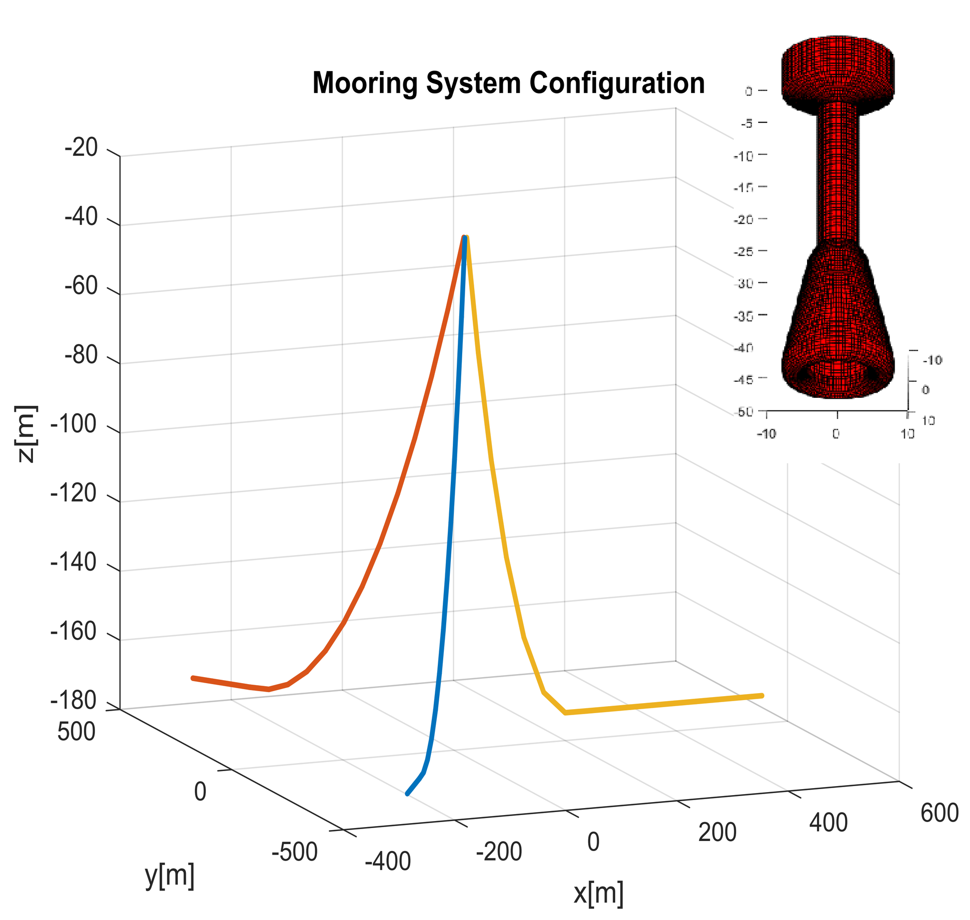

Figure 1. Mooring system configuration and OWC device

Time domain simulation

An OWC wave energy converter has been modelled and analysed, moored with a 3 line catenary mooring system. 3 hour time domain simulations have been carried out representing 24 operational sea states from within the Bimep scatter diagram. It has been assumed uniaxial tensions in the mooring lines. Therefore, material tension was calculated using the equivalent section provided in [1]. Two approaches for the fatigue damage assessment have been used, the Rainflow cycle counting method [2] and an approach based on the equivalent Rayleigh distribution [3]. The fatigue damage in each sea state has been estimated by means of the Palmgren-Miner rule [4], as shown in equation (1).

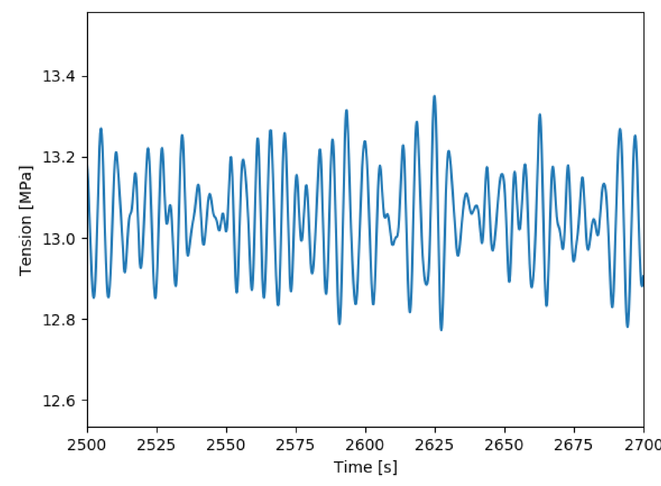

Figure 2. Mooring line tension for OWC device in $H_s = 0{,}75\ m$ and $T_p = 6\ s$.

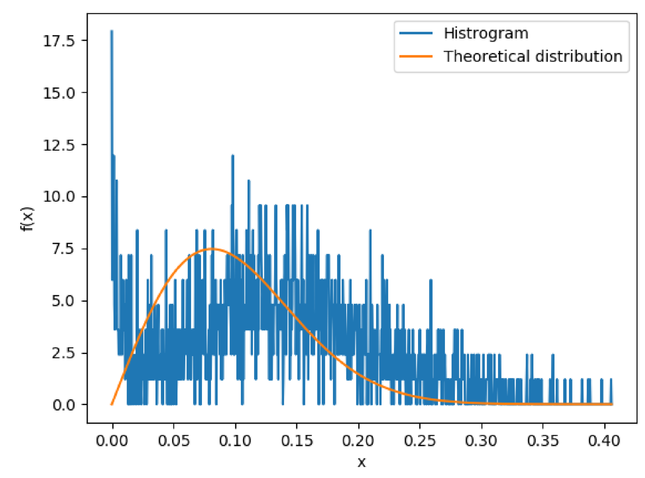

Figure 3. Tension ranges series histogram and theoretical distribution for OWC device in $H_s = 0{,}75\ m$ and $T_p = 6\ s$.

Probability density function

Since a non-linear model has been simulated the line tension distribution will not be gaussian distributed. However, in the operational regime it can be expected not to have a large impact on it. Therefore, a Rayleigh distribution has been assumed, disagreements between the histogram of time series and the corresponding Rayleigh distribution are shown in figure 3.

$$D = \frac{2^m T}{K} \cdot \nu_0 \cdot \int_0^{\infty} x^m \cdot f_{max}(x) \cdot dx \qquad D = \sum_{i=1}^{N} \frac{n_i}{N_i} \qquad (1)$$

RESULTS

Time domain vs Frequency domain

The results for both, time domain and frequency domain, are presented in the Figure 3. The figure at the top shows the Fatigue Damage results after applying Palmgren-Miner rule to the cycle counts of Rainflow method. The figure at the bottom represents the Fatigue Damage assuming a Rayleigh distribution of the line tension amplitude and applying the formula introduced in the previous section. These results have been carried out for all of the sea states simulated for the 3 mooring lines. 2 of the lines presented similar values in damage because of the symmetry of the mooring system.

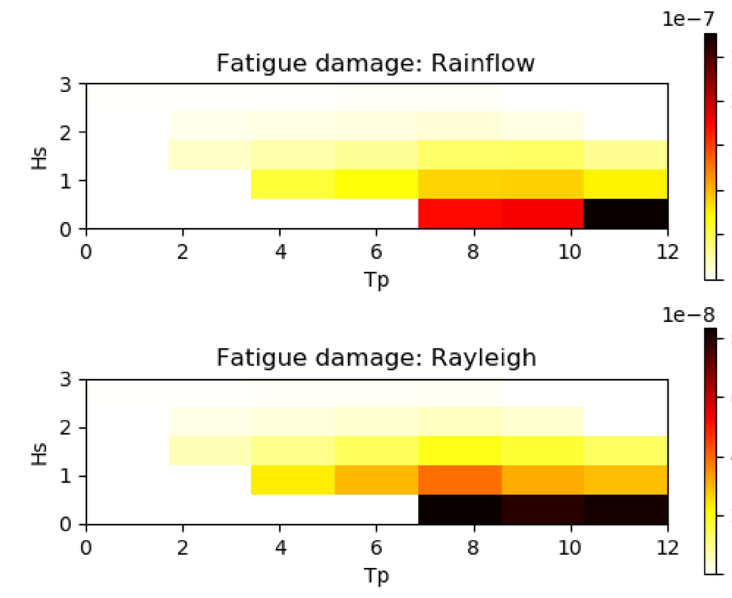

Figure 4. Fatigue damage results for OWC device in $H_s = 0{,}75\ m$ and $T_p = 6\ s$

CONCLUSIONS

A good 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 have been simulated. In order to obtain a tension range PDF, the Rainflow cycle counting method has been applied to time series and compared to the corresponding Rayleigh distribution. The obtained results show significant differences in damage values. This discrepancy is a consequence of the differences observed between both distributions. These differences can be attributed to model non linearities, such as the geometric stiffness and viscous drag of mooring lines. Results can be improved considering separately the influence of the low frequency and wave frequency terms and through Rayleigh modified tension range distributions for non-gaussian line tensions.

REFERENCES

[1] DNVGL, “DNVGL-OS-E301: Position Mooring”, 2015

[2] N. E. Dowling, “Fatigue failure predictions for complicated stress-strain histories”, Journal of Materials, vol. 7, pp. 71-87, 1972

[3] Z. Gao, T. Moan, “Fatigue damage induced by nonGaussian bimodal wave loading in mooring lines”, Ocean Research (Elsevier), 2007

[4] R. Avilés, “Métodos de cálculo de fatiga para ingeniería mecánica”, Paraninfo, 2015

[5] J.M.J Journée, W.W. Massie, “Offshore hydromechanics”, Delft University, 2001

Universidad del País Vasco Euskal Herriko Unibertsitatea

TECNALIA
Parque Tecnológico de Bizkaia
C/ Geldo Edif. 700
E-48160 Derio - Bizkaia (SPAIN)
www.tecnalia.com

Contact Information:
Javier López
Tel.: +34 663 994 392
javier.lopez@tecnalia.com

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

VI Marine Energy Conference
euskampus CAMPUS OF INTERNATIONAL EXCELLENCE