

APPLICATION OF RAINFLOW TECHNIQUES FOR THE ANALYSIS OF THE DYNAMIC RESPONSE OF MARINE FLOATING ELEMENTS

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INTRODUCTION

The two main characteristics of an oscillation are its amplitude and period. Although amplitude has always taken the spotlight in the design and verification of maritime structures, in the last twenty years, frequency dominance has gained increasing importance. The operability of maritime operations and the maintenance and preservation of port and offshore structures depend on the oscillatory dynamic response of floating bodies which, in turn, relies on the oscillatory forcing of the free surface.

Oscillations within a basin and along a berth line diminish the quality of vessel stays in the port, reduce the performance of ship stowage, and stress and fatigue moored structures and floating bodies. In the case of floating offshore structures, their dynamic response conditions the efficiency of capturing wind and wave resources, as well as the lifespan of structural elements that limit the movement of floating bodies.

In the field of port engineering, rainflow counting has demonstrated significant advantages compared to traditional wave counting methods like the zero-downcrossing approach, yet its widespread adoption remains limited.

Statistical and frequency analysis techniques are based on the prior characterization, over a time series, of the oscillation cycle. This is defined as the magnitude of an oscillation between the maximum crest and minimum trough, with a period representing the time elapsed during two consecutive (upcrossing or downcrossing) passages through a reference level, usually its mean value.

This cycle approach disregards oscillations of both short and long periods (oscillations of the sea level taking place within the waves and in a long range) even though they are not negligible (for example, waves of the same height ranging from different levels). On the contrary, the rainflow matrix, by characterizing each cycle in terms of its maximum and minimum, considers any possible oscillations, regardless of the values of their ranges or periods.

The (traditionally) neglected oscillations may be crucial for assessing the impact of movements on a floating wind

turbine, on a ship during loading and unloading operations, or the interaction of the ship itself with the docking and mooring structure. Loading and unloading operations of a docked ship or the operation of a floating wind turbine are feasible if they occur within a range of frequency and magnitude of oscillation, and zero-crossing methods are limited in achieving this purpose.

The rainflow concept has emerged as a powerful complement to the traditional wave concept, revolutionizing certain specialized areas such as fatigue, where rainflow analysis is now commonly accepted (Johannesson 1999).

Although the list of possible applications to coastal engineering problems is huge and includes wave groups, damage progression in breakwaters, overtopping increase, or impacts of vessel movements on durability of mooring and berthing elements (Molina, 2014), this study specifically seeks to showcase the advancements and diverse applications of this technique in the analysis of dynamic responses in floating elements, shedding light on its consequential influence on design principles and operational considerations.

METHODOLOGY

For the analysis of the dynamic response of a ship, forced by waves, it has been examined from the perspective of the rainflow technique. Some researchers, as noted in Rychlik and Leadbetter (2000) or Castillo et al. (2012), have pointed out that rainflow matrices are more suitable than classical waves because they provide a more realistic and comprehensive view of the historical record. For this analysis, the methodology developed by Gomez et al. (2013) aligned with the aforementioned authors has been applied. In this analysis, the forcing cycles have been compared with those of the float's response.

In order to make clear the concept under study, Figure 1 shows the interpretation of the sectors of a rainflow diagram using a simple example of the analysis of a time series of a ship's surge indicating the initial and final position of the floating body for each cycle.

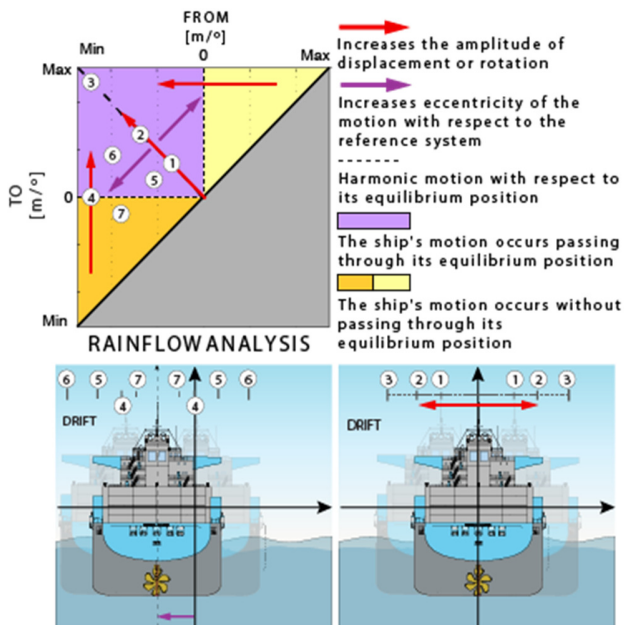


Figure 1. Correlation between the sectors of the rainflow diagram and the initial position (FROM) and ultimate position (TO) of the rainflow cycle oscillation of the floating body

RESULTS

Some results on the analysis of the dynamic response of a floating foundation for sway and surge during the installation operation are shown in figure 2. These results include both the time series and the corresponding rainflow diagrams including all cycles.

The methodology has been applied to all translational and rotational degrees of freedom of the floating element and the results have been compared to the ones attained with other methods as the traditional zero-crossing methods.

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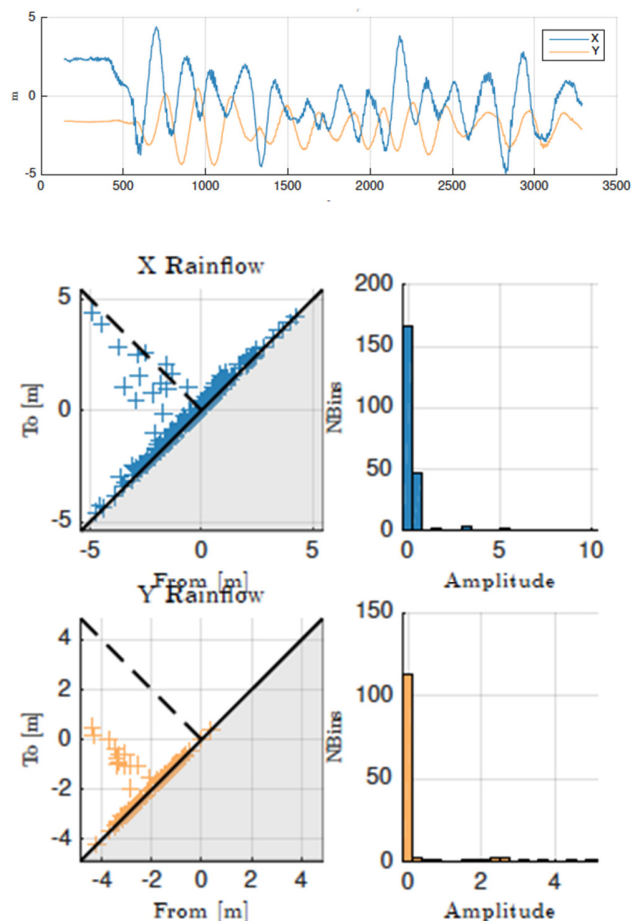


Figure 2. Analysis of the dynamic response of a floating foundation for sway (X) and surge (Y) in a sea state with significant wave height $H_s[m]=2$ and peak period $T_p[s]=7$. Gamma: 1. Pretension: 15tn. Clump Weight: 5tn. Top. Time series of X and Y. Left. Rainflow diagrams. Right. Number of rainflow cycles vs Oscillation amplitude