1 Introduction

An offshore platform and all of its installed equipments should be designed for a long life span. Therefore, it is necessary to evaluate the fatigue resistance of several of its structural components during the design stage. To evaluate this fatigue resistance, the designer needs to obtain the dynamic response of the platform to all external loads and thereafter to obtain the base excitation over these equipments. Given the base excitation and additional external loads over the equipment, the dynamic response of the equipments can be calculated, the stress time history on points that are critical for fatigue can be obtained and then the fatigue resistance can be determined. During all this process of determining the fatigue resistance, several assumptions must be made by the designer and the uncertainties on them have to be considered.

The evaluation of structural integrity is a requisite for the design of any offshore structure. The dynamic response of the structure due to the external loads needs to be investigated on early stages of the design process in order to avoid significant changes afterward. The ocean waves are the main source of external loads over offshore structures, as the structure will be subjected to many different sea states during the working life of the equipment, several sea surface elevations and dynamic responses simulations should be accomplished during such investigation phase. Any reduction on the necessary computational effort for these simulations will save working time.

Many different research areas require some source of simulation of ocean waves and structural integrity evaluation. Langley [21] investigated statistical techniques for estimating the reliability of offshore structures. He studied the reliability of an equipment modeled as a single degree of freedom system based on the available information for the intended location. Kukkanen [19] presented a procedure for the fatigue analysis of hull structures of ships. A spectral method has been applied to determine stress responses in different short-term condition, and the long-term predictions for stress responses have been determined by taking into account the operational conditions of the ship. The estimation of fatigue life of the structure has been determined using Miner's fatigue accumulation hypothesis together with probabilistic models of stress ranges and number of stress cycles. Pérez [29] was interested on testing of applications of ship motion control strategies and needed accurate and simple mathematical models to describe the exerted loads and motions of vehicles. After simulating the sea state for a given wave spectrum, the results were related to the ship motion using the Response Amplitude Operators (RAO) for the specific ship. Kukkanen [20] presented a fatigue analysis procedure for offshore floating structures based on the separation of hydrodynamic load and structural responses, on the effective fatigue load concept, and using response interpolation in order to simplify the fatigue analysis calculating just a few directional fatigue effective load cases. Such calculation can be accomplished in early stages of the project and can be easily updated during the development of the project. Forristall [10] needed to define the height of the deck of oil platforms and obtained statistics for the maximum crest over an area using a combination of analytical theory and numerical simulations. Forristall [11] investigated the damage caused by hurricanes Ivan, Katrina and Rita to deep water facilities and concluded that crest heights calculated using standard theories hardly could have caused such damage, and calculations of the maximum crest height over the area of the deck are able to explain it. Forristall [12] studied the influence of the diffraction and radiation of the incident waves due to the large columns of a Tension Leg Platform (TLP), and estimated the maximum crests under the structure. Nieslony [28] presented a method for determination of multiaxial load segments from original service histories and proposed a rainflow procedure for stress cycles counting that will be used in this work.

In all these works some kind of ocean wave's simulation and structural integrity evaluation were needed. In this work the use of reduced-order models to represent the sea surface elevation will be investigated, since its direct calculation is time consuming computational task. A simplified model for the dynamics of the platform has been used, since the platform is not the equipment being investigated. The use of such simplified models, when providing trustable results, brings great benefits when reduction on computational effort is necessary. For obtaining an approximation to the dynamics of the drilling tower a finite element model using beam elements has been used. Despite of this being a very simple model for such complex structure, a reduced-order model based on proper orthogonal modes and on prescribe modes of the structure has been used, because the necessary simulations demand a great computational effort. In practical applications global finite element models for the drilling tower and local finite element models for the areas of the structure that are critical for fatigue, will be necessary and in this case the use of reduced-order models is mandatory. The construction of the histograms for the distribution of stress ranges provides the necessary, and until the moment unknown, information for the designer evaluate the fatigue resistance of the structural detail that is being investigated. Such histograms can be adjusted to some probability density function afterward.

All these steps are present in this method, and the uncertainties on the parameters of each system can be included during simulations. Some standards and references present probability density functions for the variables that are being investigated, but the use of these functions is based on some hypothesis that not necessarily apply for the problem at hand.

Therefore the main contribution of this work is to provide a method of evaluation of the fatigue resistance of a drilling tower considering the sea surface elevation, the dynamics of the platform on which the tower is installed and the dynamics of the tower itself. In this method, reduced order models are used for obtaining the sea surface elevation and the dynamics of the tower and the uncertainties on the parameters of the components of the system can be included in the analysis as well. The analysis can be done for several sea states, according its probability distribution, and no assumption about the probability distribution of the stress ranges has to be made previously.

During the preparation of this work some publications have been done. Sacramento et al [32] and [33], presented the first version of this method. The fatigue damage on a critical detail of the drilling tower was calculated, considering the probability of occurrence of the significant wave heights. Sacramento et al [34] extended the method including the effect of the uncertainties on the parameters of the drilling tower, namely the thickness of the plates and the thickness of the welds, and the correlation between the components of the structure defined by these parameters. The version of the method presented in [34] is similar to the one presented in this work.

This work is organized as follows. Chapter 2 presents the conceptual model for the sea surface elevation. On Chapter 3 it is shown the evaluation the dynamics of the platform. The dynamic response of the platform will be used on Chapter 4 to evaluate the dynamics of the drilling tower. The fatigue analysis is accomplished on Chapter 5. Results are shown on Chapter 6 and conclusions are drawn on Chapter 7. An overview of the procedure can be seen on Fig. 1.1.

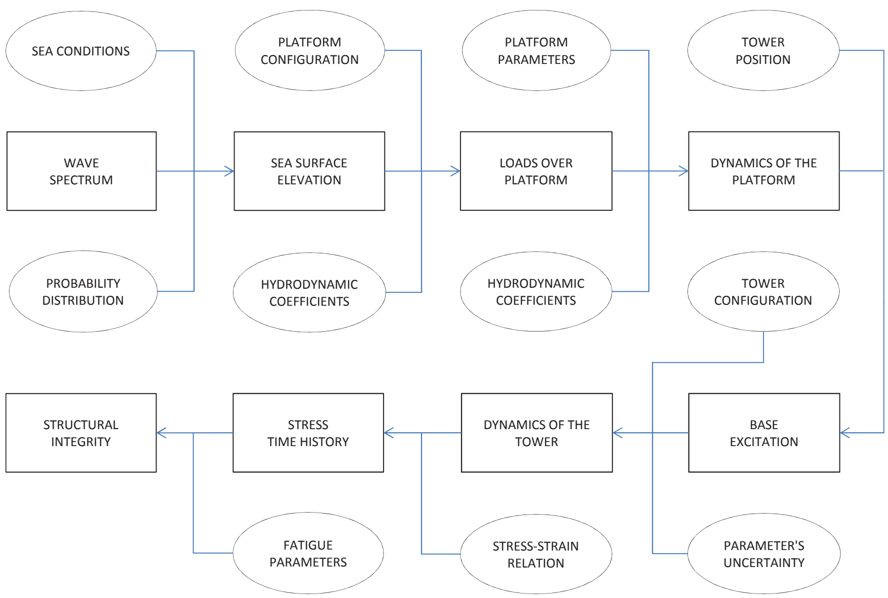

Figure 1.1: Overview of the procedure