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Summary and Conclusions

In this work, a computational model was developed to evaluate the structural integrity of a drilling tower welded to an offshore platform. The base of the tower is excited by the dynamics of the platform, which in turn is excited by the ocean waves.

The Pierson-Moskowitz spectrum has been used to identify the frequency composition of the sea surface wave elevation. This spectrum can be used only after the wind has blown constantly for a certain period of time and the sea elevation surface becomes stationary. In this case, the sea is referred to as *fully-developed*. In this work it was considered that, during its entire working life, the platform will be installed in an area whose sea surface elevation can be simulated using this spectrum. For ships or platforms that can work on different ocean areas and under different conditions, alternative spectra may be necessary.

The geometry of legs of the platform has been simplified to four cylinders. In modern design of offshore platforms, the legs can have rectangular cross section and be connected by floating pontoons. For a better simulation of the dynamics of the platform, the interaction between sea water and these pontoons has to be evaluated. This is a difficult computational task and in this case the use of reduced-order models for the simulation of the sea surface elevation would bring great benefits. A reduced-order model for the sea surface elevation has been used, and a good agreement between the results from the original and reduced-order model has been obtained.

The Froude-Krilov forces were the only considered external loads acting on the platform. In a more complex model additional loads as the drag forces can be considered.

The platform was considered a rigid body and the tower was excited at its base due to the dynamic response of the platform. In case the flexibility of the platform had been included on the system, the bending of the deck of the platform is an additional source of deformation and consequently stresses to the welds at the base of the tower.

An approximation to the dynamic response of the drilling tower has been obtained using a reduced-order finite element model. Since the external loads are presented as a base excitation it was necessary to include prescribed modes on the base of normal modes used to project the dynamics of the system. Up to the author's knowledge there are no publications about methods of obtaining such prescribed modes. The results obtained using the prescribed modes were compared with the ones obtained by the complete model and good agreement has been obtained. The method is time consuming, even for simplified models, which means that it is necessary to reduce the computational cost using reduced-order models as much as possible.

From results shown on Tab. 6.2 one can note that the main contribution for the fatigue damage is given by the significant wave heights of 3, 4 and 5m, therefore in case of a design change only these heights need to be simulated initially.

The choice of the period of simulation has a significant influence on the results, thus only the interval of the stress time history where the results are stable should be considered.

The lifting load was considered a concentrated mass at the free end of the beam/drilling tower. Such simplification can have significant influence on the obtained results. Jia [17] presented a method of calculating the fatigue damage on offshore jacket structures and concluded that the inertia effects of the structure, equipment mass in the structure and other non-structural installations have a significant contribution to fatigue damage. Elshafey et al [8] investigated the dynamic response of a scale model of an offshore jacket structure both theoretically and experimentally. They investigated the effects over dynamic response of changing the weights over the deck and noted that in some cases resonance may occur. They investigated the influence of the peak frequency of the wave spectra over the dynamic response as well. Therefore the influence of the simplifications on the construction of the model of the system should be carefully investigated.

At the realization of the time history of the stress cycles at the critical point shown on Fig. 6.8 one can note that there are several small range cycles along the time history. Such small range cycles are accounted for during the fatigue damage evaluation procedure but have no significant contribution for the damage.

It can be noted that the histogram shown on Fig. 6.9 can be approximated by a Gaussian probability density function with zero mean. It should be clear that this histogram is for the values of stress, peaks and valleys, obtained during simulation and that the stress range distribution, used to calculate the fatigue damage, is shown on histogram of Fig. 6.10, that was approximated to a Weibull probability density function. In future works it can be investigated whether the Weibull distribution for the setress ranges can be obtained from the Gaussian distribution of the stress values.

It can be noted that the uncertainty on the thickness of the weld and on the thickness of the plates can make some calculated fatigue damage to be above the acceptable level of 1 but has little influence on the dynamics of the structure. Therefore during Monte Carlo simulation different trials for the thickness of the weld and for the thickness of the plates can be used without calculating the dynamic response of the tower again. It will reduce the computational cost of the simulation.

In order to evaluate the fatigue resistance of a structural detail of a drilling tower installed on an offshore platform, it was necessary first to evaluate the sea surface elevation to be able to obtain the loads over the platform. Such loads have been used to obtain the dynamics of the platform and consequently the base excitation over the tower and its dynamic response. From the deformation of the tower, the stress time history at the structural detail can be obtained and the fatigue resistance can be calculated. Despite of this being a long path to obtain the fatigue resistance, the results have shown to be necessary to follow it.

The existing standards for fatigue resistance evaluation of offshore equipments present simplified analysis procedures based on long-term stress range distributions that depend on parameters that can not be determined a priori. Several different stress range distribution from other authors have been presented in this work and in all of them two or more parameters have to be determined. Some closed form solutions for obtaining these parameters have been presented, but in some cases they have to be obtained using some source of curve fitting technique.

Some of the presented solutions are based on assumptions about the process being narrow-banded. When the designer is investigating some structure for the first time, this kind of information is not available. When some kind of joint probability function for the parameters is necessary, it has to be evaluated in some way.

Therefore the use of the presented method is recommended when the designer has no previous information about the behavior of all the components of the system. Even initially using simplified models for the components of the system, such models can be replaced by more sophisticated ones at latter stages of the design process. The use of simplified models can provide valuable information about the behavior of the system.

After obtaining the histogram for the stress ranges the adjust to a curve is worthwhile. The histogram of stress ranges obtained for the studied detail has shown to be similar to a Weibull distribution. Such approximation can be used within an optimization strategy to find a robust design, since the parameters of the distribution can be obtained without a complete simulation be accomplished. The Eqs. 5.2 and 5.21 are proposed as an alternative for calculating the fatigue damage when the stress range distribution follows a Weibull distribution.

In this work the dynamics of the platform and of the drilling tower were obtained for two different directions, and the calculated stresses are a combination of the deformation due to the displacements on both directions. This is a much more realistic situation, since usually there is no prevailing direction for the waves.

The adjust of the obtained histograms to some known probability density function gives additional information about the behavior of the system, and the influence of the variations on parameters of the system over the parameters of the probability density functions can be investigated in future works. With this information at hands the designer could quickly identify the necessary modifications on the design or use such approximations within an optimization strategy.

The method provided in this work can be used by designers of offshore equipments to obtain more economic designs. Since the available standards not necessarily cover the problem at hands, and in this case some conservative assumptions are usually made, this method can be used as a detailed evaluation of the fatigue resistance of the required structural detail, and the results can be submitted to the classification societies to be approved, despite of the use of more sophisticated models for obtaining the dynamics of the platform and the dynamics of the drilling tower demand a lot of computational resources.

Several publications about evaluation of fatigue resistance of offshore structures are available. The investigated details are usually off a jacket, ship or platform. In this work the investigated structural detail is part of an equipment installed on a platform, and the dynamic response of this equipment due to the base excitation originated from the platform was considered when evaluating the fatigue resistance.