

On Some Uncertainties in the Modelling of Ocean Waves and Their Effects on TLP Response

Sverre Haver
 Statoil, Stavanger, Norway

Birger Natvig
 Aker Engineering, Oslo, Norway

ABSTRACT

The effects of uncertainties in the modelling of ocean waves is considered both with respect to fatigue and predicted extremes. A tension leg platform (TLP) is adopted as the example structure and the platform is assumed to be located at Haltenbanken. A statistical model for the wave climate is presented and some uncertainties related to this model are identified. Various models for the wave spectrum are also considered. The adequacy of these models with respect to the actual structural quantity is indicated by also calculating the fatigue damage using mean measured spectra.

INTRODUCTION

The stochastic long-term method (Battjes, 1970, 1979; Moan et al. 1977; Inglis et al. 1985) is a most convenient method for estimating the wave-induced response of linear/linearized structural systems. The marginal (long-term) distribution function for a given response quantity is then estimated as a weighted sum of the short-term distributions for all possible sea states. Thus the probabilities of exceedance from the various sea states are properly accounted for, and the problem of selecting a consistent set of design storms is avoided.

From the marginal distribution function, the fatigue life is easily estimated using the Miner-Palmgren hypothesis. Extremes corresponding to a given return period are also conveniently estimated from the distribution function assuming statistical independence between the crest heights of adjacent zero-crossing cycles.

An adequate formulation of the long-term method requires that the wave conditions are properly described both in a short- and long-term sense. Concerning the short-term description, the waves are in a statistical sense completely characterized by the spectral density function, provided the sea surface elevation can be modelled as a Gaussian process. This hypothesis is assumed to be of reasonable accuracy as far as deep water conditions are considered.

In practical applications, a standard model involving some few characteristic parameters is most frequently adopted for the wave spectrum. Accordingly, the long-term climate is described by the joint probability distribution of the actual characteristics. The significant wave height, the spectral peak period, and often also the main wave direction are typically chosen as characteristic parameters.

Uncertainties will of course be introduced both by the short- and long-term description of ocean waves. Concerning the short-term description, uncertainties are introduced both through the choice of spectral model and through the adopted expressions for the spectral parameters in terms of the main sea state characteristics. With respect to long-term modelling, the main uncertainties

are related to the estimation of the joint distribution for the significant wave height and spectral peak period for a given number of direction sectors. Additionally, uncertainties will of course be associated with the adequacy of the Gaussian assumption. However, this will essentially be a problem as we enter into more shallow water, and it will not be considered herein.

The purpose of the present paper is to evaluate the sensitivity of the predicted structural load effects to the uncertainties introduced through the stochastic modelling of ocean waves. A tension leg platform (TLP) is considered, and the actual response quantity is the normal stress in the column-pontoon intersection. The effects of these uncertainties both regarding the predicted fatigue life and the predicted extremes are discussed. For further details on the structure and the stress transfer function, reference is made to Natvig (1989).

STOCHASTIC RESPONSE CALCULATION

The stochastic long-term analysis is reviewed in some detail in Haver (1989). It is therein shown that the long-term distribution of the primary maxima Y_x of a Gaussian process $X(t)$ with slowly varying properties reads:

$$F_{Y_x}(y) = \frac{1}{v_0^+} \int_h \int_t \int_\theta v_0^+(h, t, \theta) F_{Y_x|HmoTp\theta}(y | h, t, \theta) f_{HmoTp\theta}(h, t, \theta) dh dt d\theta \quad (1)$$

where the long-term mean zero upcrossing frequency is given by

$$v_0^+ = \int_h \int_t \int_\theta v_0^+(h, t, \theta) f_{HmoTp\theta}(h, t, \theta) dh dt d\theta \quad (2)$$

$f_{HmoTp\theta}(h, t, \theta)$ is the joint probability density function for significant wave height, spectral peak period and main wave direction. The short-term distribution of Y_x is considered a conditional distribution given the sea state characteristics, and it is reasonably well-modelled by the Rayleigh distribution, i.e.:

$$F_{Y_x|HmoTp\theta}(y | h, t, \theta) = 1 - \exp \left[-1/2 \left(\frac{y}{\sigma_x(h, t, \theta)} \right)^2 \right] \quad (3)$$