On the Assessment of Extreme Response of Steel Risers

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ABSTRACT

Two design criteria used to calculate the extreme response of steel risers are reviewed in this paper. The first criterion is concerned with the definition of the maximum response throughout the environmental contour of random load parameters. The second one is based on the long-term response statistics, in which all relevant sea states should be simulated. The use of inflated contour is also discussed and an omission sensitivity factor is calibrated. The results from these two methods are then compared in two examples of steel risers.

KEYWORDS: steel risers; extreme response; environmental contour; long-term response; inflated contour.

INTRODUCTION

The design of steel risers must satisfy ultimate, fatigue and accidental limit states. The assessment of such limit states should be carried out using the most relevant sea states in each case. Sea states are described in terms of environmental parameters, for example, wave height and period, and wind velocity. A statistical description is needed due to the random nature of such parameters, so that one can determine the relevant load conditions. For such purpose, scatter diagrams are widely used to describe the joint occurrence of significant wave height and zero up-crossing wave period (DNV, 2007). From this discrete data diagram one can fit a joint distribution probability model, which is very useful in extrapolating measured data and predicting extreme events (Bitner-Gregersen and Haver, 1991).

The ultimate limit state is defined as the collapse of the structure, which means the loss of its ability to withstand loads. Steel risers are subjected to the combined effects of effective tension, bending moment, internal and external pressure. Upon combining such effects, a yielding limit criterion can then be defined at any point of the riser cross section. The key task is to select those sea states that will give the worst response in terms of combined load effect. Recent research based on structural reliability is still being conducted, but some practical results have already been introduced to offshore regulations (DNV, 2001; DNV, 2004), and at least three design criteria are available for steel risers: design storm, environmental contours and long-term response statistics. Only the last two will be discussed herein.

Steel risers undergo dynamic and nonlinear behavior when they are subjected to environmental loads and top-end vessel motions. Therefore, extreme response is not necessarily associated to extreme loads. A full long-term analysis is deemed to be the most satisfactory approach to determine extreme response (Moan and Naess, 2005). It consists of a convolution integral over all relevant sea states, so that one can obtain the statistical description of response and then determine the characteristic value for a given return period. On the other hand, this procedure requires a large number of simulations so as to appropriately cover the region of the scatter diagram that most contributes to the extreme response. Additionally, it must be pointed out that the precision of long-term response approach depends on the quality of the integration, i.e., the most relevant sea states should be accounted for. Otherwise, a significant content may be lost and a non-conservative response will be obtained.

Another design criterion is based on environmental contours. The extreme response is then taken as the most unfavorable one among those sea states with the same return period. This means that extreme response is associated with extreme loads and that statistical response itself is neglected. Fewer simulations are required, hence this design criteria is more suitable for practical purposes.

Hernández et al. (2007) compared the aforementioned design criteria for mooring lines axial load response. They showed that the use of long-term response design criterion leads to more uniform reliability indexes than those obtained using environmental contour. An alternative way to get better results from this last design criterion is the use of inflated contour, in which an omission sensitivity factor is calibrated so as to obtain an equivalent inflated contour associated to a longer return period (Winternstein et al., 1993). So, the response randomness is offset by using a more severe environmental load condition.

The use of an omission sensitivity factor to inflate load contour applied to TLP tendons was investigated by Niedzwechi et al. (1998). Inflated contour was explored in order to compensate the uncertainties associated to the pretensioning and fluid/structure interaction. The