Reliability and Response Based Design of a Moored FPSO in West Africa Using Multivariate Environmental Contours and Response Surfaces

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ABSTRACT

The application of Inverse First-Order Reliability Methodology (IFORM) to the determination of response maxima using environmental contours and response surfaces is presented in this paper. In the first part concerned by the environmental data modelling, the directional effects are analysed for the current, wind and wave parameters, and taken into account if necessary. The response modelling is presented in the second part. Current, wind and wave responses are derived using response surface models (RSM). Directional coefficients are obtained from harmonic analysis. Two types of response are considered in this study: the total offset and the total tension in one particular mooring line. The third part is devoted to the application of IFORM approach to the specific case of a moored FPSO in West Africa in ballast condition. Design points and response maxima are computed with a robust iterative gradient method. Directional effects on response maxima are analysed. Results are compared with statistical extreme values from a Direct Simulation Analysis. Finally, some perspectives for further developments are given in conclusions.

KEY WORDS: FPSO; West Africa; structural reliability; joint environment; response-based design; inverse reliability method; environmental contour; response surface.

INTRODUCTION

The traditional approach to the design of offshore structures has been to quantitatively assess the loads created by simultaneous and colinear extreme return values of wind, wave and current. It has now long time been recognised that this represents an overly conservative assessment of the environmental forces, and during the past fifteen to twenty years, Response-Based Design has been proposed as a more realistic and less conservative alternative because it aims at:

- Achieving 1- to 100-year return periods for design parameters of interest (such as vessel excursions, mooring or riser design loads) rather than environmental parameters;
- Accounting for joint probabilities of wind, wave and current;
- Accounting for structural loading and response characteristics. However, this design method requires:

- the knowledge of extreme values and joint probability distributions of the environmental variables (see e.g. Winterstein, 1993),
- together with the ability to describe accurately and rapidly the structural response.

Precisely, it seems that the time has been reached when Response-Based Design is made potentially more reliable thanks to a detailed metocean database available for a site offshore West Africa, and to complex hydrodynamic and structural models with improved computing time, which can be simplified efficiently with Response Surface Models (RSM).

The work presented in this publication is a part of a study of “Joint Probabilities of Wind / Wave/ Current and Response-Based Design of FPSO, Moorings and Risers” funded by TOTAL S.A., R&D division, with the support of TOTAL E&P Angola.

The scope of the present work is to determine the design points and the response maxima of a moored FPSO in West Africa using the combination of Inverse First Order Reliability Method – IFORM – (Orsoro, 2006, François et al., ISOPE 2007) and Response Surface Modelling – RSM - in three steps:

- Integration of all elements and data (environmental and response variables) into a coherent formulation
  - Environmental data and statistical description of current, wind and wave directions and intensities (Frelin & Nerzic, 2006, Nerzic et al., ISOPE 2007)
  - Numerical modelling of response by means of response surfaces including directional coefficients (Fontaine, 2006, Fontaine, Ledoux, Leguennec, ISOPE 2007)
  - Use of IFORM methodology to derive response maxima and design points
- Numerical solution of the inverse reliability problem
  - Intersection of response surfaces with environmental contours
  - Search for response maxima at design points defined as combined environmental data generating response maxima for a given return period and a given reliability index
- Assessment of the method by comparison with results from Direct Simulation Analysis (DSA) (Ledoux, 2006, Fontaine, Ledoux, Leguennec, ISOPE 2007) in similar loading condition

Application to a moored FPSO in West Africa has been carried out by Orsoro (2006). Results are compared with extreme values obtained by statistical analysis from Direct Simulation Analysis. Finally, some perspectives for further developments are given in conclusions.