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Design Load Calculations for Iceberg Impacts

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ABSTRACT

A probabilistic framework is presented for determining design global iceberg impact loads for offshore structures, with example calculations provided for a cylindrical GBS (gravity based structure) and an FPSO (floating production, storage, and offloading system). Emphasis is given to the development of efficient simulation techniques, the effect of iceberg rotation on loads, modelling local shape of the iceberg at contact point, and sensitivity analysis to evaluate areas of uncertainty which cannot be treated probabilistically.

INTRODUCTION

A number of offshore oil production systems have been proposed for the Grand Banks region off Canada's east coast, the two main systems at present being a GBS and a ship-shaped FPSO. For both systems the possibility of iceberg impacts must be included in the structural design requirements. For the GBS, consideration must be given to possible impacts with large icebergs that cannot be towed. For the FPSO, design requirements are reduced as larger icebergs can be detected and avoided by towing or moving the system off location. While considerable experience has been acquired in designing for wave loads, experience in designing for iceberg impact loads is limited. As a consequence, it is necessary to place a higher degree of reliance on analytic and physical modelling. Using probabilistic methods, variations in iceberg size and shape, ice strength, detection capability, wave-induced velocity and impact eccentricity can be accounted for, to the extent that the models and parameter distributions used are accurate. Where data are limited and processes are not fully understood, calculated design loads should be considered conditional on the particular assumptions used. Sensitivity analysis is an important tool in evaluating the importance of different assumptions, determining if adequate information is available, and choosing a final design value.

Matskevitch (1996) gives a brief review of models of iceberg-structure impacts including Cammaert and Tsinker (1981), Swamidas and Arockiasamy (1986), Johnston and Prodanovic (1989), Bass et al. (1985), Salvalaggio and Rojanski (1986), Duthinh and Marsden (1986), Holthe(1989), and Croasdale (1989). Examples of probabilistic studies to determine design loads include Lindberg and Anderson (1987) and Isaacson and McTaggart (1989). The present paper addresses the question of iceberg shape and the increased probability of nondetection and higher impact velocities in severe sea states.

Emphasis is given first to the overall probabilistic framework and the use of efficient Monte-Carlo techniques. Further, an analytical impact model which accounts for rotation and local shape of the iceberg is presented, followed by the development of distributions for the required shape parameters, and by model results. Sensitivity analyses relating to number of icebergs, water depth, iceberg management, impact velocity, iceberg global and local shape, and ice failure strength are included.

PROBABILISTIC FRAMEWORK

The steps used to determine design global impact loads are illustrated in Fig. 1. First, the number, shapes, and sizes of icebergs, environmental conditions, and any seasonal correlation between the two are characterized. Iceberg size is defined by waterline length and the environment is defined by significant wave height H_S. Since the probability of impact is proportional to iceberg drift velocity, a model of iceberg drift velocity as a function of L and H_S is required. Details are given in Fuglem et al. (1996a). Since that publication, a new waterline length distribution has been implemented and a draft cut-off has been applied to allow consideration of different water depths. A probabilistic relationship between length and draft is used.

In the encounter model, the expected annual number of impacts which would occur if no avoidance procedures were carried out is

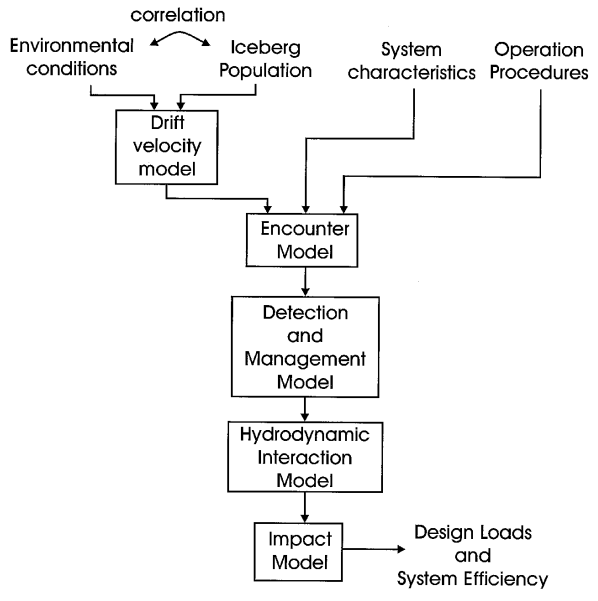

Fig. 1 Methodology for determing design iceberg impact loads

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KEY WORDS: Iceberg, impact, shape, importance sampling, design load, FPSO, GBS.