NONLINEAR DYNAMIC ANALYSIS
OF
OFFSHORE TOWERS

by

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TO MY PARENTS

C E R T I F I C A T E

This is to certify that the thesis entitled "NON LINEAR DYNAMIC ANALYSIS OF OFFSHORE TOWERS" being submitted by Mr. Arvind Kumar Jain to the Indian Institute of Technology, Delhi for the award of the degree of DOCTOR OF PHILOSOPHY is a record of the bonafide research work carried out by him.

Mr. Arvind Kumar Jain has fulfilled the requirements for the submission of this thesis which to my knowledge has reached the requisite standard.

The thesis, or any part thereof, has not been submitted to any other University or Institute for the award of any Degree or Diploma.

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ABSTRACT

This study is concerned with the treatment of the nonlinearities due to the drag component of the wave force and the variable submergence of the structure near the splash zone, in the frequency domain analysis of fixed base offshore structures. It also aims at evaluating the severity of these effects, on the response of the structure, under both regular and random waves in the presence of steady current.

For treating the nonlinearity due to the drag component of the wave force, in the frequency domain analysis, six different methods have been developed for solving a SDOF system. They are : (i) Exact Newton-Raphson Method (Method A), (ii) Approximate Newton-Raphson Method (Method B), (iii) Hydrodynamic Damping Method (Method C), (iv) Simple Iteration Method (Method D), (v) Extrapolation Method (Method E) and (vi) Approximate Linearized Method (Method F). In Method A, the drag related nonlinearity is handled by using the Newton-Raphson method for simultaneous equations, whereas the other effects are incorporated by 'correcting' the loading term in every iteration. The Newton-Raphson iteration method requires, the derivatives of the harmonics of the drag loading with respect to the harmonics of the displacement, in its solution procedure. Methods B and C

are also based on Newton-Raphson method. The main difference between these methods is in the use of the iteration equation employed in their solution procedure. In Method B, the off-diagonal submatrices of the Jacobian matrix are taken as null, whereas in Method C, the fourier transforms of the relative velocity, used in the iteration equation, are taken as zero. In Method D, the hydrodynamic damping (as found in Method C) is taken as zero in the iteration equation. The Method D has linear convergence, whereas Method A based on the exact version of the Newton-Raphson method converges quadratically. Method E accelerates the convergence of Method D by using the delta - square extrapolation technique. Method F uses changed system parameters (frequency and damping), which take care of the full non-linearity of the drag force, thus obviating the need for any iteration. Out of the above methods, the one which is based on the Exact Newton-Raphson Method is found to have the fastest convergence.

Three methods namely, (i) Approximate Newton-Raphson Method, (ii) Simple Iterative Method and (iii) Extrapolation Method are then extended for solving MDOF system (an idealized fixed base offshore tower), subjected to hydrodynamic forces produced by regular waves and steady current. The methods also take into consideration the effect of variable submergence. This effect is included in the computation of hydrodynamic loading by two approaches namely, Chakrabarti's and Hogben's. Variable submergence is found to have considerable influence on the response, specially upon the harmonic contents of the hydrodynamic loading. Inclusion of current in the computation of hydrodynamic loading also changes its harmonic contents.

The two iterative frequency domain methods namely, (i) Approximate Newton-Raphson Method and (ii) Simple Iterative Method are then applied for calculating the dynamic stochastic response of MDOF system. The effect of variable submergence is included in the computation of hydrodynamic loading in an approximate manner, by using Chakrabarti's and Hogben's approaches. Iterative frequency domain methods use the fourier transforms of the time histories of the random wave forces, at each iterative cycle. These time histories are generated with the help of simulation procedure (Wave superposition technique). For the proper simulation, of the time histories, optimum values of some parameters like the number of wave components and the record length etc. are obtained through a separate numerical study.

The efficiency of the two iterative methods in obtaining the response of a fixed base offshore tower, under random waves is compared with the help of a parametric study. The effect of the variable submergence and nonlinearity of the drag component of wave loading, on the statistical characteristics of the response, are also examined. Suitable statistical models to describe the extreme values of response, for the case of drag nonlinearity and variable submergence, are then finally proposed.

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