

**Non-Linear Dynamic Analysis and Reliability
Assessment of Deep -Water Floating Structures**

by

Mohd Jameel

Department of Applied Mechanics

Submitted

in fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

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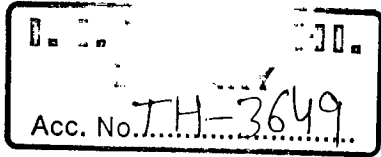


INDIAN INSTITUTE OF TECHNOLOGY, DELHI

HAUZ KHAS, NEW DELHI – 110 016, INDIA

July 2008

Sea with waves ② Dynamic systems



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Dedicated to my

Mother

CERTIFICATE

This is to certify that the thesis entitled *Non-Linear Dynamic Analysis and Reliability Assessment of Deep -Water Floating Structures*, being submitted by *Mr. Mohd Jameel* to the Indian Institute of Technology, New Delhi, India, for the award of the degree of *Doctor of Philosophy* in Applied Mechanics, is a record of the bonafied research work carried out by him under my supervision. He has fulfilled the requirements for submission of this thesis, which is the best of my knowledge, has reached the requisite standard.

The material contained in this thesis has not been submitted in part or full to any other university or institute for the award of any degree.

Date: 21.07.2002.



(Suhail Ahmad)

Professor

Department of Applied Mechanics

Indian Institute of Technology, Delhi

New Delhi- 110 016, India

ACKNOWLEDGEMENTS

I express all my gratitude to the Almighty ALLAH, for the successful completion of this thesis under the able guidance of Prof. Suhail Ahmad. This thesis would not have been possible without the support, the trenchant critiques, the probing questions, and the remarkable patience of my supervisor.

I sincerely appreciate and thankfully acknowledge Mr. Mushtaq Hussain Khan, Dr. Gurumurthy, Dr. Amit K Agarwal, Dr. Najamur Rahman, Dr. Nadeem Khalil, Dr. Zahir Hasan and Dr. Zaheer Khan for their help, valuable suggestions and moral support.

I also extend my sincere thanks to Rizwan, Dr. Naushad, Dr. Noor, Dr. S. D. Kulkarni, Dr. Nadeem Hasan, Dr. Fahad Anwar, Adnan Qamar, Anish, Vijay, Asif Shah, Shiraz, Rupesh, Kallol, Ibrahim, Danish, Moonis and many others for their inspiration and time to help. I am grateful to Dr. Shriram Hegde for his help in facilitating the computational facilities during the course of this work.

I remain indebted to my parents for providing me the means to learn and understand. I can't thank my parents enough for their love, continuous support and sincere prayers. Thanks also go to my sisters and brothers for their encouragement and motivation.


Mohd Jameel

ABSTRACT

Spar platform is an offshore structure most suited for deep water oil exploration and production. An integrated coupled Spar-mooring system is modeled as an assemblage of finite elements. Rigid Spar cylinder and flexible mooring lines are idealized as rigid and hybrid beam elements respectively. Fairlead mooring connections are modeled by six springs with requisite stiffnesses to maintain joint continuity. Likewise, the sea bed and mooring interaction is represented through contact modeling. The extreme mooring end is hinged to the sea bed. Wave and current induced hydrodynamic loadings are idealized under regular sea using Morison's approach and the procedure based on wave diffraction against large Spar like cylinders. Monte Carlo simulation is adopted to model random sea environment. All the three sea way idealization focus on various important aspects of Spar response governed by complex mooring behaviour.

Static profile of Spar-mooring system is first obtained after gradual equilibrium of the structural load against buoyancy forces. Some validation studies are carried out against well established published results. The implicit solver involves step-by-step time integration of equation of motion. Salient nonlinearities due to environmental loading and large deformations are duly accounted for. Severe nonlinearities influence the response under regular sea as evident from the irregular response of Spar and mooring lines in shallow and deep water conditions. Power spectra of the response record show the low and wave frequency responses. Mooring line tension fluctuations show its influence on overall stiffness matrix and resulting convergence problem.

A significant quantum of work is dedicated to the determination of wave forces on large cylinder considering wave diffraction. This wave structure interaction model is

given in terms of complex sequence of analytical formulation. The diffraction forces comprise linear, mean, oscillatory and quadratic force components. A computer code “*SPDIFF06*” has been developed to obtain wave forces on large cylinders. It is fully validated with the published results. Various force component variations are shown against “*ka*”, the product of wave number and radius of the cylinder. The dynamic response of Spar-mooring system under wave diffraction forces is obtained. It is found to be a more realistic wave force idealization for most of the sea states Spar encounters during its service life. Significance of diffraction approach viz-a viz the conventional one has been established after comparative assessment of dynamic responses. It is found to be more appreciable in terms of mooring tension response history.

Idealization of sea state is adopted to be an ergodic random process and the consequential response is obtained and used as the basic input for cumulative fatigue damage. Stress histories and the Spar displacement records of random nature are thoroughly analyzed and concluded with important informations. Statistical characteristics are obtained for the wide range of random sea states representing a probabilistic profile. Low and wave frequency responses are shown through power spectra. Other characteristics of random behaviour are also highlighted.

Risk and reliability assessment of Spar-mooring system, idealized as an integrated finite element assemblage, has been made. Uncertainties associated with various random parameters representing stress and resistance characteristics are satisfactorily modeled. Vital limit states identified are due to ultimate strength attainment and cumulative fatigue damage of mooring lines. FORM and Monte Carlo methods are employed for the reliability assessment. Probabilities of failure and reliability indices are obtained for the

twelve sea states covering the stipulated service life of 20 years. Sensitivity analysis of performance function with respect to random parameters has been carried out. It works as an effective optimization tool for the probabilistic design of the system. Correlation of various random parameters has also been studied as an influence on limit states under consideration.

Conclusions at the end of each chapter are listed as per the detailed discussions of the results. Integrated system idealized as a finite element assemblage in ABAQUS/AQUA environment has proved to be realistic and reliable. It has been supported by crucial validation. Various wave force idealizations have been proved to be successful in producing crucial results. “*SPDIFF06*”, the code developed for the estimation of wave forces comprising first order and second order diffraction effects works satisfactorily. It is found to be well suited for determination of the Spar-mooring system response. Apart from the low and wave frequency responses, other important aspects have been explored and supported with authentic findings.

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