

# RELIABILITY ANALYSIS OF A COMPLIANT OFF-SHORE PLATFORM

*By*

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## CERTIFICATE

This is to certify that the thesis entitled *Reliability analysis of a compliant offshore platform*, being submitted by *Mr. Nadeem Ahsan Siddiqui* 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 bonafide research work carried out by him under my supervision and guidance. 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 or diploma.

Dated : 15<sup>th</sup> January, 1999.



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## ABSTRACT

As exploration and exploitation of off-shore oil and gas have been extended to deeper waters beyond the economic application of fixed platform technologies, alternative structural systems are evolved. Compliant offshore platforms, comply with wind and waves, offer an economic solution to deep water applications. The three types of such structures, widely employed are: *Articulated Towers*; *Guyed Towers* and *Tension Leg Platforms (TLP)*. The basis of probabilistic design of these platforms is reliability analysis. The tension leg platform (TLP) is a moored floating structure whose buoyancy is more than its weight. Its mooring system known as *tethers* or *tendons* are the most vulnerable part of the platform. The critical reliability assessment of TLP tethers is all the more important as its failure may lead to the failure of the entire structure causing a great loss of money, life and the energy resources. In the present study, various aspects of the TLP tethers' reliability problem have been explored through a comprehensive literature review. An improved methodology has been established for its reliability analysis after carrying out a detailed comparative study of various reliability assessment methods. A comprehensive reliability analysis of TLP tethers has then been carried out against ultimate collapse, progressive collapse, fatigue and fracture limit states. The methodology offered here is well suited for the other type of compliant platforms and may further be extended to any structural system.

In the ultimate collapse limit state (maximum and minimum tension) a realistic Von-Mises failure theory has been adopted to define the failure of a tether against maximum tension. The minimum tension failure has been assumed to occur when the tethers slack due to loss of tension. Statistical characteristics are required as the basic input for reliability assessment of a TLP tether. A nonlinear dynamic analysis has, therefore, been carried out to obtain these response statistics. Some improvements have also been made in modeling the sea environment in the existing dynamic analysis software. Limit state functions for the two modes of failure (i.e. maximum and minimum tension) have been derived in terms of various random variables. A computationally efficient algorithm based on advanced first order reliability method (FORM) has been adopted for reliability assessment and the results are compared with that obtained by the mean value first order second moment method (MVFOSM). The tethers

reliability, measured in terms of reliability indices, and probabilities of failure have been obtained for various sea states. The probabilities of failure so obtained for different sea states have been used for the calculation of annual and life time probabilities of failure. The sensitivity of tether reliability to various random variables for ultimate limit state has been studied. Design points, important for probabilistic design of TLP tethers, have been located on failure surfaces. Simplified limit state functions have also been derived and results so obtained are compared with that for the original limit state functions. It highlights the significance and importance of adopting a complex limit state function. Effect of wind on tether reliability have also been studied, attempting wide range of parametric studies.

The above study has been further extended to a case where one tether out of a group of four in one column has been failed or removed for some repair as a maintenance routine (progressive collapse). The reliability assessment has been made for the progressive collapse and the results are compared with that obtained for an intact system under various sea environments.

Fatigue is another principal mode of failure of TLP tether joints under oscillating waves and wind. It has been taken as a failure criteria for reliability analysis. Nonlinear limit state functions using Palmgren-Miner's rule ( $S-N$  curve approach) and fracture mechanics approach have been derived in terms of random variables. FORM and simulation methods have then been employed for reliability estimation. The sensitivity analysis for various random variables and their effect on overall probability of failure has been studied. Design points have been located on failure surfaces. Some important parametric studies have been carried out.

A comprehensive reliability analysis software COMPRAS'98 has been developed incorporating all above mentioned aspects of analyses. The software has been validated with the published results. The software is capable of assessing the tether reliability for different modes of failure in a varied marine environments.

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