NONLINEAR DYNAMIC RESPONSE
OF
TENSION-LEG PLATFORM

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CERTIFICATE

This is to certify that the thesis entitled **"Nonlinear Dynamic Response of Tension Leg Platform"**, being submitted by Mr. Abdul Ali to the Indian Institute of Technology, New Delhi, 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 to 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: December 1994.

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SUMMARY

Environmental loads to which a TLP dynamically responds include wind loads acting on the exposed super structure, sea wave, current loads on the immersed part of the platform. The coupling of aerodynamic and hydrodynamic effects influence the TLP response in six coupled degrees of freedom in time dependent fashion. The hydrodynamic loading is first applied in the form of regular waves and later modelled as long crested and short crested random sea. Computer softwares developed for TLP analyses, under regular waves, long crested sea, directional random sea, mean and fluctuating wind, are validated with the results of some cases available in the literature. Wide range of sources of nonlinearities are included and a deterministic dynamic analysis model for six degrees of freedom is formulated involving the behaviour of the mooring cables and forces, time variant in nature. The wide difference in the natural periods of surge, sway, yaw, roll, pitch and heave degrees of freedom exists. Numerical integration of all the six coupled differential equations is computationally expensive as the time interval is governed by the lowest natural period. The regular waves do not induce resonance in soft degrees of freedom (surge, sway and yaw) due to their high natural periods. The RAO presentation in a three dimensional fashion is more realistic and informative. Inter column distance of TLP hull may prove to be an important parameter in terms of wave loading, as the predominant wave lengths in the region may critically interact. Likewise the wave heights influence the response attenuation, important in achieving the steady state. The modelling of sea state in long crested and short

crested fashion highlights some significant findings. The heave response is found to be highly under-estimated if the effect of coupling is ignored. Estimation of instantaneous tether tension is directly influenced. Variable wetting of the TLP structure has proved to be a major source of nonlinearity and significantly influences the surge and heave responses. Tether pretension and TLP's geometric configuration play a vital role in the response behaviour. The directional spreading versus frequency constitutes a realistics theoretical model of wave spectrum. A rational response study under short crested sea can justify the reduction of safety factor. A realistic assessment of hydrodynamic loading is possible by directional modelling. The effect of coupling is found to be well pronounced under short crested sea. Not only heave but rest of the other five degrees of freedom are also influenced under directional wave loading. Furthermore, the phase distribution in short crested sea simulation influences the response to a greater extent. For instance, the yaw response may be under-estimated to a greater extent if some critical phase distribution is ignored. The power spectra for irregular sea show the possibilities of sub- and super harmonic resonances and amplified responses. These response spectra are very informative in terms of energy distribution against frequencies. Intermode energy transfer due to closer natural frequencies show higher response in some cases which otherwise could not be correctly evaluated. The pulsating and mean wind loading with and without wave forces activate many TLP responses of design interest. The coupling of various degrees of freedom in presence of wind influence the yaw response most significantly. Location of aerodynamic centre of TLP with respect to centre of gravity influences the response behaviour to a greater extent. Low frequency energy concentration in the response spectrum substantiates the adequacy of Emil Simiu's wind spectrum for compliant off-shore structures. Instantaneous tether tension fluctuations occur with due participation of various responses activated simultaneously. Response time histories for different cases of interest are developed and reported. The time dependent responses are suitably studied under various cases and presented in terms of statistical characteristics.

In course of the present study, ample scope of the future work, relevant to field application, is highlighted. The new dimensions may significantly contribute to reliability, optimization, ringing phenomenon and active control of tension leg platforms.

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