NONLINEAR ANALYSIS OF OFFSHORE TENSION LEG PLATFORMS SUBJECTED TO ENVIRONMENTAL LOADINGS

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CERTIFICATE

This is to certify that the thesis entitled "NONLINEAR ANALYSIS OF OFFSHORE TENSION LEG PLATFORMS SUBJECTED TO ENVIRONMENTAL LOADINGS", being submitted by Mr. S.CHANDRASEKARAN, to the INDIAN INSTITUTE OF TECHNOLOGY, DELHI, for the award of DOCTOR OF PHILOSOPHY in Civil Engineering, is a record of the bonafide research work carried out by him under my supervision and guidance. He has fulfilled the requirements for the submission of this thesis, which 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.

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ABSTRACT

The nonlinear dynamic analysis of triangular configuration Offshore Tension Leg Platform used for oil exploration in deep-sea, under various environmental loadings, is taken to be the focus of the study. Advantages of Tension Leg Platform over various other types of offshore structures are discussed from the literature review. Geometric, structural and hydrodynamic properties of various four-legged Offshore Tension Leg Platform constructed till 1995 are procured from the literature. Thereafter a new equivalent triangular configuration Tension Leg Platform has been chosen for further studies, which has similar natural frequencies as that of the four-legged Offshore Tension Leg Platform.

Different sources of environmental loads acting on the Offshore Tension Leg Platform are studied and the methods of analysis of Tension Leg Platform performed by various researchers are discussed. A new triangular configuration Tension Leg Platform concept is proposed and objectives are stated to study the response behaviour of triangular configuration Tension Leg Platform under various environmental loads by carrying out a detailed dynamic analysis taking into account most of the nonlinearities arising from the wave-wind-structure interaction.

To form the basis of comparison of the newly proposed triangular configuration Tension Leg Platform with that of an existing four-legged Offshore Tension Leg

Platform, two cases are considered for comparison of the structural properties, vis-à-vis.

- Total initial pretension in the tethers in both the platforms is kept same and hence the initial pretension per tether of the triangular configuration Tension Leg Platform is 4/3 times that of the similar four-legged Tension Leg Platform.
- Initial pretension per tether, for both the platforms are kept the same and hence the total initial pretension in the tethers of the triangular configuration Tension Leg Platform is ¾ times that of the similar four-legged Tension Leg Platform.

The suitable structural mass and buoyancy are maintained for equilibrium.

Equilibrium equations are written for the triangular configuration Tension Leg Platform for both the above cases of comparison. The stiffness matrix coefficients of the triangular configuration Tension Leg Platform are derived from the first principles. Natural structural frequency in all the six degrees –of – freedom are computed and compared with the respective equivalent four-legged Tension Leg Platforms.

For response behaviour comparison only one typical case of the triangular configuration Tension Leg Platform is taken for the numerical study, to compare its response behaviour with that of the four-legged Tension Leg Platform, under the regular waves with different combinations of wave height and wave period. Effect of coupling of stiffness coefficients on the response behaviour of triangular configuration Tension Let Platform is studied under different combinations of wave height and wave period. Due to the wave loading of regular wave height of 10m and wave period of 10s, the effect of variable submergence and the consequent stretching modifications to the Airy's linear wave theory, suggested by various researchers, and its effect on the coupled response of triangular configuration Tension Leg Platform is studied. Parametric study is conducted to highlight the effect of hydrodynamic drag coefficient, inertia coefficient, wave height, wave period, structural damping and current velocity on the response behaviour of triangular configuration Tension Leg Platform under regular waves with wave period 10secs. Results and conclusions are drawn based on the parametric study conducted.

The response behaviour of triangular configuration Tension Leg Platform is studied under the random waves with different H_s-T_z combinations. The effect of coupling of stiffness coefficients, the effect of consideration of variable submergence by Chakrabarti's approach and the effect of current velocity on the response behaviour of the triangular configuration Tension Leg Platform is studied. Also, statistical analysis is performed on the time history of the coupled response in various degrees-of-freedom and conclusions are drawn based on the numerical study conducted. A new method namely, Iterative Frequency Domain is proposed for performing nonlinear analysis of triangular configuration Tension Leg Platform under random waves. The results obtained through the Iterative Frequency Domain method are compared with those obtained by the Time Domain Method.

The analysis of the triangular configuration Tension Leg Platform due to the wind loads along with random wave loads is carried out, to study the influence of wind on the coupled response of triangular configuration Tension Leg Platform. The coupled responses obtained under the presence of wave and wind are compared with that obtained under the presence of random waves only and conclusions are drawn to highlight the influence of wind forces on the response behaviour of triangular configuration Tension Leg Platform. Also, the effect of Chakrabarti's modification to the Airy's linear wave theory, the effect of coupling of stiffness coefficients, the effect of consideration of current velocity in the random wave environment, the presence of wind (considering no modification of the Airy's linear wave theory due to the wind) on the response behaviour of triangular configuration Tension Leg Platform are studied and conclusions are drawn based on the numerical study conducted.

The response behaviour of triangular configuration Tension Leg Platform under the seismic loads is studied in two parts. Firstly, the effect of vertical seismic focus on the tethers of a triangular configuration Tension Leg Platform is studied. Secondly, the response behaviour of triangular configuration Tension Leg

Platform under the presence of moderate regular waves, with the unbalanced initial tension in the tethers, caused due to the vertical seismic forces is studied. Different wave height-wave period combinations along with the unbalanced initial tension caused in the tethers due to El Centro earthquake (1940) and artificially generated earthquake using Kani-Tazimi's power spectrum are considered for the numerical study. Conclusions are drawn based on the numerical study conducted.

Based on the numerical studies conducted and the structural idealization assumed at various stages of the analysis, conclusions are drawn for the response behaviour of the triangular configuration Tension Leg Platform.

Recommendations for the scope of future research work, to be carried out, are given at the end of the Thesis.

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