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Behaviour of Offshore Structures and Overturning Stability Analysis of Jack up Rigs

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ABSTRACT: The main aim of the thesis to check the jack up overturning stability under harsh environmental conditions in different situations. In addition to this site assessment where the platform is installed is done and jack up is analyzed under different conditions. Non - linear analysis is performed using SACS software and $P \delta$ effects are studied. This thesis gives brief introduction to offshore engineering with basic concepts of various types of offshore structures and provide insight into various design issues and requirements fabrication and installation techniques. It covers important aspects of offshore structures, design, simulation and installation. The thesis covers the basic background material and its application in offshore engineering. Particular emphasis is placed in the application of the theory to practical problems. It includes the practical aspects of the offshore structures with handy design guides simple description of the various component of the offshore engineering and their functions. This thesis emphasizes the practical aspects rather than the theoretical treatments needed in the research the field of offshore engineering. In particular, it describes the do's and don'ts of all aspects of offshore structures. This thesis covers the brief background about the analysis of offshore simulated, how the structures are simulated according to the real conditions.

KEYWORDS: Offshore Structures, Jack up rigs, Overturning stability. Environmental loads.

I. INTRODUCTION

Structures constructed in water i.e. in oceans and seas are offshore structures. These structures may be fixed or floating. The branch that deals with the application of design, construction and maintenance of these structures is known as offshore structures. The offshore structures can be of various kinds. Mainly jackets are used for extracting oil and gas from the bottom of the sea. An offshore structure has no fixed access to dry land and may be required to stay in position in all weather conditions. Offshore structures may be fixed to the seabed or may be floating. Floating structures may be moored to the seabed, dynamically positioned by thrusters or may be allowed to drift freely. We will study in this thesis about the jack up rigs, their background & history. Jack ups are self - elevating units. Trident IX was the first jack up developed for 400ft. Nowadays jack ups are capable of working upto 500ft. They are mainly used for drilling operations. In earlier days drilling the rigs was an onshore activity. In 1970 mobile rigs were used for shallow foundation. Drilling the oil wells was not an easy task and also it was costlier. Their assembling was also not easy. Jackup rigs are basically used for drilling the oil wells in the bottom of the sea for the purpose of extraction of oil and gas. Jack ups are installed in the jacket vicinity. Jack Up Units have been a part of the Offshore Oil Industry exploration fleet since the 1950's. They have been used for exploration drilling, tender assisted drilling, production, accommodation, and work/maintenance platforms. As with every innovative technology, Jack Up Units have been used to their operational and design limitations. These limitations include deck load carrying limits when afloat, load carrying capabilities when elevated, environmental limits, drilling limits, and soil (foundation) limits. The reasons for pushing these limits include the desire to explore deeper waters, deeper reservoirs in harsher environments, and in areas where soils and foundations may be challenging or even unstable.

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II. RELATED WORK

Bh. Nageshet. al (2016) did the investigation on the overturning stability analysis of a jack up Mobile Offshore Production unit by Site Specific Analysis to find a solution to avoid the failure of its lattice leg structure.

Joost van Santen (2014) did the hydrostatic analysis of a Jack up.

PV Vatsvag (2014) did the overturning stability analysis of jack up.

Yousri M. A. Welaya et. al (2015) did the investigation of jack up leg extension for deep water operations.

VP Baglioni (1982) did the foundation stability in stratified in soil profiles.

Mark Jason Cassidy (1999) did the Non – linear analysis of jack up structures subjected to Random waves.

Mahanta R et. al (2010) did a case study on geotechnical problems of a jack up rig deployment in West Bengal and Mahanadi Area of Indian Offshore.

Losethet. al (1993) determined the global limit state criteria of maximum axial force and base shear in one leg.

Karunakaranet. al (1993) determined the considerations with respect to deck displacement and foundation limit states.

Mo et. al and Dalane (1993) documents the structural leg strength capacity considerations.

Ahilan , R.V. et. al (1992) did the Reliability based assessment of a Jack up.

Baerheim M. (1993) found the structural effects of foundation fixity on a large Jack up.

Fernandes, A.C. et. al (1986) studied the dynamic behavior of a Jack up in Waves.

Fernandes, A.C. (1985) performed the analysis of a Jack up platform by Model testing.

Mo. O., Lotsberg, I., Loseth, R.M. (1991) did the response analysis of Jack up Platforms.

III. METHODOLOGY

Jack up is designed with the aim of minimizing stress concentration and is designed with respect to global stiffness. A jack up is designed for following conditions:

- Elevated, transit or damaged condition.
- Hydro stability
- Foundation stability
- 'Overturning stability

Generally LRFD method is used. According to this method a limit state is a condition beyond which a structure or part of a structure exceeds a specified design. Stochastic analysis are used when a representation of irregular nature of sea is required. Before setting up a jack up unit, site assessment needs to be done. An assessment of capacity of the jack up to withstand a design force is done. At the time of site assessment general checks such as overturning stability check, punch through checks are performed. After that geotechnical aspects are checked and bearing capacity is evaluated.

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Environmental conditions are checked and jack up is designed for elevated condition. Non – linear analysis is performed.

IV. EXPERIMENTAL SETUP

A simple jack up consists of a frame which includes the hull (pontoon) which is basically horizontal element and this hull is supported on the which are basically the columns.

Hull - It consists of a deck platform for supporting the equipments and other facilities. It is basically a pontoon or a closed tank to provide buoyancy during floating stage. Plan dimensions of pontoon depends on the drill rig top side weight and draft requirement.

Legs – They are used to support the hull. Legs are made of lattice truss or circular hollow sections with rack and pinion arrangement or lowering using hydraulic jacking system.

Drilling Rig - It is a part of the topside having arrangements both in longitudinal and transverse directions.

Spud Can – It is basically present in foundation at the bottom of legs like a spread footing to transfer the vertical loads to the soil. Diameter of spuds is 5 to 16m.

Jack up also consists of helipad, drill mast, crane, drill pipe. Cantilever portion cannot go more than 5 to 10m.

A significant structural component of a jack up drilling that is not a part of its structural system is the drilling floor support structure.

Plate elements are used to simulate the hull. The size of elements should be 5ft x 5ft in the areas of low stress and 1ft x 1ft in the area of high stress. The size of elements should be optimized according to the run time. Gear boxes, skid rail bulkheads, side shells are modeled.

V. ANALYSIS AND RESULTS

Water depth, wave height, wind speed, current velocity are defined as per code. Loads are found by the summation of all the equipment weights, dead loads and distribution this uniformly over the entire deck. Loads is assumed to be balanced among the three legs. A hydrodynamic model is generated using the SACS program. Morison's equation is used to find the hydrodynamic forces. A global structural model is generated. It is basically a FE model. Legs are simulated as stick element. The properties of this element are determined. Loads are applied on this element and also the loads from the hydrodynamic analysis are applied on this member. An important aspect of the global analysis is the simulation of the connection between the leg and hull jacking units. This is a function of the system chosen. The angle of the elements is equal to the pitch angle of the teeth on the pinion of the elevating gear unit. The stiffness of this element is determined through tests on the gear unit or as provided by the manufacturer. The arrangement illustrates the simulation of the top and bottom guides of the unit. The top guide is normally provided atop the "gear box of the jacking unit and the bottom guide is at the level of the bottom of the hull. These guides (on each leg chord) together provide the necessary moment connection between the leg and the hull. The leg should be modeled in detail to at least one bay above the top guide. The portion above this may be simulated with a "dummy" member so that wind loads on the protruding portion of the leg may be applied.

Hull is built up of a stiffened plate. The structure is configured to efficiently transfer loads acting on the various hull locations into the legs. Axial and horizontal loads are transferred into the legs through the hull leg interface and chords. A jack up in an elevated condition is subjected to environment loads which generates overturning moment M_O and the functional loads causes a restoring moment M_S .

For a structure to be safe $M_S > M_O$

Stabilising moment i.e. restoring moment is given by:

$$M_S = M_{SO} - nP \frac{(e_0 + e)}{1 - (P/P_E)}$$

n = number of legs

e = sideway deflection of barge due to wind

e_0 = maximum horizontal displacement of the jack up

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P = average axial leg load

P_E = Euler load

Any possible stabilizing effect of non - uniform soil reaction on separate leg footings should be neglected in overturning stability analysis

RESULTS

Verification of Factor of Safety

Known quantities

Load on bow leg = 25MN

Load on other two legs = 30MN

Legs cross sectional area = 0.4m^2

Moment of inertia = 5m^4

Apparent weight = 6MN

Young's Modulus = 1.6×10^5

Natural period $T_0 = T_s$

Distance b/w the legs = 50m

Wave period in extreme conditions = 14 sec

Calculation of restoring moment assuming the structure to be rigid

$M_0 = (25 + 6) \times 50 = 1550\text{MNm}$

The avg. load per leg = $(30 + 30 + 25)/3 = 38.3\text{MN}$

At bottom load = $38.33 + 6 = 44.33$

Avg. load considered = 28MN

Radius of gyration = $(5/0.4)^{1.5} = 3.536\text{m}$

$\lambda = 2l/\rho = 220/3.536 = 62.27$

$\sigma_E = \pi^2 E / \lambda = 2536\text{MPa}$

$P_E = 0.4 \times 2536 = 1014.4\text{MN}$

Reduction of restoring moment due to excursion (1.2m) = $\frac{3 \times 28 \times 1.2}{1 - (28/1014)}$

= 99.826MNm

Final restoring moment = $1550 - 99.826 = 1450.174\text{MNm}$

Calculation of OTM

$K = 1/(1 - (7/14)^2) = 1.33$

Average moment due to wind and current = $(700 - 100)/2 = 300\text{MNm}$

Amplitude of moment due to wave and current = $(700 + 100)/2 = 400\text{MNm}$

Moment due to wind = 250MNm

Average moment = 300MNm

DAF moment = $400 \times 1.33 = 532\text{MNm}$

Hence $M_S = 1482\text{MNm}$

Hence $M_S > M_0$

Hence the restoring is found to be greater than overturning moment.

Hence, structure is safe.

VI. CONCLUSIONS

The main work of this study is to study the jack up for the stability against the overturning moment and to study the dynamic response of the jack up under extreme loading conditions. For the jack up site specific assessment is done for all year operations. Various parametric studies have also been performed for the jack up and their sensitivities are quantified. Result of parametric studies show a safety level against risk of foundation collapse for all the parameters. The structure is found to be safe against overturning. A non - linear analysis was performed and dynamic analysis was performed to

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find DAF. Checks for overturning stability, preload requirements and leg sliding were performed. The structural strength and overturning stability show large variations in utilization.

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