Earthquake Analysis of Mini Tension Leg Platforms under Random Waves

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Abstract

Mini Tension Leg Platform (TLP) is a new generation TLP of comparatively low cost, developed for the economic exploration and extraction of hydrocarbons from marginal deepwater oil fields. It can also be used as a utility, satellite, or early production platform for larger deepwater discoveries. These offshore structures should be able to stand up to the dynamic effects of environmental loads throughout their lifespan. These loads vary from temporary/transient loads induced by earthquakes and ocean storms to continuous loads due to wind, waves, and ocean currents. Since floating offshore structures aren't supported directly by the ground, however, effects of earthquakes on floating structures have received less attention compared with those on fixed structures. Consequently their seismic response has not been totally studied. In this study seismic analysis of mini TLP projected at the Morpeth region is carried out using the finite element software ANSYS AQWA. Here earthquake analysis is performed under random waves with variable water depth for determining surge, heave and pitch responses. The results show that the maximum response decreases with water depth.

Keywords — *Mini Tension Leg Platform, Random Waves, Earthquake Analysis*

I. INTRODUCTION

The development of minimal offshore fields in deep water locations in a hostile environment is presently being actively pursued to satisfy the increasing demand of oil and natural gas. For economic development of such fields new concept of platform construction and technologies of exploration, production and drilling are necessary. Tension leg platforms and Spar platforms are two such choices. An objective in the development of mini TLP platform was to reduce platform cost to the extent that several development project can be economically justified by reserves proved up by a single well.

This new generation TLPs have favourable motion characteristics as those of TLPs however they do not need large initial investment, operating expenses, complexity of construction and comparatively long project amount related to TLPs. Thus, the mini TLP combines the simplicity of a spar and favourable motion response features of a TLP. It's being pursued as a promising candidate among the various choices used in constructing permanent production platforms for marginal deepwater resources. The essential elements of mini TLP are shown in fig.1.

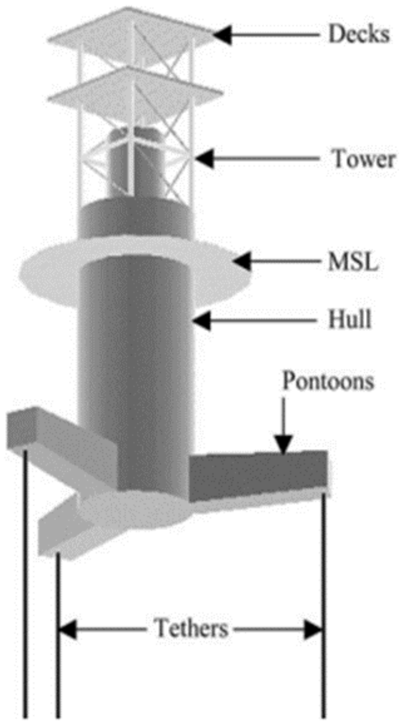

Fig. 1 Mini TLP

II. EARTHQUAKE ANALYSIS OF MINI TLP

Offshore platforms that don't have stiff connection with the ocean floor are indirectly influenced by earthquakes; those which are bottom supported are suffering from earthquakes directly. Compliant structures that are position-restrained by tethers are subjected to dynamic tether tension variations under the presence of earthquake forces. This may have an effect on the response of the platform under lateral loads. Earthquakes creates horizontal and vertical motions. Earthquake acceleration exhibits random characteristics because of (i) the character of the mechanism causing earthquakes; (ii) wave propagation; (iii) reflection. Earthquakes may result in inertia forces because of the acceleration and damping forces due to the motion of the water particles.

In case of the analysis of compliant structures like TLPs, earthquake forces may be handled in an indirect manner. Stiffness of TLP tether is modelled as axial tension members; slackening of tethers is neglected. The dynamic tether tension variation, caused by the vertical motion of the earthquakes, is employed to update the stiffness matrix of the TLP using the following equation.

$$\Delta T = \frac{AE}{l}\left[x(t) - x_g(t)\right]$$

Where x(t) is the instantaneous response vector of TLP and $x_g(t)$ is the ground displacement vector, which is given by:

$$x_g(t) = \begin{Bmatrix} x_{1g}(t) \\ 0 \\ x_{3g}(t) \\ 0 \\ 0 \\ 0 \end{Bmatrix}$$

III. MODELLING AND ANALYSIS

A. Platform Configuration of Mini TLP

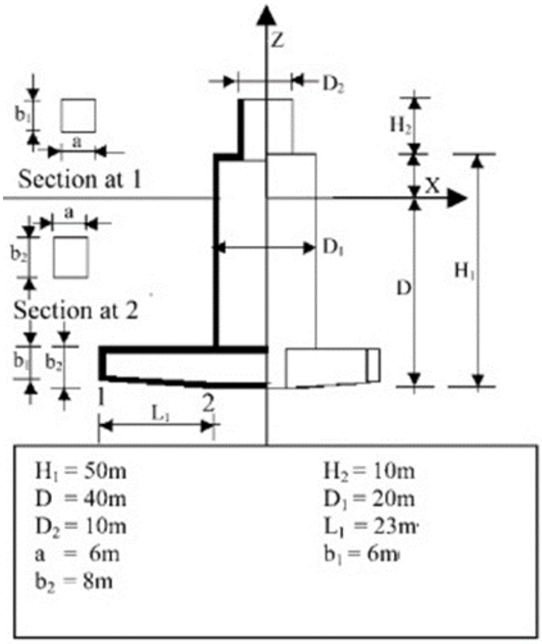

Fig. 2 Geometry of mini TLP

The platform selected for the study is called Morpeth Seastar mini TLP. The Morpeth project is that the world's initial application of a seastar mini TLP and establishes that mono-column TLP's will be used to economically develop deep water fields. The Morpeth field is located in Gulf of Mexico in Ewing Bank (EW) blocks 921, 964 and 965 of the shore of Louisiana. It had been developed by British Borneo, although the company has been bought by Agip. The platform geometry is shown in figure 2 and details are given in table one.

B. Environmental Details

For random waves, the wave train is generally specified by a wave spectral density S(f). In the present study a single parameter Pierson-Moskowitz wave spectrum is taken as the representative spectrum. It is given by,

$$S(f) = \frac{5H_s^2}{16f_0}\frac{1}{\frac{f}{f_0}}\exp(-1.25 \times \left(\frac{f}{f_0}\right)^{-4})$$

TABLE I PLATFORM DATA OF MINI TLP

Item	Platform Data
Water depth(d)	300m, 518m and 1036m
Draft(D)	40m
Height of hull(H_1)	50m
Length of tether(L)	260m, 478m and 996m
Water plane area	1000x1000m^2
Water density	1025kg/m^3
Vertical centre of gravity from keel	15.5m

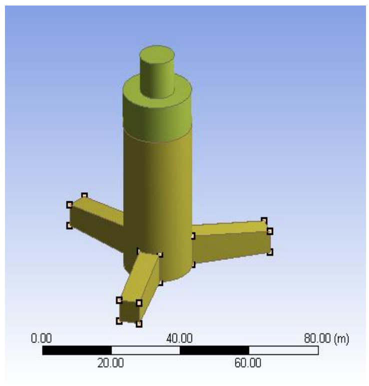

Fig. 3 Model created in ANSYS DM

IV. RESULTS AND DISCUSSION

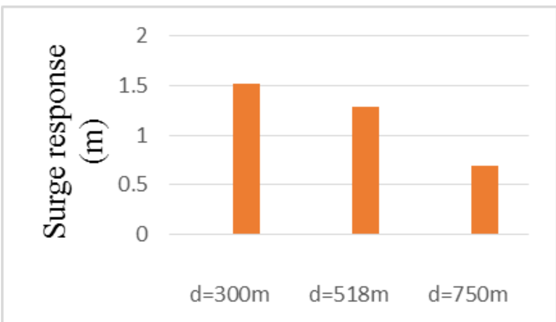

Fig. 4 Comparison of surge response Hs=16m

Earthquake analysis of the mini Tension Leg Platform is performed under random waves. The analysis is carried out for water depths of 300,518m and 750m. The response of the mini TLP in the x (surge) and z (heave) directions and rotation in y direction (pitch) has been plotted against time for significant wave height 16m and zero crossing period 20s.

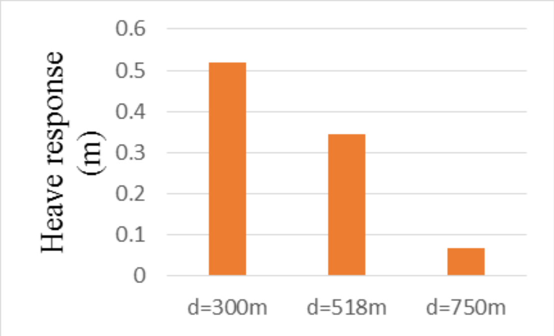

Fig. 5 Comparison of Heave Response Hs=16m

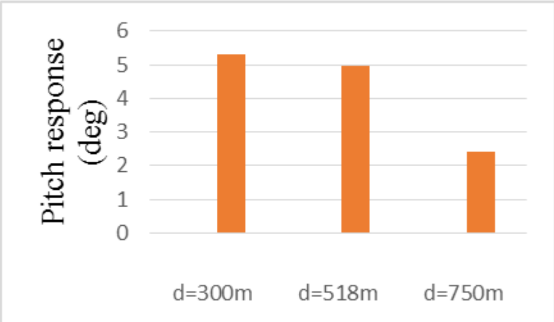

Fig. 6 Comparison of Pitch Response Hs=16m

The maximum responses shown by the mini TLP when the water depth is 300m in all the cases. When the water depth increases from 300m to 518m the maximum surge value decreases to 15% and when it is increases to 750m the surge value decreases to 46%. Similarly maximum heave and pitch values are also decreases when the water depth increases. Maximum heave value decreases 33% when the water depth reaches 518m and it again decreases to 80% for further increase in water depth. Pitch response decreases 7% initially and it decreases to 51% when the water depth reaches 750m.

The seismic analysis is performed without waves also and compared with the statistical parameters of responses under random waves.

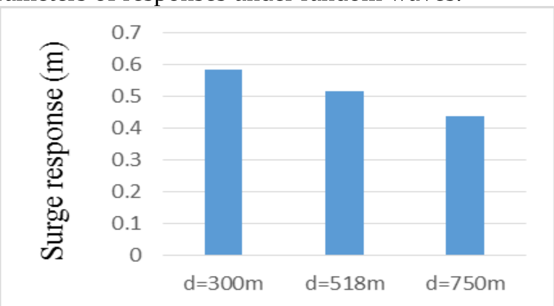

Fig. 7 Comparison of Surge Response Without Wave

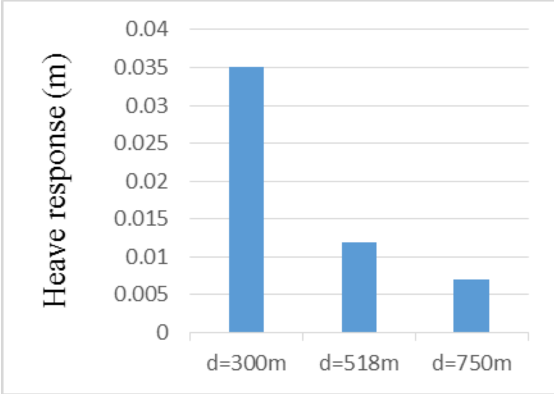

Fig. 8 Comparison of Heave Response Without Wave

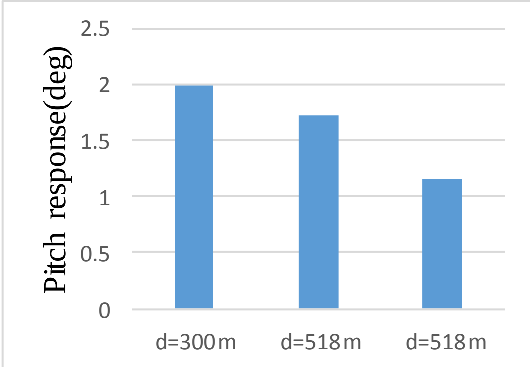

Fig. 9 Comparison of Pitch Response Without Wave

Table II Tether tension variation

Water depth (m)	Tether tension (N)
300	$1.734x10^6$
518	$4.499x10^5$
750	$7.565x10^4$

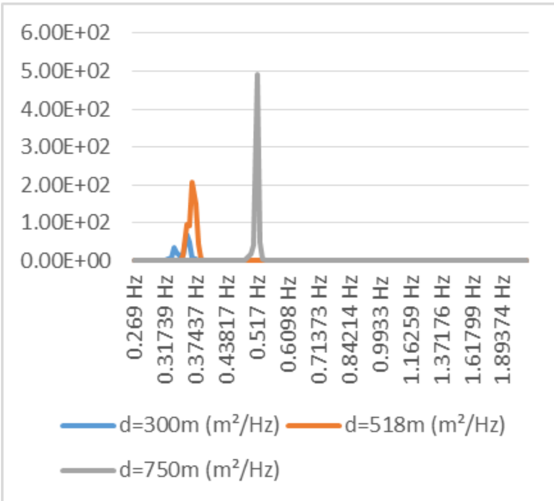

Fig. 10 Spectral Distribution for Surge (Hs=16m)

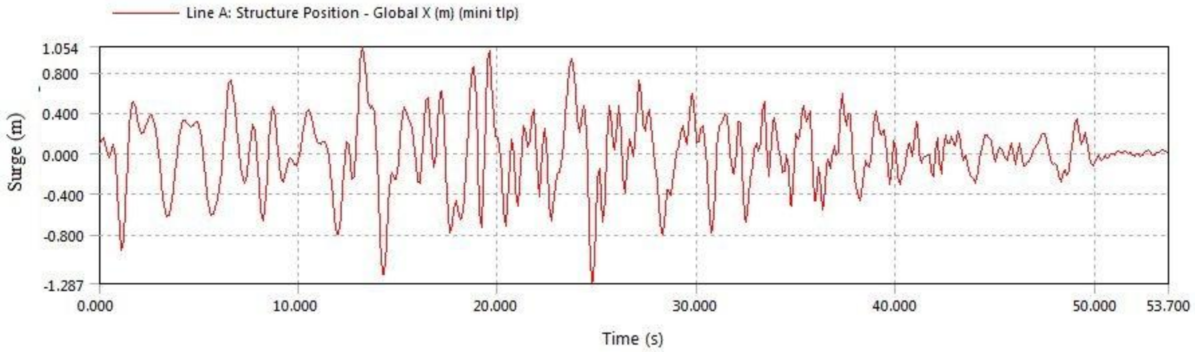

Fig. 11 Time history for Surge Under the Presence of Earthquake (Hs=16m, Tz=20sec)

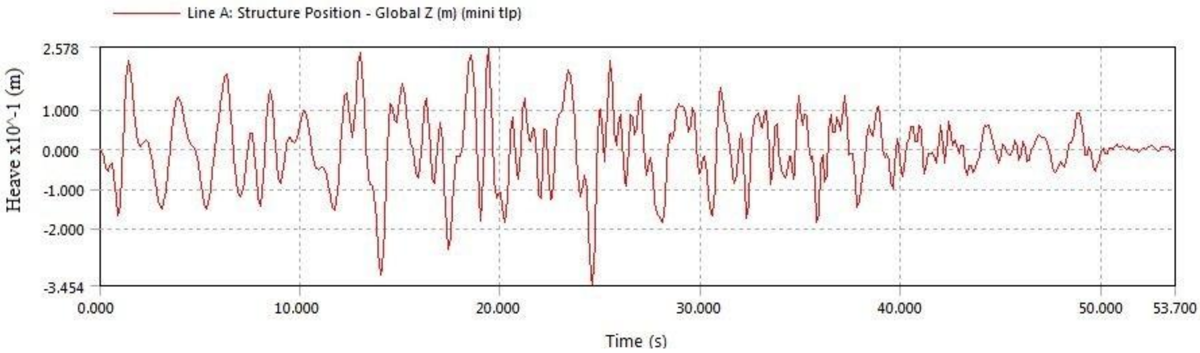

Fig. 12 Time History of Heave Under the Presence of Earthquake (Hs=16m, Tz=20sec)

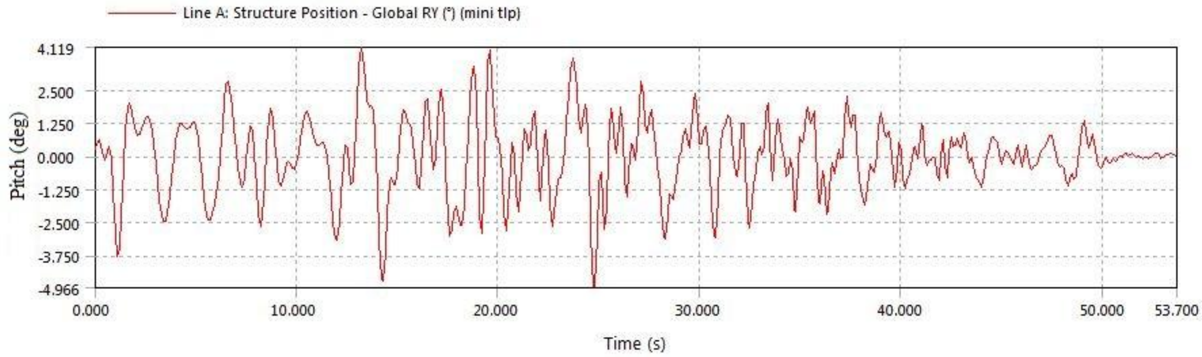

Fig. 13 Time History of Pitch Under the Presence of Earthquake (Hs=16m, Tz=20sec)

Table III Comparison of Statistical Values of Responses for Different Water Depth (Hs=16m)

Response	Surge(m)			Heave(m)			Pitch(deg)		
Water depth	300m	518m	750m	300m	518m	750m	300m	518m	750m
Maximum	1.525	1.287	0.687	0.518	0.345	0.067	5.303	4.966	2.431
Standard deviation	0.447	0.372	0.245	0.139	0.094	0.019	1.536	1.467	0.874

Table IV Comparison of Statistical Values of Responses without Wave

Response	Surge(m)			Heave(m)			Pitch(deg)		
Water depth(m)	300	518	750	300	518	750	300	518	750
Maximum	0.586	0.519	0.44	0.035	0.012	0.007	1.988	1.728	1.163
Standard deviation	0.177	0.154	0.143	0.008	0.003	0.0028	0.6	0.515	0.476

The statistical values are less when the waves are not considering. In this case also the responses decreases with increase in water depth. The tether tension also decreases with increase in water depth.

V. CONCLUSIONS

Earthquake analysis of mini Tension Leg Platform has been performed under random waves. The mini TLP is analysed for different water depths. The analysis result shows that the maximum response due to earthquake decreases with increase in water depth. The seismic response of the mini TLP exhibits nonlinear behaviour in the presence of waves as it is non-proportionately influenced by the water depth. The rate of decrease is more in the case of heave response and rate of decrease is more when the water depth increase from 518m to 750m.

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