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Dynamic Analysis Method of Offshore Jack-up Platforms in Regular and Random Waves

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Abstract: A jack-up platform, with its particular structure, showed obvious dynamic characteristics under complex environmental loads in extreme conditions. In this paper, taking a simplified 3-D finite element dynamic model in extreme storm conditions as research object, a transient dynamic analysis method was proposed, which was under both regular and irregular wave loads. The steps of dynamic analysis under extreme conditions were illustrated with an applied case, and the dynamic amplification factor (DAF) was calculated for each response parameter of base shear, overturning moment and hull sway. Finally, the structural response results of dynamic and static were compared and analyzed. The results indicated that the static strength analysis of the Jack-up Platforms was not enough under the dynamic loads including wave and current, further dynamic response analysis considering both computational efficiency and accuracy was necessary.

Keywords: jack-up platforms; wave loads; dynamic analysis; dynamic amplification factor
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1 Introduction

Jack-up platforms are widely used in offshore oil and gas exploration, there is growing demand for this type of units drilling in deeper waters and harsher environmental conditions (Lu, 2001). Under extreme circumstances, the environmental loading (wind, waves, currents, *etc*.) and their interactions with apparent nonlinear, dynamic performance, randomness, *etc*. (Xu *et al*., 2003a) Jack-up platform is easy to produce vibration under the action of waves in deep water environments, it not only affects the structural strength, but also has a greater impact on the reliability and safety of the platform. Many scholars focus on the dynamic response of the platform structure and have been carrying out series of studies (Zhao *et al*., 2007; Cassidy *et al*., 2002; Xu *et al*., 2003b; Williams *et al*., 1999; Hunt *et al*., 2004; Williams *et al*., 1998; Martin, 1994). As accident rates due to dynamic effects and structural deficiencies remain comparatively high (Hunt *et al*., 2004), accurate analysis of jack-up behavior, avoiding excessive conservatism, becomes increasingly important, there is an augmented desire to understand their behavior under dynamic loading conditions.

There are several areas of uncertainty (Williams *et al*., 1998) in the dynamic analysis of a jack-up Platform. Jack-ups are flexible structures with natural periods of the same order as the predominant wave periods for many seas, structural modeling of the legs, the degree of base flexibility provided by the spud can and the nature of the wave loads.

The spudcans provide the counterforce of the platform's gravity and slippage, it also bears the moment delivered by the leg which is apt to be simplified. Much valuable work (Bienen *et al*., 2006; Martin, 1994; Li *et al*., 2010) had been done for the jack-up platforms' dynamic characteristic in consideration of the pile-soil-structure interaction, the Winkler beam model is used to simulate the dynamic interaction and study the depth of pitching pile (Lu *et al*., 2005).

The dynamic analysis methods (Spidsoe *et al*., 1996) are mainly single degree of freedom (SDF) method, frequency domain method and time domain method, SDF method can roughly estimate dynamic amplification factor (DAF) of the platform, and the estimation of the natural frequency is too large. The frequency domain method does not take each non-linear factor into account of loads (Zhen *et al*., 2004). The consideration with time domain method is most comprehensive, with the development of computer technology, the time domain method is to be studied further.

The authors studied the calculation method of the dynamic environmental loads in extreme conditions. The boundary conditions of the FE model were treated reasonably, the platform's structural strength and the DAF were analyzed in accordance with industrial standards, utilizing linear and non-linear wave theory and the finite element method (FEM). A comparison was performed between the dynamic results and that of the static strength assessment. The results show that further dynamic response analysis is necessary and this paper's time domain dynamic analysis method is

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efficient and accurate.

2 Environmental loads

Environmental loads of jack-up platforms include waves, currents, wind, ice loads and seismic loads *etc*. This paper only considers wave loads (including the role of ocean currents) and wind loads under extreme conditions.

2.1 Wave loads

2.1.1 Morrison force

Typical k-lattice leg is a kind of small-size structures, its Morrison force considering currents influence is calculated as

$$F=\int\left[\frac{1}{2}\rho C_D D|U|U+\rho C_M(\pi D^2/4)\dot{U}\right]\mathrm{d}z \tag{1}$$

where, U = component of the velocity vector, normal to the axis of the member; $\dot{U}$ =component of the acceleration vector of the structural member normal to its axis; C_M = inertia coefficient; C_D= drag coefficient; D= projected width of the member in the direction of the cross-flow component of velocity.

These variables related to the Morrison force are determined after the choice of wave theory (Li *et al*., 1992).

2.1.2 Wave loads in regular wave

Different wave theories have different scope of application of water depth. The Fifth-order Stokes or the stream function wave theory was suggested when doing strength assessment and structural design (ABS, 2005). This paper selects J.D. Wheeler's Wheeler Expansion (Wheeler *et al*., 1969) to correct the free wave surface caused by wave motion.

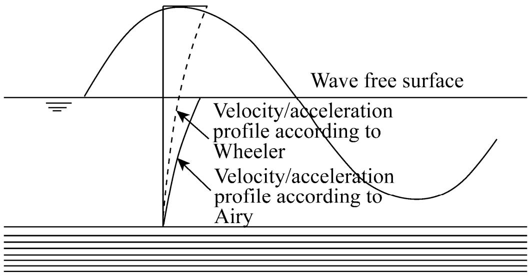


Fig.1 Velocity profile after Wheeler expansion

2.1.3 Wave loads in irregular wave

The wave is irregular actually, and is regard as the superposition of cosine waves with different period, amplitude and initial phase. Simulation of irregular wave (Qiu *et al*., 1985) was conducted based on P-M spectrum by equally dividing the energy range to get the random waves:

a) Frequency band selection

Narrow spectral range will omit some components, excessively enlarged spectral range will lead to simulation distort. ω_i is always 3 to 4 times of spectral peak frequency, the energy under wave spectrum is obtained by integration.

b) Frequency selection

The energy is divided into N pieces, and the energy under each frequency band is got. Taking ω_i as the band dividing frequency, and taking $\hat{\omega}_i$ as the representative frequency of Band-i, assumed that,

$$E(w_i)=\int_0^{w_i} S(w)\mathrm{d}w \tag{2}$$

$$\int_{\omega_{i-1}}^{\omega_i} S(\omega)\mathrm{d}\omega=E(\omega_i)-E(\omega_{i-1})=X \tag{3}$$

$$E=\rho g a_i^2/2 \tag{4}$$

Then ω_i and $\hat{\omega}_i$ are obtained.

c) Amplitude selection

For regular wave, the wave energy per unit area is

$$E=\rho g a_i^2/2 \tag{5}$$

And the wave amplitude can be determined by

$$a_i=\sqrt{2\Delta\omega S(\hat{\omega}_i)} \tag{6}$$

where $S(\hat{\omega}_i)$ is the spectral density function.

d) The selection of random phase θ_i

The waves' initial phases should be randomly distributed in the 0–2π, the random number is obtained by FORTRAN program according to the system time change. This paper selects P-M spectrum to discrete random waves, the wave spectrum is given by

$$S(\omega)=\frac{124H_S^2}{T_Z^4}\omega^{-5}\exp\left(\frac{-496}{T_Z^4}\omega^{-4}\right) \tag{7}$$

Finally, the random wave surface elevations are obtained. Elevation of Point-A in instantaneous wave surface when T_z=18.4 s and H_s=13.5 m is shown in Fig.2.

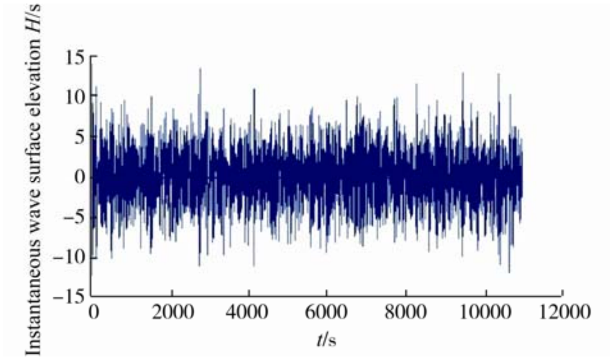


Fig.2 Elevation of point-*A* in irregular wave

American Bureau of Shipping has the following requirements (Shown in Table1) about the statistical properties of random wave (ABS, 2006).

Table 1 Random waves comparison with ABS rules (ABS, 2004)

Items	ABS rules (ABS, 2004)	This paper
Simulation duration/s	Long enough	21 600
Number of wave cycles/s	0.5	0.5
Wave elevations/m	0±1‰	−0.001 76
Standard deviation	3.375	3.405
Skewness	−0.03–0.03	−0.001 6
Kurtosis	2.9–3.1	2.99
Max. crest elevation	12.05	12.45

Note: T_z = zero up-crossing period of the wave; H_s = significant wave height.

The retrieved wave spectrum is in good agreement with the P-M spectrum, indicating the irregular wave can be used to calculate the random wave forces.

2.2 Wind loads

The wind loads are estimated according to ABS rules (ABS, 2005). Horizontal force induced by wind is assumed to act on the hull in the same direction with wave.

3 Finite element (FE) model analysis

3.1 Structural model

A three-dimensional finite element model is built based on a practical design, and simplification is made for the hull. The principal dimensions and structural details are listed in Table 2. With consideration of both stiffness distribution and mass distribution according to the design, the hull is represented by shell and mass elements. Compared to the stiffness of the jack-cases and the legs, the stiffness of the hull is very large. The overall view of FE model is displayed in Fig.3.

Table 2 Main dimension of the jack-up platform m

Item	Value
Length (modeled)	60.349
Breadth (modeled)	57.000
Hull depth	7.620
Designed draft	4.800
Leg length	128.300
Working water depth	91.440
Spudcans diameter	12.090

The added mass and water within the K-lattice legs need to be considered, the added mass per unit length of the component is calculated by the following equation:

$$m_{\text{add}} = C_m \rho_w \frac{\pi}{4} D_e^2 \qquad (8)$$

The difference is that added mass should be considered as non-structural mass and not the lumped mass in PATRAN model. In the situation of considering the model's gravity, it avoids the added mass for gravity.

Fig.3 FE model of the jack-up platform

3.2 Connection between hull and legs

In the FE model, there are four separated structural systems, i.e., one hull and three legs including pinion, guide and wear plate. The hull is connected with the chord through pinions. According to the actual gear meshing with the rack height, the nodes of legs and the jack houses at the same height are bound to the same vertical displacement, and at the clamping device bound for the displacement. The horizontal displacement of legs is constrained by the top and bottom guide plate, the nodes at the same height bound to the horizontal displacement, using MSC/PATRAN multi point constrain (MPC) to simulate the constraints.

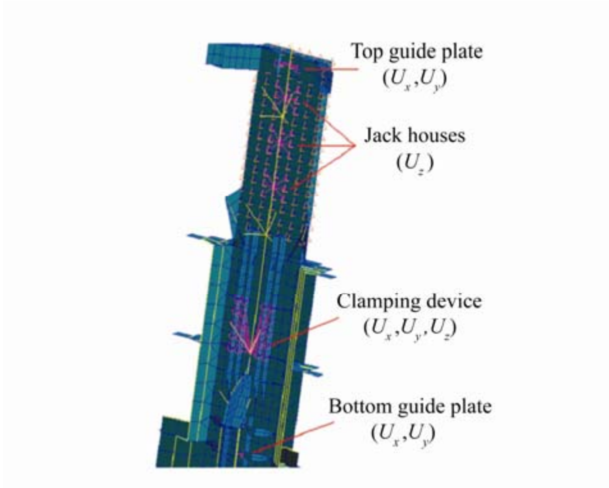


Fig.4 Connection simulation between hull and leg

3.3 Foundation model

The model of spudcan foundations considering pile-soil-structure interaction is between simple supports and fixed supports, it's reasonable to represent the behavior of a spudcan on clay. Detailed description of this model is beyond the scope of this paper. In most jack-up dynamic analyses, the constraint is modeled by simply supporting for simplification.

This paper uses spring element to simulate the interaction of the pile-soil-structure interaction based on finite element software, and the stiffness are determined according to ABS rules (ABS, 2004).

3.4 Structural loading of wave loads

The wave loads were determined on the basis of Morrison force, and the automatic loading process was carried out by Patran command language (PCL) and Fortran language. When the dynamic wave loads' lasting time was less than 20 seconds, it was short and the authors loaded wave loads based on MSC. (PCL) for convenient, instead of the long automatic and rapid loading program in Fortran language. The process flow chart is shown in Fig.5, and Fig.6 is the loading result of wave loads.

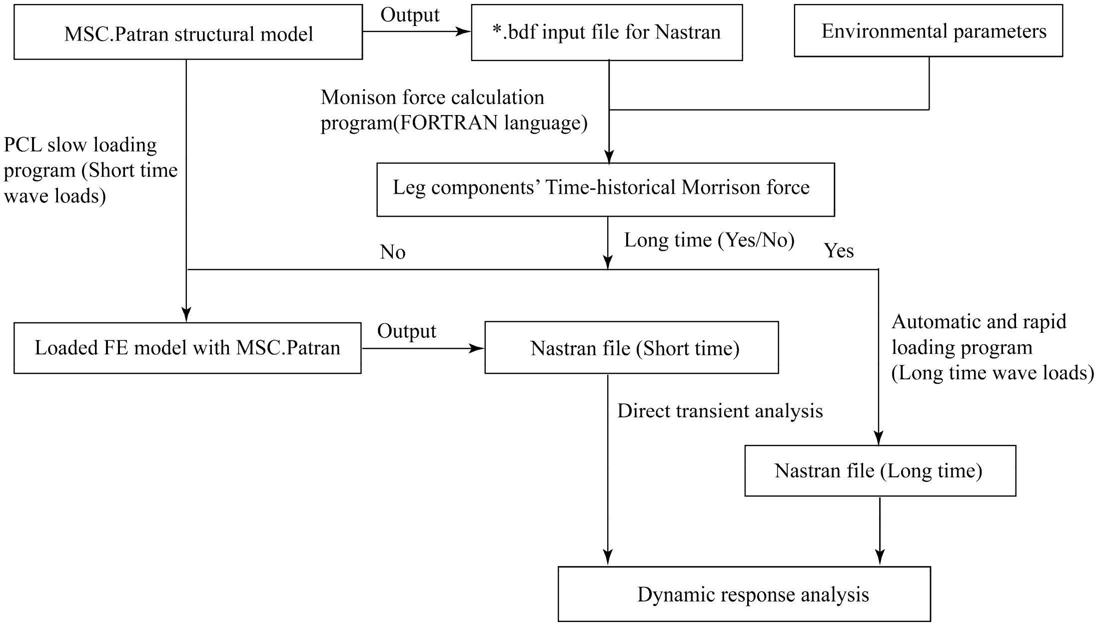


Fig.5 Flow chart of the wave load's automatic loading

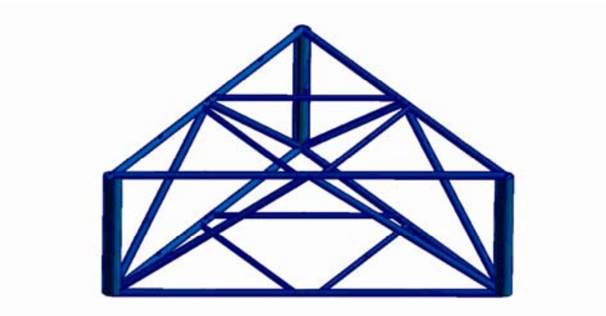


Fig.6 Loading result of wave loads for legs (0°)

4 Dynamic response analysis

4.1 Dynamic analysis method and DAF

In this paper, MSC/NASTRAN Direct transient analysis is applied to dynamic analysis, the dynamic response under regular wave and irregular wave of jack-up platforms is studied.

The dynamic response of the structure is described by a second-order matrix differential equation given by

$$M\ddot{X}(t)+C(\dot{X})+KX(t)=F(t) \qquad (9)$$

where M stands for mass matrix, C for damping matrix, and K for stiffness matrix. $X(t)$, $\dot{X}(t)$, and $\ddot{X}(t)$ are the displacement, velocity and acceleration vectors, respectively.

The dynamic amplification factor (DAF) was calculated for each response parameter of base shear, overturning moment and hull sway, in this paper, the time domain dynamic peak response of the structure is calculated (Huang *et al.*, 2010), and then the DAF is determined by

$$\mathrm{DAF}=F_i^D\,/\,F_i^S \qquad (10)$$

where i=1,2,3 stand for the base shear, overturning moment and hull sway, which are obtained from dynamic analysis and static analysis respectively. This method is more accurate than the single-degree-of-freedom (SDOF) theoretically.

During the strength analysis, static analysis approach is usually adopted, which is based on the static load, pulsing dynamic load amplification due to the analysis, the DAF can be also given as follows,

$$F_D=F_S+(\mathrm{DAF}-1)F_S \qquad (11)$$

In fact, Eq.(11) and Eq.(10) are equivalent, but the physical meaning of Eq.(11) is clearer. Detailed determination of this method is described in the Section 5 of ABS rules (ABS, 2004).

Once the DAFs are obtained by the time domain method, they can be used to establish an inertial load set that is imposed on the FE model of Quasi-Static structural analysis to simulate the dynamic response.

4.2 Dynamic analysis under regular wave

According to the modal analysis, the natural frequency of the first three vibration modes can be got.

Table 3 The natural frequencies of the first vibration modes

Vibration mode	Natural frequency of rolling/Hz	Natural frequency of pitch/Hz	Natural frequency of torsion/Hz
1	0.104	0.106	0.115

(a) Rolling vibration, *f*=0.104 Hz

(b) Pitch vibration, *f*=0.106 Hz

(c) Torsion vibration, *f*=0.115 Hz

Fig.7 The first three vibration modes

According to the modal analysis, the induced period can be chosen, and the maximum design wave height and associated period of the platform can also be calculated. Meanwhile, dynamic analysis under regular wave for the platform is to be done.

Table 4 Load cases of dynamic analysis under regular wave

LC	Wave period/s	Wave direction/(°)	Wave height/m	Current velocity/ $(\mathrm{m \cdot s^{-1}})$
1	8.70	0,90	21	0.5
2	9.43	0,90	21	0.5
3	9.62	0,90	21	0.5
4	16.0	0,90	21	0.5

The response of the jack-up platforms in different wave periods is illustrated in Fig.8. There are several points in a certain period, where the response is lower than the near periods, that is to say, the base shear is not a monotone increasing one, and the suitable description of these points is vanishing point. The process of getting the description in Fig.8 is based on the approach in ABS rules (ABS, 2004).

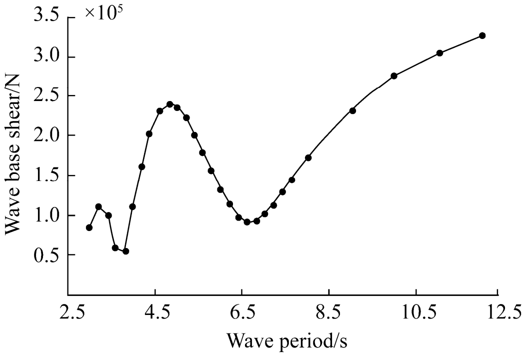


Fig.8 The base shear in different periods (0°)

Based on the chosen period, the dynamic analysis under regular wave can be done. Two of the dynamic response curves in time domain are illustrated in Fig.9 and Fig.10.

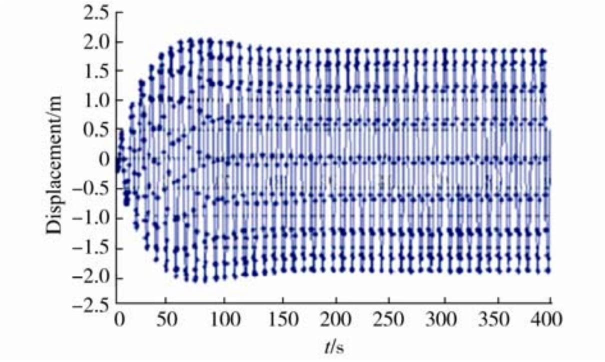


Fig.9 Displacement of a certain point in the hull (T_s=9.0 s, 0°)

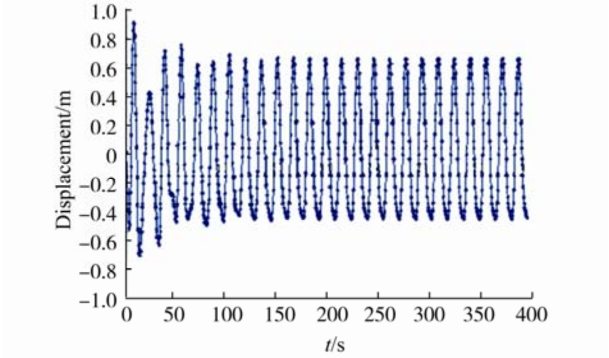


Fig.10 Displacement of a certain point in the hull (T_s=16.0 s, 0°)

The Figs.9–10 indicated that the free vibration and forced vibration are overlapped together in the early response stage, and it arrives at the steady state gradually. The first three wave periods adopted in the calculation are identical to the free vibration, but the 16 s one is relatively far from it. The response of 16 s induced period arrives at the steady state quickly, there is no significant increase of the vibration amplitude, neither is there any resonance with wave. While, near the natural period of the platform, the resonance will occur. There is an interaction for more than 150 s between the platform and wave, and the energy is amplified gradually during the process. Meanwhile, there is a significant trend of amplification of the response and the steady state is arrived at last. The response in equilibrium state is far more than the one of quasi-static response.

Table 5 The Maximum base shear response of the platform

Response/s	Dynamic analysis /MN	Quasi-static analysis /MN	DAF
8.0	3.73	1.46	2.55
9.0	9.98	1.88	5.31
10.0	10.5	2.24	4.69
12.0	5.01	3.85	1.30

Table 6 The Maximum main deck displacement (hull sway) of the platform

Response/s	Dynamic analysis /m	Quasi-static analysis /m	DAF
8.0	0.43	0.25	1.71
9.0	1.86	0.33	5.63
10.0	1.88	0.38	4.83
12.0	0.64	0.57	1.13

4.3 Application of DAF

For jack-up platforms, however, the major $P-\Delta$ effect (ABS, 2005) will thus be a static contribution to the linear stiffness, which has to be considered in static analysis of the platform. The so called $P-\Delta$ effect is directly related to the displacement and load levels in the structural element, and is treated as concentrated force acting on the center of the hull, which has some direction with wave (Feng *et al*., 2011). The comparison is carried out between dynamic analysis of dynamic amplification and static analysis of $P-\Delta$ effect using the self-compiling program of Mobility Workbench (MYWORK), which is developed to assess the structural strength of jack-up platforms based on PATRAN environment, and the response is demonstrated in Table 7, which gives results from a simulation study, based on the above methods.

Table 7 Comparison between dynamic response and static response

Response quantity/ Load case: LC4	Dynamic analysis extreme response	Static analysis extreme response
Base shear /MN	5.01	3.85
Overturning moment /(MN·m)	315.0	220.3
Main deck displacement/m	0.64	0.57
Max. Mises stress of leg /MPa	312.7	295.6

Note: wave direction=0°, wave inertial phase=0°.

This demonstration in Table 7 gives results that the dynamic properties will thus be a great contribution to the structural strength, which has a large influence to the structural design of the platform. Consequently, it demands that both the dynamic analysis and DAF should be taken other than the static analysis only.

4.4 Dynamic analysis under irregular wave

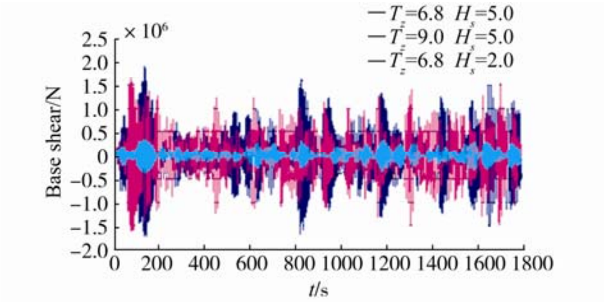
In order to study the effect to wave spectrum caused by T_z and H_s, the following four load cases are chosen in the dynamic analysis under irregular wave.

Table 8 The load cases under irregular wave

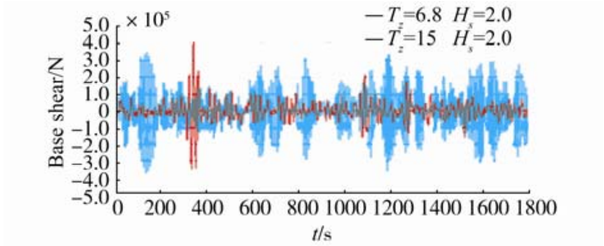
LC	Significant wave height /m	Spectrum peak period /s	Current velocity /($m \cdot s^{-1}$)
C1	5.0	9.58	0.5
C2	5.0	12.6	0.5
C3	2.0	9.58	0.5
C4	2.0	21.1	0.5

Fig.11 showed that in the load cases of the same significant wave height, the responses of C1 and C2 are nearly the same. However, there is a great difference between C3 and C4. The reason is that there is little difference among the spectrum peak period of C1, C2, C3 and the platform's natural frequency. In this condition, the resonance of the platform and wave is relatively significant. The resonance is determined by the wave energy, moreover, the significant wave heights of C1 and C2 are the same, so the responses of them are close (C1 is slightly larger as near to the resonance area). Because the significant wave height of C3 is smaller, the response is significantly less than the ones of C1 and C2.

Comparing C3 and C4, it is obvious that the load case whose spectrum peak period is close to the natural period of the platform which has a greater response. As the spectrum peak period of C4 is far from the natural period, and the wave energy does not transfer to the platform too much, which lead to the response of C4 is much smaller than the one of C3.



(a) T_Z=6.8 s, 9.0 s; H_S=2.0 m, 5.0 m



(b) T_Z=6.8 s, 15 s; H_S=2.0 m

Fig.11 The base shear comparison in different LCs

5 Conclusions

In this paper, the dynamic analysis approach has been introduced to predict the dynamic behaviors under extreme conditions. It provides an efficient and reliable approach to do structural strength analysis of offshore jack-up platforms. Based on the given discussions and example platform presented here, the following conclusions can be drawn:

1) The proposed method can be very useful in carrying out the time domain dynamic analysis of the platform responses to regular and irregular wave forces. The results of dynamic analysis under regular wave indicated that the wave force in high-frequency waves eliminates the vanishing points and strengthening points, it's recommended that the structural natural frequency avoids the frequency range of wave loads during practical structure design, and it's beneficial to making the natural frequency in step with the vanishing points too. The structural dynamic response is highly sensitive to the significant wave height. This behavior implies that dynamic response under irregular wave has a great relationship with the environmental parameters.

2) The comparison of the model's responses, which are obtained via dynamic and static analysis, gives us suggestions in using the dynamic analysis method for response predictions in other cases not considered here. In order to accomplish good quality of a practical design based on dynamic analysis, more attention should be given to the wave loads, reasonable model and DAF studies by considering the above-mentioned items as well as soil structure interaction, leg stiffness and damping matrix.

References

ABS (2004). *Dynamic analysis procedure for self-elevating drilling units*. American Bureau of Shipping, Houston, 5-20.

ABS (2005). ABS rules for building and classing mobile offshore drilling units 2001, part 3-hull construction and equipment. American Bureauof Shipping. Houston, 31-44.

Bienen B, Cassidy MJ (2006). Advances in the three-dimensional fluid–structure–soil interaction analysis of offshore jack-up structures. *Marine Structures*, **19**(2-3), 110-140.

Cassidy MJ, Taylor PH, Taylor RE (2002). Evaluation of long-term extreme response statistics of jack-up platforms. *Ocean Engineering*, **29**(13), 1603-1631.

Feng Guoqing, Li Xiaoyu, Yu Hao (2011). Strength assessment of 300ft jack-up platform in survival conditions. *Ship and Ocean Engineering*, **40**(5), 160-163.

Huang Zhaoyu, Tang Wenyong, Wang Yi (2010). Analysis and suppression on the dynamic amplification factor of self-elevating offshore platform. *Journal of Shanghai Jiao Tong University*, **44**(6), 816-819.

Hunt RJ, Marsh PD (2004). Opportunities to improve the operational and technical management of jack-up deployments. *Marine Structure*, **17**(3-4), 261-73.

Li Hua, Wu Weiguo, Gan Jin (2010). Research on multi-purpose offshore jack-up platform based on ANASYS. *Journal of Huazhong University of Science and Technology (Urban Science Edition)*, **27**(3), 86-90.

Li Runpei, Wang Zhinong (1992). *Structural analysis of offshore platform*. Shanghai Jiao Tong University Press, Shanghai, 24-54.

Lu Haohua (2005). The dynamic response of offshore Jack-up Platform. Master thesis, Wuhan University of Technology, Wuhan, 34-65.

Lu Y, Chen Y, Tan P, Bai Y (2001). Prediction of jack-up dynamic response. *Proceedings of the 20th International Conference on Offshore Mechanics and Artic Engineering (OMAE)*, Rio de Janeiro, Brazil.

Martin CM (1994). Physical and numerical modeling of offshore foundations under combined loads. PhD thesis, University of Oxford, Oxford, 22-29.

Qiu Dahong (1985). *Wave theory and its engineering application*. Higher Education Press, Beijing, 18-19.

Spidsoe N, Karunakaran D (1996). Nonlinear dynamic behaviour of jack-up platforms. *Marine Structures*, **9**(1), 71-100.

Wheeler JD (1969). Method for calculating forces produced by irregular waves. *Proc. of the Offshore Technical Conference*, Houston, 71-82.

Williams MS, Thompson RSG, Houlsby GT (1998). Non-linear dynamic analysis of offshore jack-up units. *Computers and Structures*, **69**(2), 171-180.

Williams MS, Thompson RSG, Houlsb GT (1999). A parametric study of the non-linear dynamic behaviour of an offshore jack-up unit. *Engineering Structures*, **21**(5), 383-394.

Xu Changhang, Chen Guoming, Xie Jing (2003a). A general review of research works on the structure response analysis and reliability assessment for jack-up platform. *China Offshore Platform*, **18**(4), 6-11.

Xu Changhang, Chen Guoming, Xie Jing (2003b). Non-linear dynamic analysis model for jack-ups under extreme storm condition. *Journal of the University of Petroleum*, **27**(4), 80-87.

Zhao Jingrui (2007). The static and dynamic analysis of the jack-up platform's legs in survival condition. Master thesis, Tianjin University, Tianjin, 36-41.

Zheng XY, Liaw CY (2004). Non-linear frequency domain analysis of jack-up platforms. *International Journal of Non-linear Mechanics*, **39**(2), 1519-1534.

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