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Dynamic Analysis on Underwater Leveling-Gripping System of Jacket Under Offshore Environmental Loads

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Abstract—**This paper aimed to dynamic analysis on underwater leveling-gripping system which is mounted on jacket under influence of offshore environmental loads. In order to get a leveling-gripping system dynamic response in the time domain, according to the parameters of the P-M spectrum, based on the Shinozuka theory, the effect of wave load in the time domain is analyzed. The effect of ocean current and wind load on the jacket structure is studied as constant load. The main environmental loads and its combination which jacket withstand in leveling process is defined. With SACS software, according to the South China Sea conditions, a platform bottom dynamic response is calculated under extreme environmental loads in different return period. Use ADAMS software to dynamic analyze the force of key clamping contact parts of leveling-gripping system in leveling process.**

Keywords- dynamic analysis;leveling-gripping system; offshore environmental load; time domain ; contact

I. INTRODUCTION

Jacket platform is widely used in the world's offshore oil fields, which the number up to 95% of the number of a variety of platforms. Jacket platform installation technology is one of the key technologies of the offshore oil and gas resources development[1]. A large number of jackets were installed in East China Sea and South China Sea, water depth ranging from a few meters to a few hundred meters. When installing a platform, in order to achieve the leveling precision of the engineering requirements, the jacket must be adjusted by leveling-gripping system after platform jacket fall into the seabed. During the leveling process, jacket withstand environment loads include wind, wave, ocean current and so on[2], so leveling-gripping system of jacket have obvious dynamic response[3]. In order to ensure the stable operation of the system, dynamic analysis on leveling-gripping system of Jacket is the key which cannot be ignored. The paper introduce a method to get the effect of wave load in the time domain, with SACS and ADAMS to dynamic analyze the leveling-gripping system in leveling process.

II. CALCULATION THEORY OF ENVIRONMENT LOAD

A. Time domain analysis of wave load

The effect of wave load on offshore structure is studied based on the Morrison formula and the Stokes five order wave theory[4,5].

The components of jacket legs are space tilt rod. In order to calculate for offshore inclined structures bar, Morrison formula is adjusted as follow:

$$\begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = \frac{1}{2}\rho C_D D|\omega_n| \cdot \begin{bmatrix} u_{nx} \\ u_{ny} \\ u_{nz} \end{bmatrix} + \rho C_M A \begin{bmatrix} \dot{u}_{nx} \\ \dot{u}_{ny} \\ \dot{u}_{nz} \end{bmatrix}$$

F ——Wave force acting on pile, KN;
u ——Velocity of water particle, m/s;
$\dot{u}$ ——Acceleration of water particle, $\mathrm{m/s^2}$;
ρ ——Density of water, $\mathrm{kg/m^3}$;
D ——Cross section diameter of the pile, m;
C_D ——Drag coefficient, $C_D = 0.6 \sim 1.2$;
C_M ——Inertial force coefficient, $C_M = 1.3 \sim 2.0$.

The wave is generated by the wind is a kind of highly irregular phenomenon and will not be repeated, so the wave is actually a kind of random wave[6,7]. At present, the analysis of offshore structures is mainly based on spectrum analysis. In order to study the dynamic response of the key parts of the leveling-gripping system in the leveling process, the dynamic analysis of jacket structure under wave load must be carried out in the time domain.

The harmonic wave superposition method is used to simulate the random wave[8]. According to the Shinozuka theory, the surface of wave $h(t)$ can be simulated as follows:

$$h(t) = \sum_{j=1}^{N} \sqrt{2S(\omega)\Delta\omega}\cos(\omega t + \phi_j)$$

N ——Sufficiently large integer;
$S(\omega)$ ——Random wave spectrum;
$\Delta\omega$ ——Frequency increment;
ϕ_j ——Random variable is distributed in $(0, 2\pi)$.

The single parameter I.T.T.C P-M spectrum is selected to describe the wave:

$$S(\omega) = 0.78\omega^{-5}\exp\left(\frac{-3.11}{H_s^2\omega^4}\right)$$

The effective height of wave $H_s = 8.5\text{m}$, wave spectrum curve as shown in Figure1, and 500 seconds of wave height curve as shown in Figure 2.

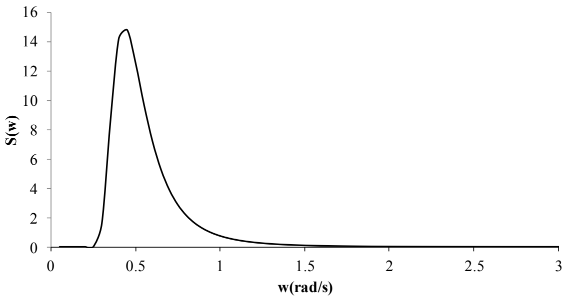

Fig.1 The I.T.T.C wave spectrum curve

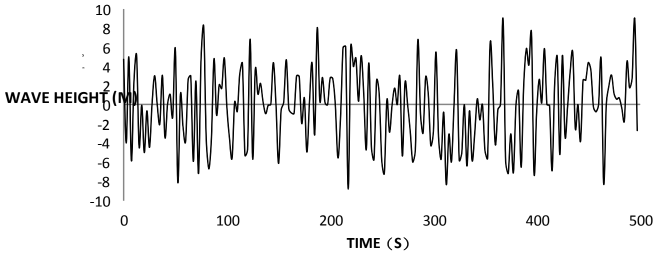

Fig.2 The curve of wave height

B. *Analysis of current load.*

When the current and wave direction are the same, the current make total load increases, but on the contrary, the current weaken the total load, so the current has obvious effect on the wave load.

The current force formula as follow:

$$F_c = \frac{1}{2} C_D \rho D v_c^{\ 2}$$

v_c ——Velocity of current, m/s.

The wave velocity vector is set to v, the angle between the wave and current direction is set to φ. To calculate the joint action of wave and current according to Morrison formula, then the drag force vector as follow:

$$F_D = \frac{1}{2} C_D \rho D \left(v + v_c\right) \left|v + v_c\right|$$

C. *Analysis of wind load.*

Wind load is usually can be used as a constant force to analysis. By using the calculation method of wind in API RP 2A, the form of the formula as follow:

$$F = (\omega / 2g) V^2 C_S A$$

F ——Force of wind, N;
ω ——Density of air, N/m^3;
g ——Acceleration of gravity, m/s^2;
V ——Velocity of wind, m/s;
C_S ——Shape coefficient;
A ——Windward area of structure, m^2.

III. THE BASE SHEAR OF JACKET UNDER OFFSHORE ENVIRONMENTAL LOADS

The jacket leveling-gripping system is installed to connect between jacket legs and steel pipe pile, have a great effect by environmental loads, and the horizontal direction is the main direction, therefore, the base shear of the jacket under environmental loads must be analyzed.

A. *Analysis model of jacket*

A jacket platform located in the South China Sea has been selected as the object to analyze. This platform is the four legged jacket platform, fixed in the seabed by steel pipe pile, water depth of the location is about 354 feet. The model is calculated and analyzed by application of SACS（Seastate Analysis Computer System） software, which is developed by Engineering Dynamics Company in USA. The analysis model is shown in Figure3.

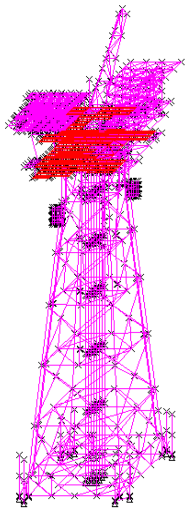

Fig.3 A jacket platform SACS analysis model

B. *Determination of environmental loads factor*

The working time of leveling-gripping system is generally a few days, and the offshore environment loads always include wind, wave and current. In order to ensure the performance of leveling-gripping system, the environment loads of wave, current and wind is analyzed respectively in different return period for one year, ten years and one hundred years of the South China Sea[9]. Environmental loads factor data are shown in table 1.

TABLE I. ENVIRONMENT LOAD FACTOR DATA TABLE

Environmental loads factor	**unit**	**Return period (years)**		
		1	***10***	***100***
1 minute average wind speed	m/s	33.2	38.3	51.7
3 second wind	m/s	37.8	43.6	58.7
effective wave height	m	8.5	10.7	13.9
effective period	s	11.9	13.7	15
Zero mean period	s	9.6	10.8	12.3
maximum wave height	m	14.2	17.9	23.3
period of wave spectrum peak	s	12.7	14.6	16
surface current velocity	m/s	1.09	1.61	2.19
middle current velocity	m/s	0.7	1.13	1.82
Bottom current velocity	m/s	0.33	0.49	0.93

C. The maximum base shear of jacket

As the most dangerous situation, jacket is analyzed and calculated with all environmental loads act in the same direction. The incident angle of environmental loads action to jacket is analyzed in eight directions, and the relationship between different return period maximum base shear and incident angle is shown in Fig.4.

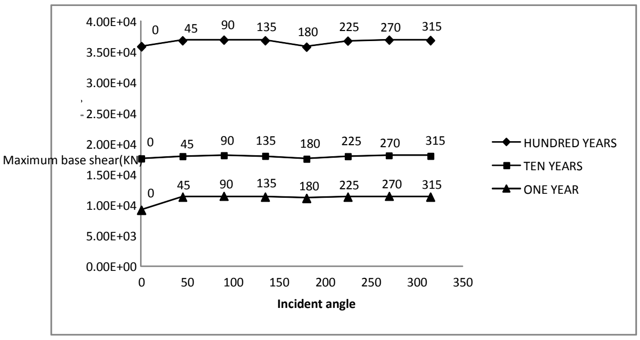

Fig.4 The relationship between base shear and incident angle

IV. DYNAMIC RESPONSE OF LEVELING-GRIPPING SYSTEM KEY PARTS

In the system, the clamping contact parts between steel pipe pile and clamping claw are key parts, and the contact force directly determines the leveling-gripping system leveling performance and stability. The contact forces are in the horizontal plane, same with the offshore environment loads include the waves, currents and wind, resulting in contact forces are directly influenced by the environment loads, and have obvious dynamic response.

The whole process of the system leveling under environmental loads is analyzed by ADAMS software, include analysis of dynamics and kinematics, to get the dynamic response of the clamping contact parts. System dynamics model as shown in Figure 5.

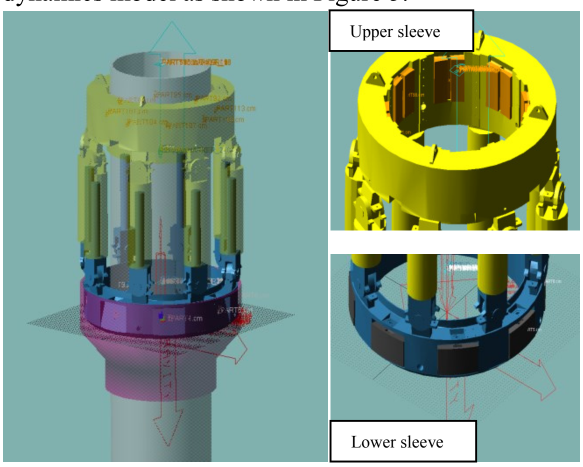

Fig.5 Leveling-gripping system dynamics model

Figure 6 shows the different contact position of upper sleeve clamping claws and direction of environment load.

Under one year return period of sea conditions, the upper sleeve clamping position is analyzed, as leveling, the time curve of contact force between the gripper and steel pipe pile in 1#, 3#, 7# position as shown in Figure 7.

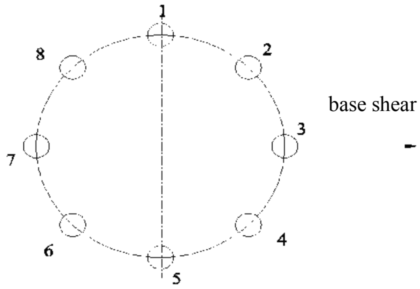

Fig.6 The contact position and loading direction

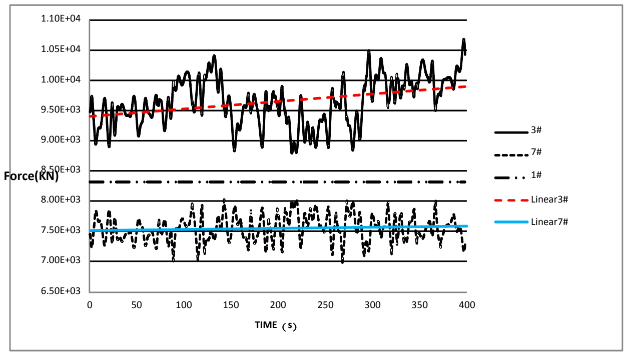

Fig.7 The time curve of each contact position force in upper sleeve

With the analysis of the calculation results, because of the direction of pressure and environment load is vertical, the force of 1# position is not affected by the environment load. The force of 3# position increased significantly, while the 7# pressure decreased significantly under the influence of environment load, and with the hydraulic cylinder extending, the effects of forces of 3# and 7# position is increasing.

Under the ten years return period and one hundred years extreme sea conditions, time curve of force of 3# position in upper sleeve can be obtain, in the same way, are shown in Figure 8 and Figure 9.

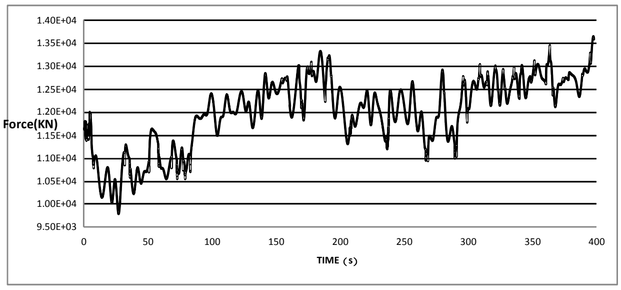

Fig.8 Upper clamping claw 3# position force time curve(10years)

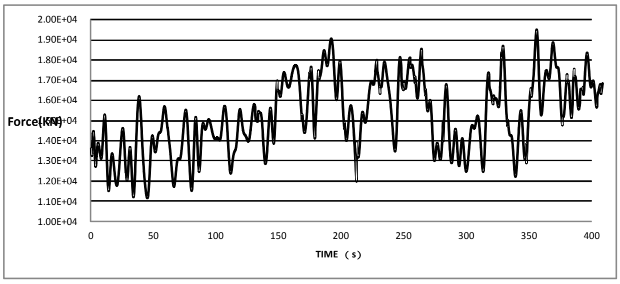

Fig.9 Upper clamping claw 3# position force time curve(100years)

With the curves are shown in above, the influence of environmental loads can be seen clearly, which cannot be ignored.

CONCLUSION

Generally, wave is analyzed in the frequency domain. In order to obtain the relationship between forces of key parts of marine mechanical equipment and working time under the offshore environmental loads, this paper presented a method of dynamic analysis on leveling-gripping system of jacket under the influence of wave, current and wind. In this method, the wave is analyzed in the time domain, model is established by SACS and dynamics analyzed is simulated by ADAMS. By this method, dynamic response of key clamping contact parts of leveling-gripping system can be obtained, and provide a means for dynamics analysis on the Marine Engineering.

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