ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Energy Procedia 14 (2012) 1267 – 1272
Energy Procedia

2011 2nd International Conference on Advances in Energy Engineering (ICAEE2011)

The wind tunnel tests of wind pressure acting on the derrick of deepwater semi-submersible drilling platform

Gangjun Zhai[a], Zhe Ma[a]*, Hang Zhu[b]

[a]*Deepwater Engineering Research Centre, Dalian University of Technology，Dalian, Liaoning 116023, P. R.China*
[b]*Shipbuilding technology research institute,Shanghai, 200032, P. R.China*

Abstract

The increasing importance of the sustainability challenge in ocean engineering has led to the development of floating ocean structure. In this study, according to the 1/100 scale model of the HYSY-981 semi-submersible platform, the investigation on the wind resistant properties of the platform is measured through wind tunnel tests. The wind pressure coefficients of the derrick in 0~90° wind directions were obtained by calculation. The distribution of the wind pressures on windward side of the derrick was studied. These results may serve as a reference on the design for wind loads acting on the platform.

Keywords: semi-submersible platform; wind tunnel test; wind pressure

1. Introduction

As the development of mining technology, offshore oil exploration and development has been proposed requirements into the deep sea in China. Deepwater drilling Semi- submersible platform is very important and necessary in oil and gas exploration fields. Semi-submersible structures are designed for random wind and wave loads, and practical estimation of designed dynamic wind loads for complex shape such as deck, columns and derrick is an involved exercise. Many failures involving deck components caused by extreme wind have already been reported in damage-investigation [1]. More than look the overall lateral loads on the platform as a whole, the deck components need to be carefully considered when they are designed to resist lateral loads. These lateral loads are mainly caused by winds. Wind load contribution is 10% of total lateral loads in jackets and about 25% in compliants during normal winds, and

* Corresponding author. Tel.: +0086-411-84706757; fax: +0086-411-84706747.
E-mail address: deep_mzh@dlut.edu.cn.

doi:10.1016/j.egypro.2011.12.887

in the event of cyclonic winds, these loads tend to increase to 20% and 40-50% respectively. In the worldwide, the security of offshore platform under the extreme wind conditions gets more industry's attention. The field observation, numerical simulation and wind tunnel tests are main researching methods using widely. Iskender Sahin [3], Gomathinayagam [4] and Davenport [5] studied wind loads and dynamic responses of the offshore platform with the above methods.

2. The practical semi-submersible platform

The target platform is the 6th generation semi-submersible drilling platform (Fig.1), standing for the highest level of offshore-oil-drilling platform technology in the modern world. The platform will be the first super-deepwater submersible drilling platform designed by Chinese. It has the capability of exploration, drilling, completion and workover etc. The maximum operation depth is 3,000m, and the drilling depth reaches 10,000m. The platform is 30,670 tons, 114m long and 79m wide, with an area bigger than a standard football field. The bottom of the platform is 130m, over 40-storey high, from the top of the derrick. The wire is totally 650km long, equals to 10 times of the circumference of the 4th Ring Road of Beijing. The platform has multiple independent innovations: first, according to the sever condition in South Sea in China, the platform is suitably designed, and the structure is stable and strong enough for the worst typhoon in 200 years. Second, its thruster has high horsepower with the DP3 power positioning system, and it can be put in 1,500m-depth water by anchoring. Third, the dock has a maximum variable load of 9,000 tons. Fourth, the platform can be operated not only in the deepwater in South Sea in China, but also in Southeast Asia and West Africa areas. Last but not least, the platform's designed serving time is 30 years.

Fig.1 The 6th generation semi-submersible drilling platform

Target platform adopted double-hull pontoon, four columns, lateral bracing connection, and box deck. For Main-scale optimization and determination, the principles are: minimize the column height, reduce the high of box deck，consider the arrangement of space, sports performance and stability requirements for the size of the deck and the column，determine the scale of displacement and the pontoon based on the weight and loading requirement，and use tube-type cross brace. Following is the main particulars of the Semi-submersible under survival condition (Table 1).

3. The model semi-submersible platform

3.1. Boundary layer profiles

The dynamic pressure profile follows a power law given by

Table 1 Main particulars of the semi-submersible platform under survival condition

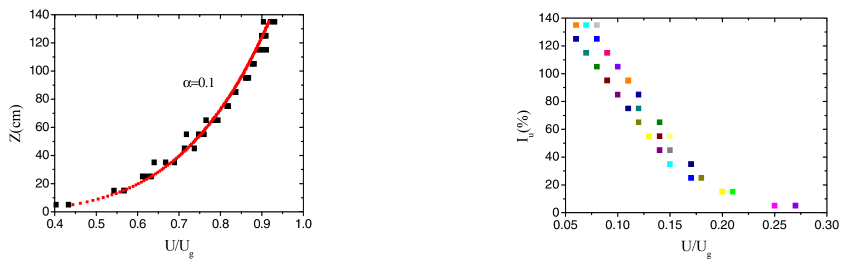
Main structure of the platform	Parameter (m)
Pontoon	114.07×20.12×8.54
Column	17.385×17.385×21.46
Deck	74.42×74.42×8.60
Height of derrick	64
Waterline	16
Static air gap	14

$$q(z)=q_{ref}\left(\frac{z}{z_{ref}}\right)^{2a} \tag{1}$$

Where $q(z)$ is the dynamic pressure at a given height z, and q_{ref} is the reference dynamic pressure at the reference height y_{ref}.The reference dynamic pressure was 1435 Pa at the reference height of 0.6m above the water line corresponding to a full-scale reference height of 10m (Fig.3). Ug is the wind gradient velocity, and the height of wind gradient is 300m in the nature. For the ABS profile, an exponent factor a =0.1. The corresponding velocity profile obtained from Eq. (1) is given by

$$U(z)=U_{ref}\left(\frac{z}{z_{ref}}\right)^{a} \tag{2}$$

The pictures of the final boundary layer fences and corresponding turbulence profile for the final ABS profiles are shown in Fig.2



(a) (b)

Fig.2 (a) Boundary layer profile obtained to simulate the ABS profile (left);
(b)Turbulence intensity measurements for ABS profile(right)

3.2. Model description

The tested model was a 1:100 scale representation of the HYSY-981 drilling platform (Fig.3a). The pontoons, columns, column braces, deck, crane pedestals, and derrick base were built of polymethyl methacrylate. Many simplifications, such as modeling buildings and pipe stacks with rectangular blocks, were made. The model center was defined as the center of the plane formed at the water line by the columns.

(a) (b)

Fig.3 (a) The model of the semi-submersible platform(left); (b)Wind incident angle(right)

3.3. Wind condition

The total wind loads acting on the platform in different wind directions were calculated according to the shape coefficient with 100-yr time return periods. The wind velocity of reference points is 15 m/s. In the wind tunnel test, each wind incident angle will be deal as a working condition. The interval of the wind incident angle is 15^{o}. There are total 24 working conditions. Fig.3b defined the direction of the wind incident angle in clockwise direction.

4. Results

4.1. The distribution of wind load on windward side of the derrick

The wind pressure coefficient calculation formula is given by

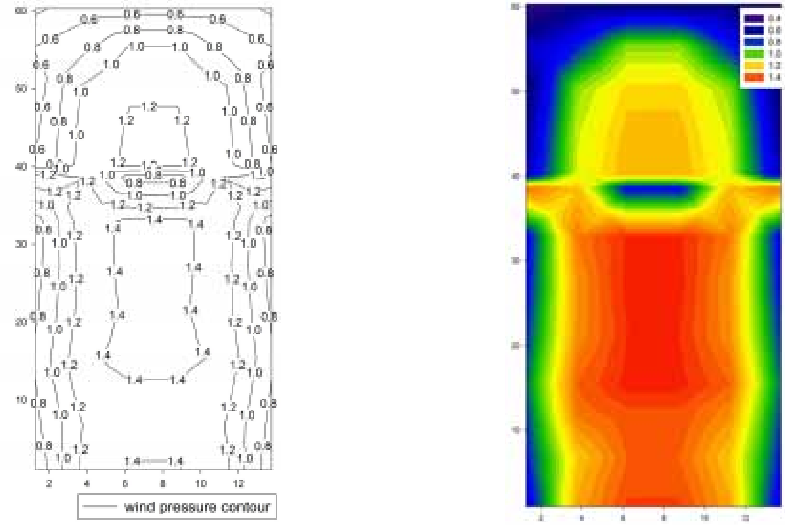
$$C_p = \frac{p}{2\rho U_{10}^2} \tag{3}$$

Where C_p is the wind pressure coefficient at a given air density ρ and wind velocity is at the reference height of 10m.

Fig.5 presents the distribution of wind pressure on the windward side of derrick at 0º wind incident angle. In contrast with fig.4a and fig.4b, the wind pressure coefficient is always positive, and the larger value appeared in Centroid and joint between derrick and deck.

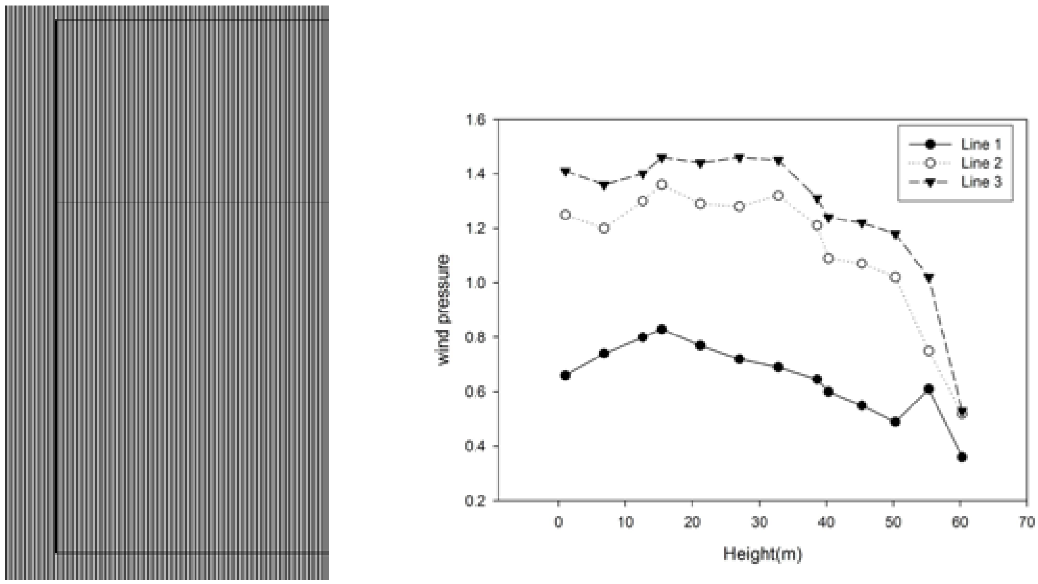
4.2. Comparison of wind pressure between 3 lines on the derrick

The distribution of the wind pressure has some changed in different areas on the derrick. The paper defines 3 lines position for comparing these differences (fig.5a). Fig.6b shows the decrease of the wind pressure coefficient as height increases form 0m to 60m. From the picture, we can see that the markers of the same shape (i.e. the different No. of the line) are ranked with some variations and respond to the height of the derrick in unison as a whole. This implies that height of the derrick has substantial effect on wind coefficient. The overall results show that wind pressure changes with a maximum of 60% in different heights from 0-60m.In contrast, the wind pressure coefficient is strongly affected by the position of the derrick. A significant drop of wind pressure coefficient can be observed in the 45m height.



(a) (b)

Fig.4 the distribution contour (a) and filled contour (b) of wind pressure on the windward side of derrick at 0° wind incident angle



(a) (b)

Fig.5 Lines position (a) and wind pressure coefficient (b) of these lines on the windward side of derrick at 0° wind incident angle

5. Conclusion

a. The shape coefficients show the similar trends on the column, deck and derrick. But the overall results show the value of shape coefficient changes with a maximum of 60% in different incident angles from 0^o -90^o ;

b. As a result of different windage area effect, the peak value of the total wind load appears in 45^o, and peak value is about 17400 KN;

c. The wind pressure coefficient of the derrick is always positive on the windward side, and the larger value appeared in Centroid and joint between derrick and deck.

Acknowledgements

This work was financially supported by the Funds for Creative Research Groups of China (Grant No. 50921001)

References

[1]A. Kareem, C.E. Smith, Performance of offshore platforms in Hurricane Andrew, Proceedings of the seminar on Hurricanes, Miami, Florida, USA, 1993, pp. C3 I-1-10.

[2]Iskender Sahin A survey on semi-submersible wind loads Ocean Engineering Volume 12, Issue 3, 1985, Pages 253-261.

[3]S. Gomathinayagam Dynamic effects of wind loads on offshore deck structures — A critical evaluation of provisions and practices Journal of Wind Engineering and Industrial Aerodynamics Volume 84, Issue 3, February 2000, Pages 345-367.

[4]A.G. Davenport and E.C. Hambly, Turbulent wind loading and dynamic response of jack-up platform Offshore Technology Conference, Houston, Texas, 1984, Paper No. OTC4824.

[5]Guidelines for wind Tunnel of Mobile Offshore Drilling Units,The Society of Naval Architects and Marine Engineers,Aug.1988

[6]Low Speed Wind Tunnel Facility Handbook,Aerospace Engineering Division Texas Engineering Experiment Station,The Texas A&M University System,Sept.2000.