Determination of current loads of floating platform for special purposes

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Abstract. This article studied a new floating offshore platform for special purposes, which was assembled by standard floating modules. The environmental load calculation of the platform is an important part of the research of the ocean platform, which has always been paid attention to by engineers. In addition to wave loads, the wind loads and current loads are also important environmental factors that affect the dynamic response of the offshore platform. The current loads on the bottom structure should not be ignored. By Fluent software, the hydrostatic conditions and external current loads of the platform were calculated in this paper. The coefficient which is independent of the current velocity, namely, current force coefficient, can be fitted through current loads, which can be used for the consequent hydrodynamic and mooring analyses.

1. Introduction

Offshore platform is a structure which provide producing and living facilities for drilling, oil extraction, observation, navigation, construction, etc. Traditional offshore platforms--drilling platforms, for example--include barge-type drilling platform, semi-submersible drilling platform[1], Tension-Leg Platform (TLP)[2], Spar Platform[3], Floating Production Storage Offloading (FPSO), Very Large Floating Structures (VLFS) and Mobile Offshore Bases (MOB)[4]. In addition, as National Blue Ocean Strategy develops[5], a multi-purpose offshore simple floating platform, which can be used in both shallow sea and deep sea, is urgently needed for offshore operations, such as marine pasture observation, leisure fishing, offshore playground and aquaculture. This platform should meet the satisfaction of stability and resistance of wind, waves, current, corrosion and fouling, and have room for upper equipment.

This article discuss a new floating offshore platform (figure 1, figure 2) for special purposes assembled by standard floating modules, whose upper part is steel-frame structure and plank laying, the buoys are adopted for buoyancy at the bottom. Any size can be combined by these two parts as needed. This kind of platform can be used for leisure, and also as an observation platform or offshore wind power and solar power generation platform with the placement of relevant equipment.

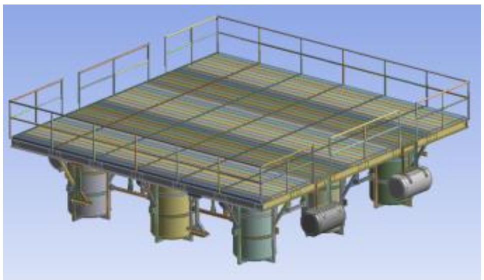

Figure 1. Axonometric drawing 1

Figure 2. Axonometric drawing 2

In a bid to make sure that designing platform has the seakeeping quality, the finite element model of this new floating platform is required to be created, hydrodynamic characteristics and structural strength of which need to be analyzed[6-9]. External environmental loads of platform contain three environment loads including wave load, wind load, current load, and sometimes, plus ice load and earthquake load based on design needs. External current load platform undertakes is analyzed in this article, and the final results are shown, which can be applied in subsequently designing and analyzing steps.

2. Analyses of hydrostatic conditions

The dimensions and weight of the platform are shown in table 1.

Table 1. Dimensions and weight of the platform

Basic parameters of platform	Length (m)	Width (m)	Height (m)	Weight (kg)	Height of the center of gravity above the bottom (m)
	6	6	1.475	3480.95	1.183

The moments of inertia of the platform based on the center of gravity are shown in table 2.

Table 2. Moment of inertia of the platform based on the center of gravity

Moment of inertia	Ixx (kg·m2)	Iyy (kg·m2)	Izz (kg·m2)
	11637	11497	21995.8

First of all, model of floating platform (figure 1, figure 2) should be created. On the condition of known weight, center of gravity and moment of inertia of platform, static waterline can be calculated by AQWA software (table 3).

Table 3. Hydrostatic conditions of platform

Hydrostatic conditions	Weight (kg)	Volume of drainage (m^3)	Draught (m)	Height of the center of gravity above water plane (m)
	3480.95	3.396	0.791	0.392

AQWA software is a hydrodynamic analyzing software product by ANSYS Inc., which is mainly used in calculating hydrodynamic properties of ocean engineering. AQWA has the abilities of calculation of the first and second order wave forces and various analyses of the seakeeping quality, stability, mooring, launching, colliding, air gaps and cable dynamics.

The basic processes of AQWA calculating hydrostatic conditions of floating are as follows:

- Set a position of waterline randomly as well as appoint known message of weight.
- Position of static floating can be calculated after balance analyzing.
- Modify the position of waterline to the calculated one of static floating.

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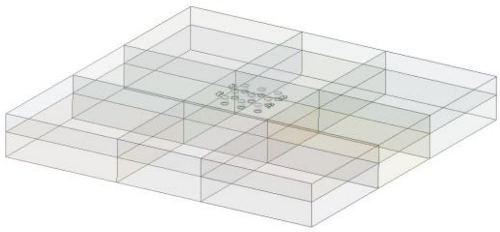
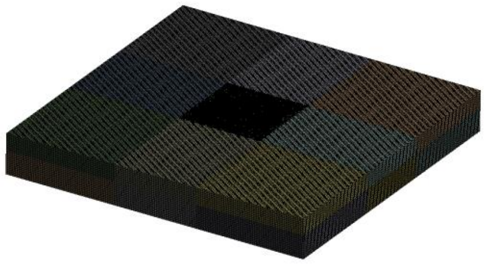
3. Calculation of current loads

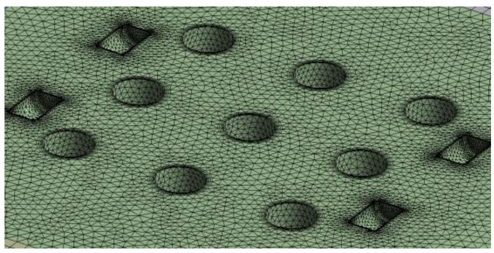
Wet surfaces can be extracted with static draft of floating, and external flow field model is established. The length, width and height of created computational domain of flow field are all six times of size of floating. For the convenience of designing different sizes of units when meshing, external process is divided into several parts.



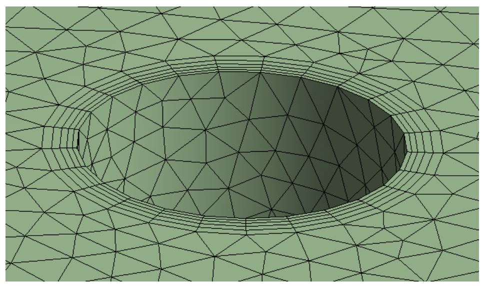
(a) Model of water flow field



(b) Meshing of external water flow field (all-hexahedral mesh)



(c) Meshing of middle water flow field (tetrahedron mesh)



(d) Wet surface meshing of the platform

Figure 3. Geometry and mesh model of CFD calculating

In this model, the computational domain of external water flow field is divided by all-hexahedral mesh, whose cell size is 0.2m; middle computational domain is divided by tetrahedron mesh, whose cell size is 0.15m; cell size of wet surfaces of floating is 0.1m, which is divided into five boundary layers. Geometry and mesh model created is shown in figure 3.

In this article, the current force loads of the wet surfaces of this platform were calculated by Fluent under the circumstances of different velocities and directions of current. Five different working conditions of current velocities varying from 1m/s to 5m/s has been calculated in Fluent by k-e turbulence model and method of enhancing wall function, and current forces have been extracted from each direction of wet surfaces. Coefficients of water which are calculated under different current velocities can be fitted according to formula (1).

$$\begin{cases} F_{cufx} = CUFX_{\phi} V_{current}^2 \\ F_{cufy} = CUFY_{\phi} V_{current}^2 \\ F_{cufz} = CUFZ_{\phi} V_{current}^2 \\ F_{curx} = CURX_{\phi} V_{current}^2 \\ F_{cury} = CURY_{\phi} V_{current}^2 \\ F_{curz} = CURZ_{\phi} V_{current}^2 \end{cases} \quad (1)$$

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In these formulations, F_{cufx},F_{cufy}, F_{cufz},F_{curx}, F_{cury}, F_{curz} represent current forces and moments of directions of X,Y,Z respectively; $CUFX_{\phi}$, $CUFY_{\phi}$, $CUFZ_{\phi}$, $CURX_{\phi}$, $CURY_{\phi}$, $CURZ_{\phi}$ represent translational and rotational coefficients of water of directions of X,Y,Z;$V_{current}$ is velocity of current.

It is not enough to describe the complex water environment only considering the condition of current velocity of 1m/s, thus, current forces under different current velocities need to be calculated in order to fit coefficient of water (table 4, table 5, figure 4 and figure 5).

Table 4. Current load of direction of X of floating

Velocity of X direction (m/s)	Fx (N)	Fy (N)	Fz (N)	Mx (N·m)	My (N·m)	Mz (N·m)
1	967.23	2.42	-1372.86	5.88	-1048.71	3.98
2	3781.24	8.48	-5688.66	6.89	-4154.62	14.90
3	8501.82	8.71	-12942.18	17.63	-9739.38	32.06
4	15216.77	14.66	-23141.82	24.06	-17576.04	49.75
5	24062.56	57.78	-36803.53	33.47	-27491.68	74.61

Note: Bending moments Mx, My, Mz in this table are all based on the center of gravity of floating.

Table 5. Current load of direction of Y of floating

Velocity of Y direction (m/s)	Fx (N)	Fy (N)	Fz (N)	Mx (N·m)	My (N·m)	Mz (N·m)
1	1.08	913.92	-1304.33	970.68	-0.95	-26.71
2	4.91	3563.28	-5184.92	3963.96	-4.89	-60.65
3	5.29	8043.04	-11797.38	8820.45	-5.387	-41.47
4	6.86	14391.33	-21397.99	15247.24	-8.31	51.17
5	16.12	22853.41	-33779.15	24978.7	-16.03	-7.73

Note: Bending moments Mx, My, Mz in this table are all based on the center of gravity of floating.

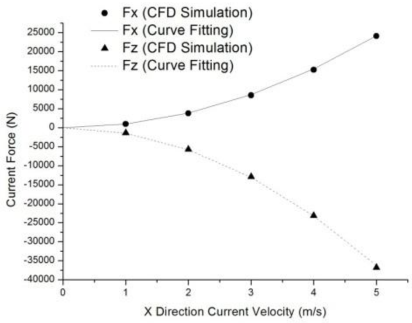

Figure 4. Curve fitting of coefficient of water of X direction

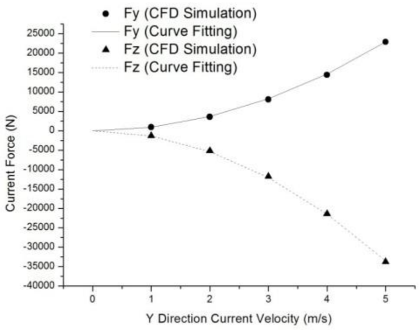

Figure 5. Curve fitting of coefficient of water of Y direction

If current loads of positive direction of X and Y are set to be 0 degree and 90 degrees respectively, coefficients of water of $CUFX_{\phi}$,$CUFY_{\phi}$,$CUFZ_{\phi}$,$CURX_{\phi}$,$CURY_{\phi}$,$CURZ_{\phi}$ (table 6), which are shown in formula (1), can be fitted according to data associating current load and current velocity in table 4 and table 5.

Table 6. Result of fitting coefficient of water

Direction of current	$CUFX_\varphi$	$CUFY_\varphi$	$CUFZ_\varphi$	$CURX_\varphi$	$CURY_\varphi$	$CURZ_\varphi$
0	965	0	-1450	0	-1090	0
90	0	914	-1340	971	0	0

4. Conclusion

This article mainly calculated the hydrostatic conditions and the external current load of the platform, which is calculated by Fluent software. As we can see from table 2-4, there exists a quadratic function relationship between current load and current velocity.

Coefficient which is independent of current velocity, namely, coefficient of water, can be fitted with current load and used for consequent hydrodynamic and mooring analyses.

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