Research on motion response of wind turbine installation vessel in navigation

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Abstract

The proposal of this investigation is motion response of wind turbine installation vessel in navigation. The topic is studied based on the combinations of theoretical analysis and numerical simulation. It is established a three dimensional numerical pool, the finite volume method is adopted to solve the Navier-Stokes equations, to the actual sea condition of wind turbine installation of numerical analysis of the motion response of the vessel, makes comparison and validation on combining experimental wind wave motion of the ship installation numerical prediction is established. By incident boundary ahead on the way to create the incident wave spectrum functions are defined, at the very back of the computational domain to define momentum source to wave damping, water quality in the area of the wave point on the vertical direction of vibration attenuation finally reached zero, step by step to avoid the influence of reflection wave. When solving the Navier-Stokes equations using Reynolds time-averaged (RANS) numerical simulation method, assuming that turbulent flow field in the change from an average and a pulsating quantity of based on grid control unit to solve mass conservation, momentum conservation equation, energy conservation and VOF volume control, solving the free surface and the flow field near the structure. In order to ensure the accuracy of the calculation, a 2-order time difference scheme is adopted, and the HRIC difference scheme is adopted in the space with the combination of windward difference and downwind difference. In addition, various meshing formats and mesh size sensitivity are verified.

More systematic and innovative conclusions are drawn, which provides a theoretical basis and technical support for prediction of wave motion response for wind turbine installation vessel.

Keywords: wind turbine installation vessel, computation overset grids, wave motion response, VOF

Introduction

With the development of marine strategy, the great attention has been paid to the process of offshoring and large-scale of offshore fans in recent years, they have been higher demand of the equipment for the transport capacity, operation depth and lifting power. Self-propelled marine wind turbine installation vessel is specially adapted for offshore wind farm development and maintenance. The characteristics of Strong force, high operation efficiency and good economic benefits have gradually made it become the first choice for installation and maintenance of large offshore fans[1][2].

The research on offshore wind turbine installation vessel mostly focuses on the structural strength analysis[3] of wind turbine installation vessel under operating conditions, and also on the performance of wind turbine installation vessel[4] under lifting conditions, the application of AQWA software[5] to study the performance of wind turbine installation vessel under self-propelled condition as well.

In the course of the wind farm, all the windmill blades and motor equipment placed on the deck, causing ship full loaded with the position of the center of gravity under the condition of a ballast condition at the same time increase a lot, in the process of navigation to leg back to the main hull, the position of the center of gravity further increased, so the motion performance of wind turbine installation vessel is great difference from other general ship. At the same time, the ordinary merchant is usually based on the motion analysis of infinite depth assumption, the target ship in the wind farm area navigation with shallow water depth, only tens of meters with lowly speed, so it is necessary to study the motion characteristics of the navigation process.

There are some advantages of Overset Grids.one is easier to perform and automate parametric studies. With a single set of grids, many different configurations can be computed. Grid quality is not affected by changing position or orientation of bodies; Boundary conditions easier to set and so on. The other is easier to handle relative motion of bodies, arbitrary motion can be handled, paths can cross, the tangential motion at close proximity can be handled as well. It can be easy transition to other multiphase models such as VOF to Lagrangian and vice-versa, Fluid film to VOF and vice versa Eulerian or Lagrangian multiphase models within VOF phases.

Numerical Equation

In order to analyze the wave performance of wind turbine installation vessels, the calculation of movement response of ships in waves based on wave potential flow theory[6]. Firstly, the velocity potential of the flow field is solved based on the Laplace equation and boundary conditions. Secondly, the hydrodynamic pressure distribution of the floating body is solved according to Bernoulli equation. Thirdly, the surface integral of the wet surface of the object is subjected to the wave force of the floating body.

$$F_j^{(1)}(\omega) = \iint_S p^{(1)} n_k ds = \left(f_{0k} + f_{7k} + \sum_{j=1}^{6} T_{kj} x_j\right) e^{-i\omega t} \quad (1)$$

Where: f_{0k}—The incoming power;

f_{7k}—The diffraction force;

T_{kj}—The radial force in the k direction in which the floating body is subjected to the j degree of freedom at unit velocity;

$p^{(1)}$—The pressure distribution;

n_k—The normal direction of the object.

Using generalized wave force, additive mass and damping in the frequency domain, the generalized wave force, additive mass and delay function are obtained by transformation in the time domain. The delay function is expressed as:

$$K_{ij}(t) = \frac{2}{\pi}\int_0^\infty \lambda_{ij}(\omega)\cos(\omega t)d\omega \qquad (2)$$

In the equation: λ—the damping matrix of the floating body in the frequency domain.
The additional mass expression of floating body in time domain is expressed.

$$m_{ij}(t) = \mu_{ij}(\omega_0) + \frac{1}{\omega_0}\int_0^\infty K_{ij}(t)\sin(\omega_0 t)\,dt \qquad (3)$$

In the formula: μ— the additional mass matrix of floating body in the frequency domain.
Express it as:

$$F_{\omega i}(t) = \int_0^t h_i^1\,(t-\tau)\eta(\tau)d\tau \qquad (4)$$

In the formula: $F_{\omega i}(t)$ — the first wave force of the floating body in the i direction;
$\eta(\tau)$ — wave time calendar;
$h_i^1(\omega)$ —frequency domain wave force Fourier transform.

The motion characteristics of the ship are solved according to the floating time domain equation (5).

$$M + m(t)\ddot{x}(t) + \int_{-\infty}^t K(t-\tau)\times\dot{x}(t)\}d\tau + Cx(t) = F(t) \qquad (5)$$

In the formula: M — the generalized mass matrix of floating body;
$m(t)$— additional mass matrix of floating body;
$K(t-\tau)$ — system delay function matrix;
C — the static water recovery coefficient matrix of floating body;
$F(t)$ —generalized force matrix for floating bodies.

Numerical analysis

The principal dimensions:

length: 133. 1 m	width: 39. 2 m
depth: 9. 8 m	Draft: 5. 6 m
operating depth: 40 m	design speed: 12 kn

The numerical simulation of wind turbine installation vessel has chosen cycle 20s, wave Angle from 0° ,45° ,90° ,135° to180° as well.

VOF-approach is suitable, when the grid is fine enough to resolve the interface between two immiscible fluids. VOF considers a single effective fluid whose properties vary according to volume fraction of individual fluids.

The Integral calculation is based on a nested grid (Overset Cell), which is surrounded by a grid of the hull, and the rest is a background grid shown in Figure 1, Figure9, Figure 10, Figure 13 and Figure 14.

In this paper, the VOF algorithm is adopted to show the volume fraction of the air and water in the middle section of the ship, showing the position of free liquid surface in Figure 2, Figure 11, Figure 12, Figure 15 and Figure 16.

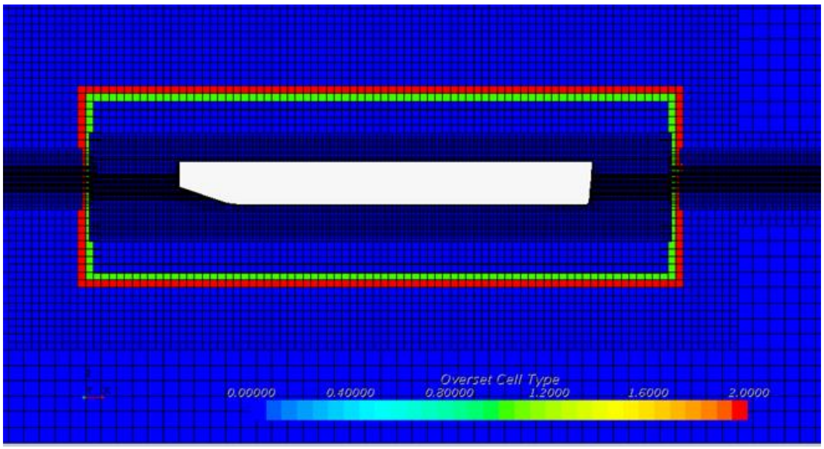

Figure 1. Overset Cell schematic with 90°

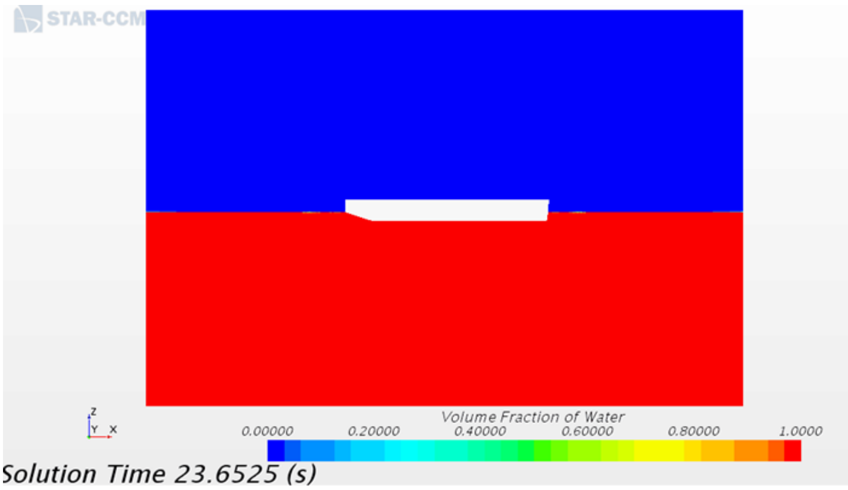

Figure 2. VOF algorithm schematic with 90°

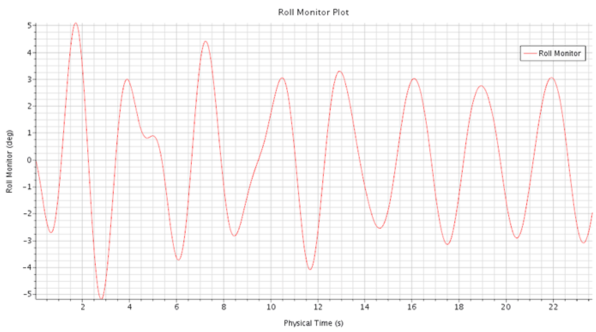

Figure 3. roll monitor plot with 90°

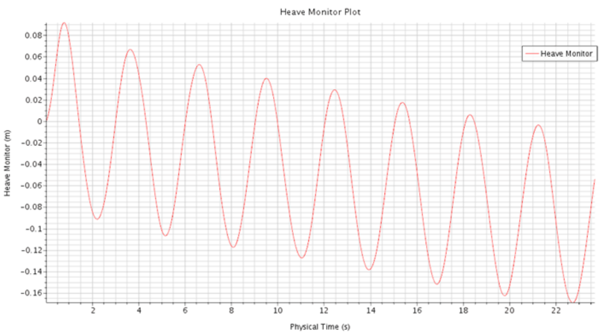

Figure 4. heave monitor plot with 90°

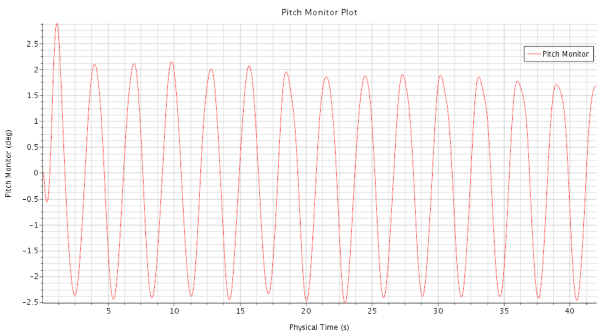

Figure 5. pitch monitor plot with 0°

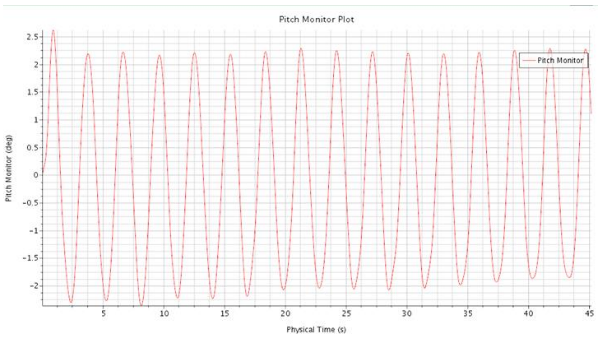

Figure 6. pitch monitor plot with 180°

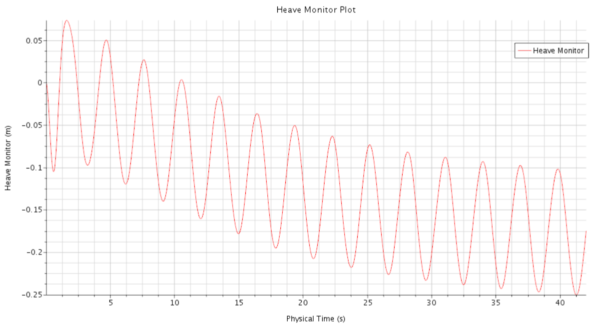

Figure 7. heave monitor plot with 0°

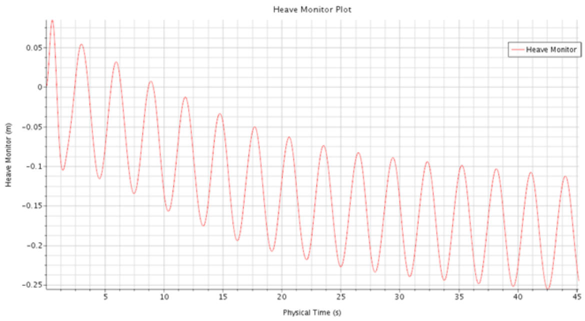

Figure 8. heave monitor plot with 180°

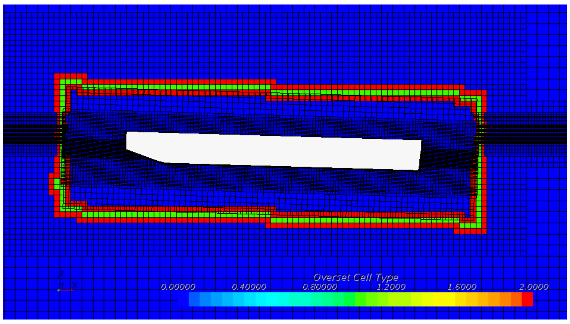

Figure 9. Overset Cell schematic with 0°

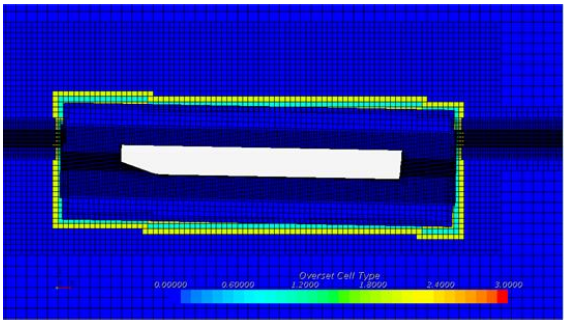

Figure 10. Overset Cell schematic with 180°

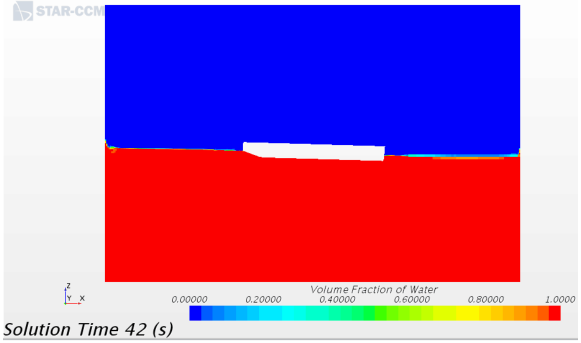

Figure 11. VOF schematic with 0°

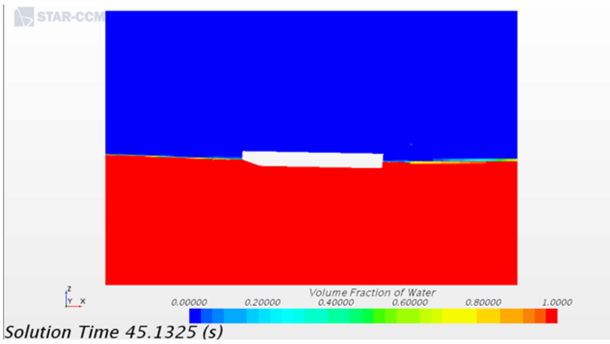

Figure 12. VOF schematic with 180°

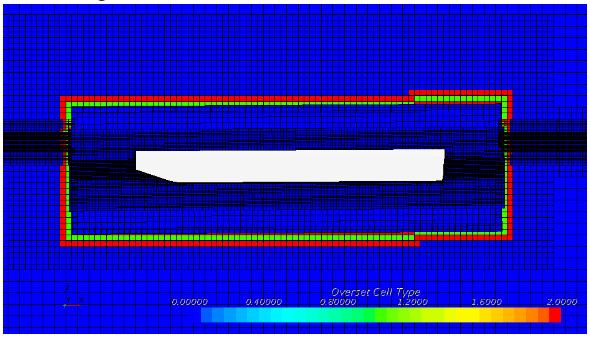

Figure 13. Overset Cell with 45°

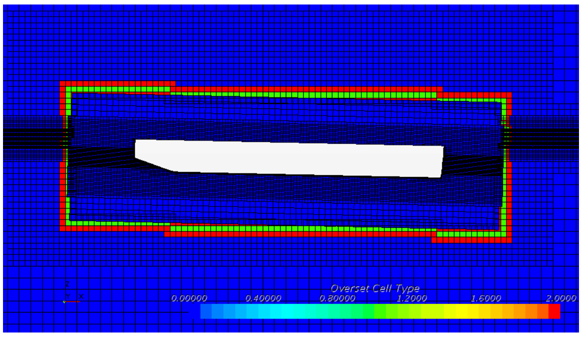

Figure 14. Overset Cell with 135°

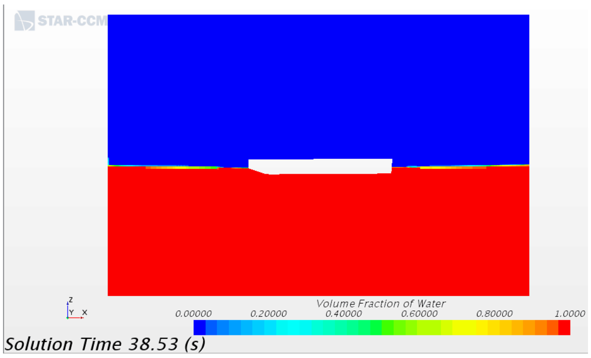

Figure 15. VOF schematic with 45°

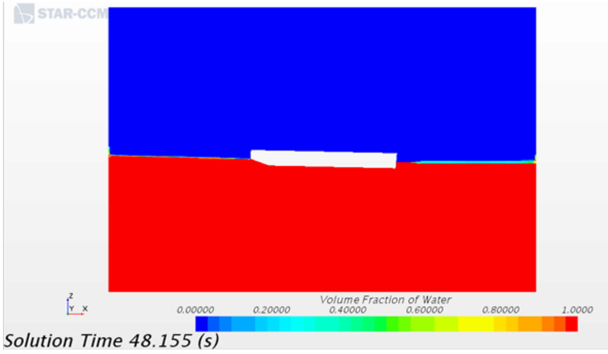

Figure 16. VOF schematic with 135°

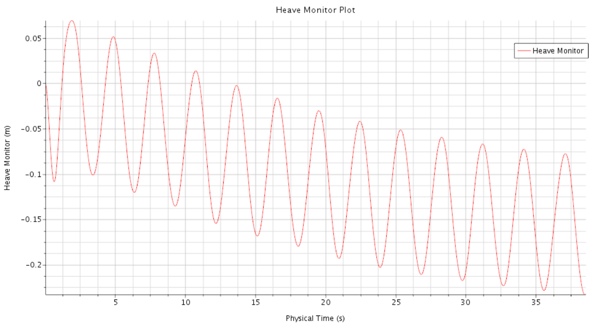

Figure 17. heave monitor plot with 0°

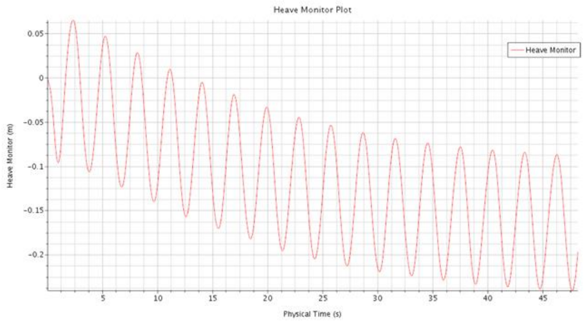

Figure 18. heave monitor plot with 180°

Conclusions

The topic are shown the change of the ship's pitch and the calculation time with 0° and 180° , showing that the period of the ship's pitch is consistent with the period of the incident wave, and presents the periodic change, just as Figure 5 and Figure 6 are shown.
The figures show the heave of the hull with the time of calculation, which shows that the period of the ship's heaving and sinking are consistent with the period of the incident wave, and presents periodic changes. Just as Figure4, Figure7 and Figure 8, Figure17 and Figure 18 are shown.
Traditional theory of potential flow is usually combined with the far field boundary conditions using the boundary element method is used to solve the wave potential function and stream function, the algorithm can more quickly and efficiently solving the wave diffraction and radiation problems of structure, but to the breaking of waves and the splash phenomenon such as the lack of effective means to solve. Through CFD discrete finite Volume method is used to solve the Navier-Stokes equations, for a large scale such as waves of two intersecting interface using Eulerian multiphase flow VOF (Volume of Fluid) method for processing. It is able to directly capture wave propagation phenomena, such as crushing and splash in the process of model can be directly obtained also ship hydrodynamics problems, and full dimensions can be more accurate to calculate and forecast problems such as the motion response of wind turbine installation vessel.

References

[1] Ding jinhong, tan jiahua. (2009) Overview of special installation ships for offshore wind power, *China Offshore platform* **5**, 6–11.

[2] He yanping, Yang qi, du pengfei, etc. (2009)Transportation, installation and maintenance of offshore wind turbine units, *SHIP＆OCEAN ENGINEERING* **4**, 136-139.
[3] Yao zhenqiu, ma yimeng, han qiang, et al. (2014)Finite element analysis of the structural strength of the whole ship of Marine fan hoisting operation, *Ship mechanics* **16**:136 -146.
[4] Tu yan, xu rong, Yang jun, et al. (2014) Analysis of motion response frequency domain under the self-promotion of superlarge fan installation platform , *SHIP＆OCEAN ENGINEERING* **3**,148-152.
[5] ZHANG Li-jun，ZHAO Zhi-jian, WANG Wen-hua , WANG Yan-ying. (2015) Analysis on Motion Response of Wind Turbine Installation Vessel in Navigation, *SHIP＆OCEAN ENGINEERING* **8**, 28-31.
[6] YATES M L, BENOIT M. (2015) Accuracy and efficiency of two numerical methods of solving the potential flow problem for highly nonlinear and dispersive water waves, *International Journal for Numerical Methods in Fluids* **10**,610-640.