E-proceedings of the 38th IAHR World Congress
September 1-6, 2019, Panama City, Panama
doi:10.3850/38WC092019-1506

EVALUATION OF HYDRODYNAMIC LOADS ON OFFSHORE TRUSS STRUCTURE USING LARGE EDDY SIMULATION METHOD

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ABSTRACT

A Large-eddy Simulation (LES) has been conducted of the flow around typical oil-production jacket platform in a sea of relatively shallow water depth. The LES solves for a three-dimensional flow with moving free surface using appropriate sub-grid turbulence and wall models. The structure consists of various slender tubular members in truss configuration. It is assumed rigid and the pressure distribution obtained by the LES is integrated over individual members and over the entire structure to evaluate the loads. The flow approaching the jacket platform is assumed known but is possible to be obtained from the larger-scale simulation reflecting the details of the bathymetry of the surrounding sea bed and the metocean conditions. Although the results need to be examined in detail and cases with different current speed, direction and wave heights but the present results are reasonable and promising first step for further calculation..

Keywords: *Offshore* jacket platform, LES, hydrodynamic loads

1 INTRODUCTION

The hydrodynamic loads on realistic offshore structures have been traditionally computed by semi-empirical formula such as Morrison formula (Chakrabarti, 1987). Recent development of numerical simulation methods of free surface flows is making realistic simulation of the flow and the loads on solid or elastic structures possible. The Large-Eddy Simulation (LES) methods combined with accurate representation of the free surface movement are promising technique to apply to obtain hydrodynamic loads on offshore structures or realistic scales. Difficulties in applying these numerical methods are due to limited computer capacity to represent turbulent flows with wide range of scales of fluctuations past structures of complex geometry. A uniform flow past a truss structure of relatively simple configuration has been computed by a large eddy simulation method (Nakayama et al., 2010). The computation indicated that in order to represent the overall flow field disturbed by the structure, the computational region must be at least a few times larger than the overall dimension of the structure, while to represent the turbulent motion with significant energy that contributes to the pressure and the shear forces on the structure, the smallest members need to be resolved by at least several meshes. These opposite requirement indicate that the number of grids needed in the calculation becomes large. However, many easily accessible computers nowadays allow tens of millions of grid points and simulation past complex truss structures consisted of many slender members is becoming a realistic alternative.

In the present work, a large eddy simulation method that is applicable to turbulent flows with free surface (Nakayama, 2012) is used to simulate the flow past a jacket platform that is deployed in shallow sea. The flow approaching the platform is obtained by letting the bottom boundary layer to develop to the full depth of the sea and used as the initial condition. The details of the flow and the loads on the whole structure and representative members are obtained from the simulation.

2 LARGE EDDY SIMULATION OF FLOW PAST A TRUSS STRUCTURE

In the simulation of natural streams and those in coastal areas, we observe that the flow regions are very irregular in shape and change in time. Second, the scales of the flow, both spatial and time-wise are very large and the spacing of grid points and the time step that can be accommodated by a readily available computer system are nowhere enough to resolve dissipation scales. Yet with a reasonable number of grid points like a few million points, which can divide the total flow region into cubes of orders-of-magnitude smaller in length, most of the large-scale flow and a good fraction of the turbulent fluctuations can be resolved from which not only the mean flow but turbulent stresses can be evaluated.

A LES method developed by one of the present authors can be used for this purpose. It is a finite difference code constructed on a rectangular grid system. The turbulence model for the sub-grid scales used the Smagorinsky model with a wall model based on smooth or rough surface wall similarity. The free surface is represented by the depth function which is solved by a method similar to the VOF method. Detailed description of the method is given in Nakayama (2012). The main feature is that the wall turbulence that cannot be resolved by the grid is modeled by the standard wall model for smooth and rough boundaries. It allows reasonable simulation of flows of very large Reynolds numbers.

3 SIMULATION OF FLOW PAST JACKET PLATFORM

We consider a model jacket platform that is very close to the real one deployed in shallow sea area off Malaysian coast. Figure 1 shows a sketch of the platform and the flow past it. The jacket consists of four cylindrical legs of diameter 1.5m and about 38m below the sea surface braced with horizontal and diagonal members. Since the structure above the water does not contribute to the hydrodynamic characteristics it is abbreviated.

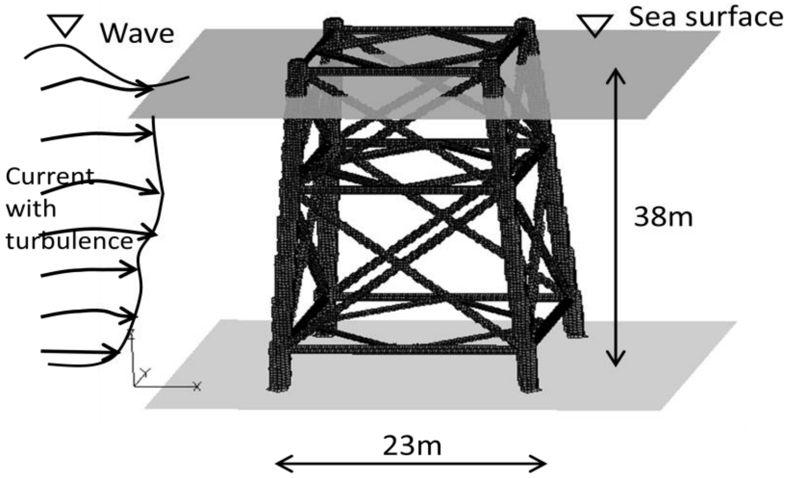

Figure 1. Model Jacket platform in shallow sea.

For the present simulation of the flow, the ocean current is assumed to be a fully developed flow in the direction perpendicular to the plane of the truss structure as shown in this figure. The average velocity of the current is taken to be 0.7m/s which is a typical current used for design purposes of offshore structures in this region. The flow is computed in a rectangular domain including the structure from 50m upstream to 40m downstream of the structure and y=-25m to 25m, where x is the coordinate in the direction of the current with the origin at the center of the jacket and y is the horizontal coordinate perpendicular to the direction of the current. The grid of 155 x 125 x 138 is used and is shown in Figure 2. The grid spacing is taken so that the cross section of the thinnest member is resolved at least by 2 x 2 grids.

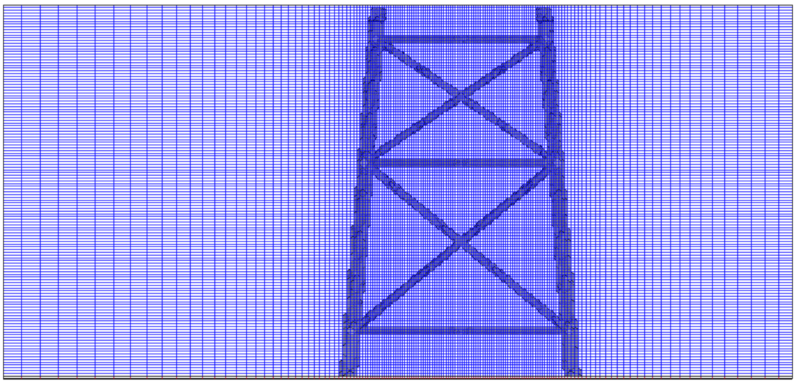

Figure 2. Computational grid. The spacing in the vertical direction is constant 0.3m, the smallest horizontal spacing is 0.25m and the largest spacing is 2m.

4 SIMULATION RESULTS AND DISCUSSION

An overall view of the simulated flow at an instant is shown in Figure 3. It shows the free surface elevation, the flow velocity vectors on it and in a vertical cross section along the current at the center of the jacket structure. The color of the solid surfaces indicates the pressure and the color of the velocity vector in the cross section indicates the velocity magnitude.

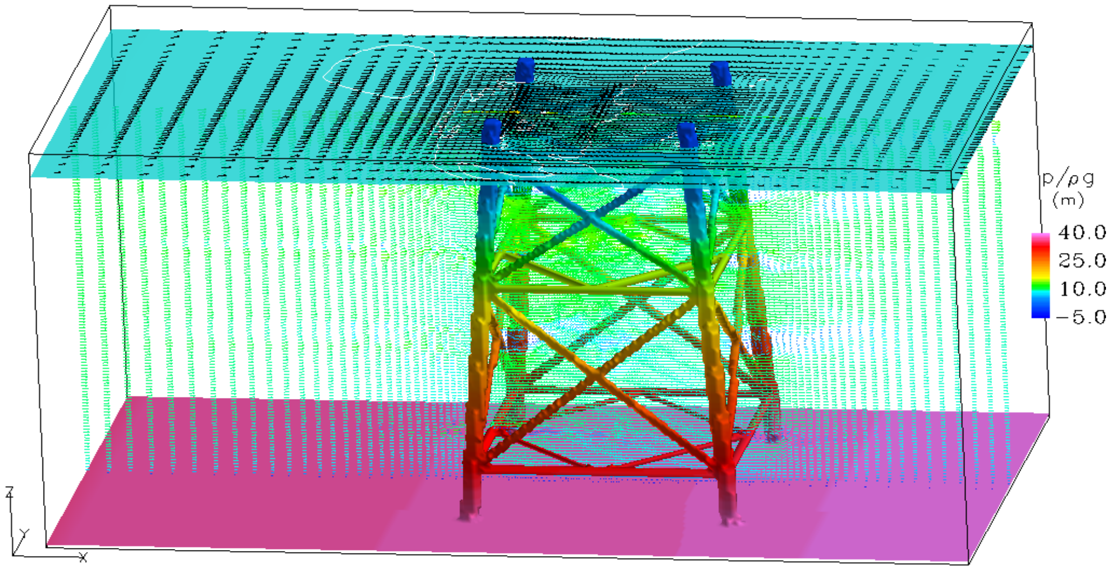

Figure 3. Example of simulated flow when a uniform current approaches. The color on the structure surface indicates the pressure and the color of the arrows indicate the velocity magnitude.

The time variation of the hydrodynamic force in the direction of the current on the entire structure is shown in Figure 4. The fluctuation is large and about 1/3 to 1/2 of its magnitude. Different time scales of the time variations are seen. First a small time scale of less than 100th of a second is a small scale turbulent fluctuations. The fluctuation period of about 0.05 sec appears seen from t=3.5sec. It is the fluctuation caused by the small cylindrical members which has a diameter of 0.5m. The slower undulation of period al large as 1 sec is also seen. This can be from the large scale turbulence of the boundary layer with the depth of 38m.

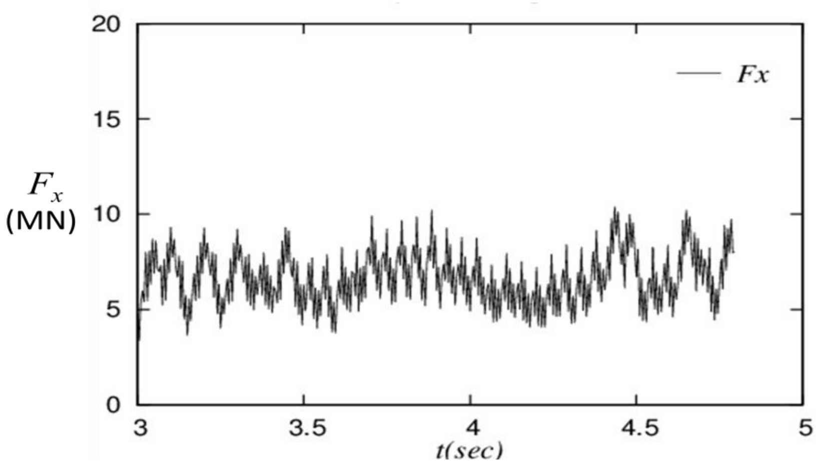

Figure 4. Hydrodynamic force in the horizontal direction of the current.

Figure 5 further shows the instantaneous velocity profiles along selected vertical lines. These are basically the velocity profiles in a turbulent boundary layer and those at places downstream of the structure are the wake flow disturbed by the structure. It is seen that even at x=0 and 10m which are within the structure and immediately downstream, respectively the disturbances are at most of the same magnitude as the turbulent fluctuation.

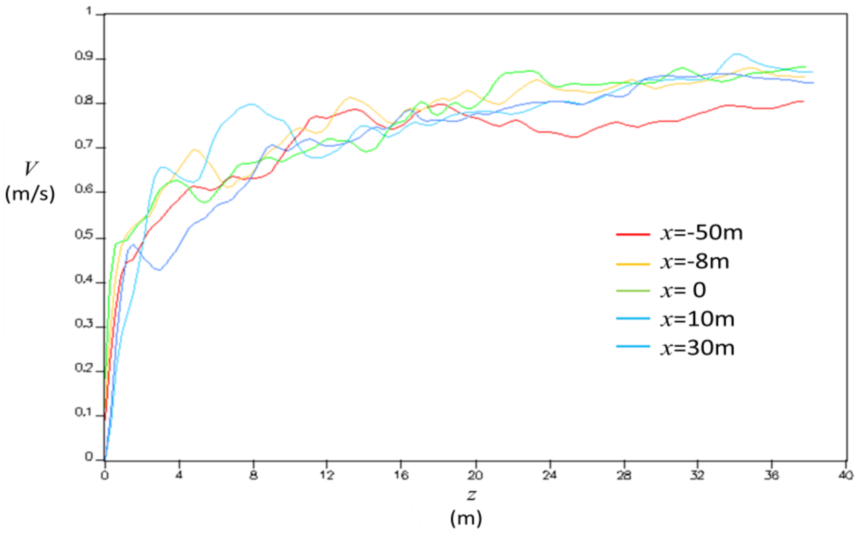

Figure 4. Velocity distribution at the center plane y=0 at three w the figure and within figure/illustration width.

5 CONCLUSIONS

The flow past a model of complex offshore jacket structure has been simulated using LES technique. The results are preliminary but appear to represent the complex flow with reasonable accuracy. The main feature is that the fluctuation of the hydrodynamic forces is large and the fluctuations are consisted of a few different time scales. They are considered to be due to different scales of the structure. The small scales are the thickness of the small members and the large scale is the overall size of the structure and the depth of the sea. The quantitative evaluation still needs to be done and comparison with existing methods of analysis should be made.

ACKNOWLEDGEMENT

This work was conducted with a support of Fundamental Research Grant Scheme (FRGS) of Malaysian Ministry of Higher Education.

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