Simulation of the Dynamics of Spar-type Floating Offshore Wind Turbine in the ANSYS Aqwa Environment Extended by the Coefficients of Viscosity Forces Determined on the Basis of RANSE-CFD Analysis

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1 Introduction

In recent years, there has been a significant increase in interest in platforms for offshore wind turbines. The transfer of wind energy to sea areas is justified for various reasons. Higher and more stable than on land, wind speeds that are not supported by buildings or green areas allow the installation of more powerful turbines. The size of turbine wings, which in marine conditions may be larger than land-based, also allows for high performance of installed turbines. Lack of public favor for turbines installed near inhabited areas is another factor decisive for displacing them from the mainland.

Offshore wind energy is a new and rapidly developing issue. Innovative solutions are tested, especially in the area of solutions where the turbine platform is a floating object. The authors, as part of their previous work, analyzed three basic types of platforms: Jack-up, Tension Leg Platfrom and Spar. The last concept, the Spar type platform, designed for deep water reservoirs (60-70 m), was decided to be modified and developed. The presented materials contain the results together with a detailed description of the dynamics simulations of the discussed platform. The discussed simulations were carried out in the ANSYS Aqwa environment, using hybrid methods combining fast calculation methods with boundary elements, extended by interaction of fluid viscosity with a resistance coefficient determined on the basis of simulations performed with RANSE CFD methods. The work discusses the Ansys Aqwa environment, and then presents the platform's geometry, its mass properties, boundary conditions as well as the method of obtaining resistance coefficients.

2 Ansys Aqwa

ANSYS Aqwa provides an engineering toolset for the investigation of the effects of wave, wind and current on floating and fixed offshore and marine structures, including: spars; floating production, storage, and offloading (FPSO) systems; semi-submersibles; tension leg platforms (TLPs); ships; renewable energy systems and breakwater design.

The calculations in ANSYS Aqwa are divided into two main parts, in the first (Aqwa Hydrodynamic Diffraction) calculations of hydrostatics and frequency characteristics are performed, which are the basis for the temporal responses of the object under wave conditions (regular or irregular) calculated in the second part (Aqwa Hydrodynamic Response) with additional wind and / or current operation.

In the Aqwa program, he applied a three-dimensional theory of radiation / diffraction and / or the Morison equation in regular waves in the frequency domain.

Elements with non-cylindrical shapes, as well as cylinders with dimensions beyond the possible application of the Morison equation, are modeled in Aqwa using surface panels for which a three-dimensional radiation theory is applied. This theory, however, does not take into account the forces associated with the viscosity of the fluid, therefore, determine the resistance factors of the object for the main directions of motion and give them in matrix form. Similarly, in the case of loading the part of the aquatic platform with the action of wind. Aqwa models the wind velocity distribution according to the spectrum chosen by the user (here Ochi), but calculates the forces based on the integrated pressure over the surface, only determines the force based on the instant wind speed, direction, current position of the platform and the corresponding factor previously given by the user to the program in tabular form.

For modeling anchors aqwa distinguishes 4 basic types: Linear Elastic, Nonlinear Polynomial, Nonlinear Steel Wire and Nonlinear Catenary, allowing to reflect the nature of the anchorage depending on the complexity of the tested model. In the analyzed case, the Nonlinear Polinomial was the best model.

In the case of constructions for which calculations made using the Morisson equation are correct, the rope being the axis of the structure is introduced into the program and defines its cross-section. In other cases, the geometry should be introduced in the form of the surface model, therefore the mass, position of the center of gravity and moments of inertia are not calculated by the program, but are asked by the user.

3 Geometry and mass properties of the platform

The Spar platform type discussed in this presentation was called the three-column spar, unlike the cell spar type analyzed earlier by the authors. The name three-column, of course, refers to the three displacement columns connecting the ballast part of the structure (closed in the lower case) with the free side supporting the column on which the wind turbine is installed. The visualization of the structure is shown in Figure 1

Mass properties are presented in tab. 1

Table 1 Mass propeties

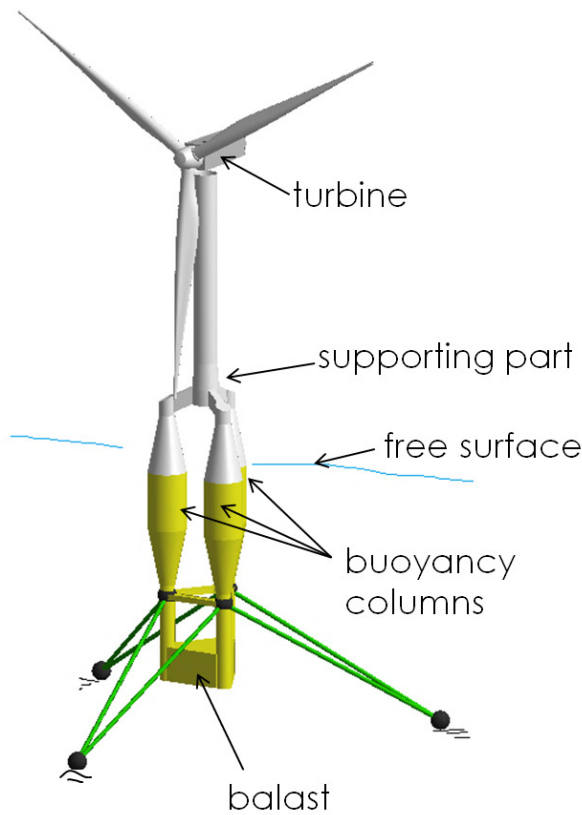| Mass	M [t]	Center of gravity	X_G[m]	Y_G[m]	Z_G[m]	Moment of inertia	I_{xx} [kg m^2]	I_{YY} [kg m^2]	I_{ZZ} [kg m^2]
	8 178		0	0	-30.62		1.18E+10	1.18E+10	3.85E+08

Fig. 1 Geometry

4 Hydro and aerodynamic coefficients

As mentioned in the introduction, the calculation methods used in the Ansys Aqwa software require an expansion with an appropriate ratio. For basic shapes, they can be derived from the literature Sarpkaya (2010), and for complex shapes, model or numerical calculations are performed using the RANSE-CFD codes. The second approach is described here.

The coefficients of resistance allowing to determine the share of forces related to the viscosity of the fluid generated on the object subjected to the action of sea waves were determined based on the Morisson Eq. (1)

$$F(t) = \frac{\pi}{4}\rho C_M D^2 \cdot \dot{u}(t) + \frac{1}{2}\rho C_D D \cdot u(t)|u(t)| \tag{1}$$

Where: ρ [kg m^-3] – density of water, D[m] – diameter of cylinder, u[m s^-1] – velocity of water, C_M-coefficient of inertia forces, C_D- coefficient of drag forces

From this equation it follows that if an object is settled in an oscillatory flow, there will be changes in such moments when the whole is heard will form a component of forces related to inertia (u (t) = 0) and resistance forces (du / dt = 0) On the basis of the obtained values of forces (exemplary shown in Fig. 2), the average coefficient of resistance was determined. The method of determining the Morrison equation coefficients is described in detail in the paper Dymarski et al. (2016)
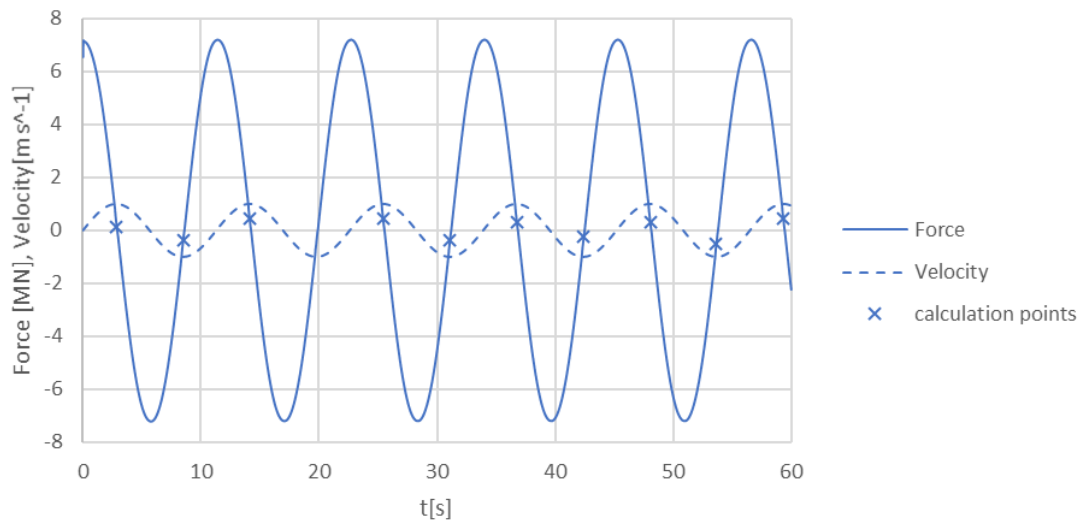

Fig. 2 The force acting on the structure placed in the oscillatory flow at the set speed

The forces caused by the action of wind on the platform's overhead part and on the turbine wings were also modeled using the appropriate coefficient. Similarly to coefficients of hydrodynamic forces, also in this case both model and numerical calculations can be used. These are traditional resistance tests, that is, the object is subjected to the action of a uniform speed velocity and the resulting force is determined. The coefficients obtained allow us to model a windmill under storm conditions, with the turbine turned off (zero moment on the wings)

4 Load

The irregular wave was adopted in the form of Jonswap spectrum, with the parameters given in tab. 2 and the distribution shown in Fig. 3
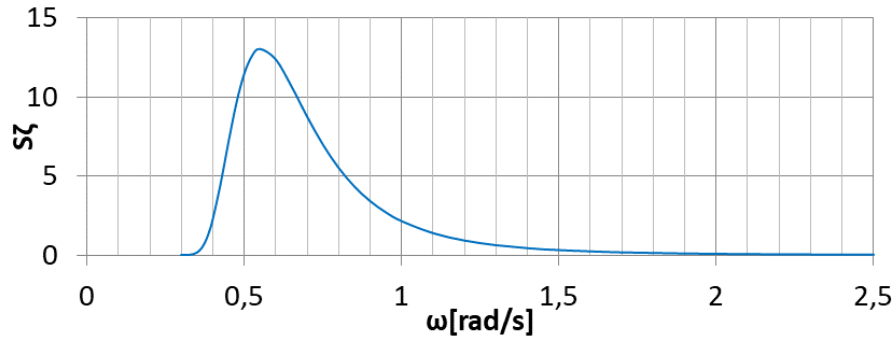
Significant height H_s[m]	9.01
Peak period T_p[s]	11.3
Factor γ[-]	4.12

The impact of wind was modeled with the help of Ochi and Shin Spectrum with a velocity of v = 29.1 m / s at a height of 10 m.

4 Results and Conclusions

As a result of the calculations platform movements were obtained at all six degrees of freedom during the hour simulation. Fig. 4 (translation) and Fig. 5 (rotation)
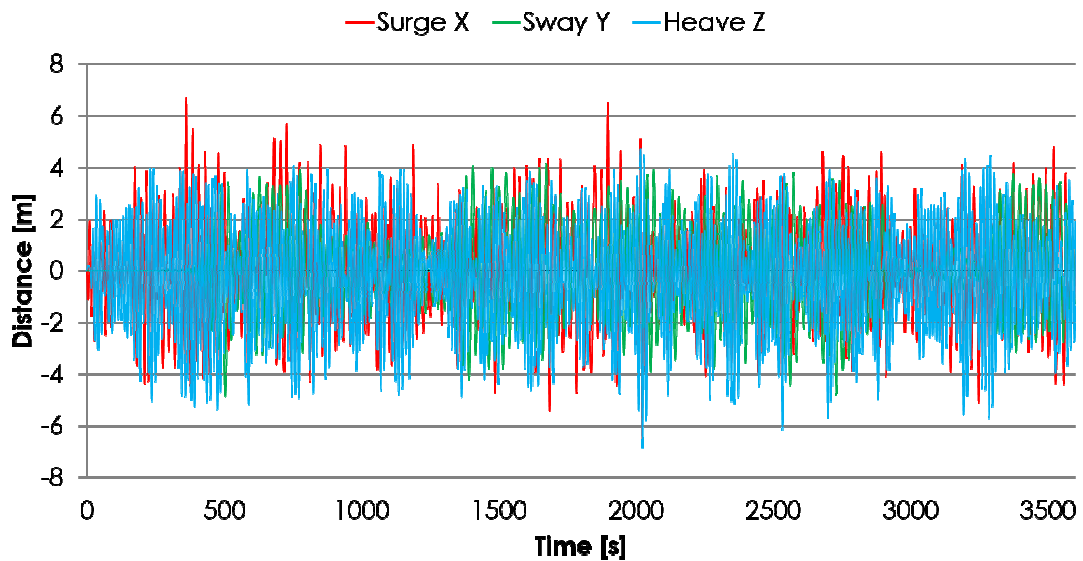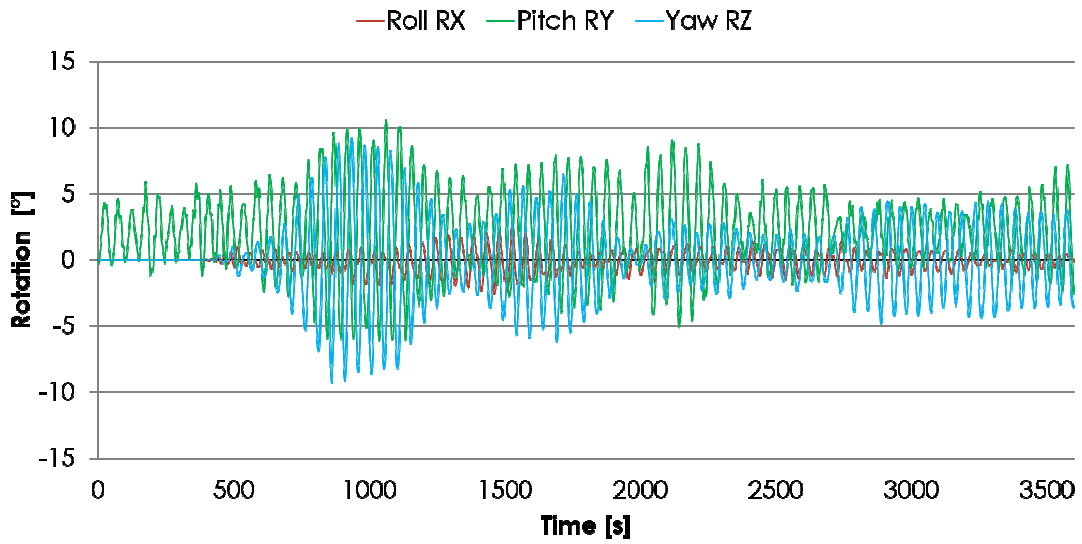
Fig. 5 Rotation of platform

On the basis of which the mean and maximum values were drawn, which are shown in Figs. 6
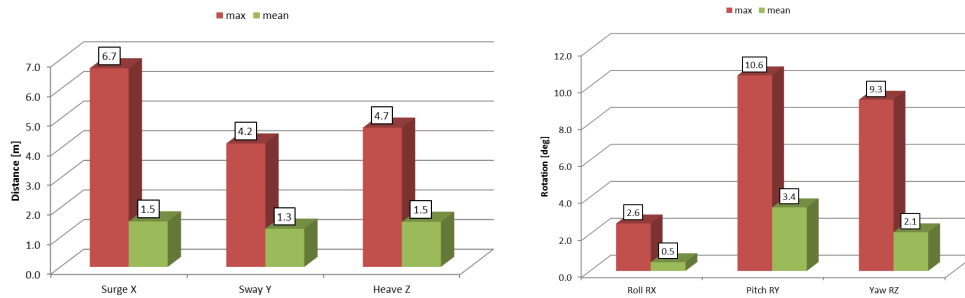

Fig. 6 Max and mean translation, rotation

The forces appearing in the ties were also checked to locate the highest value. Fig. 7.
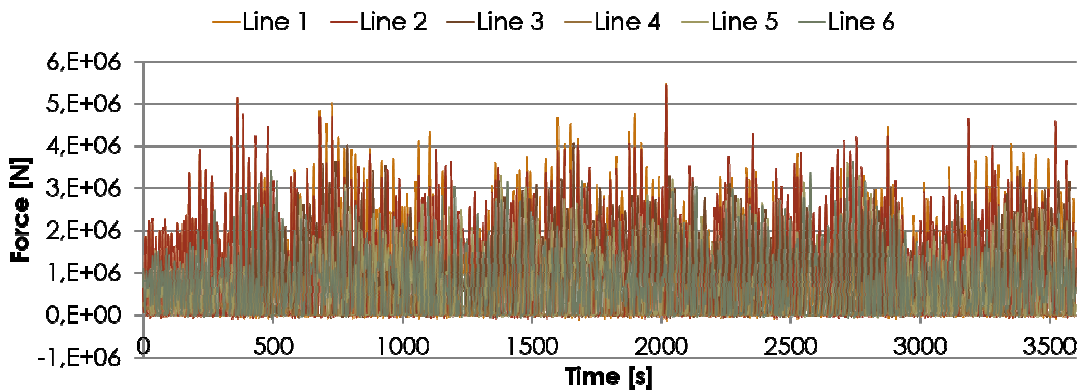

Fig. 7 Force on line

On the basis of the results presented, the following conclusions can be drawn. The results of calculations for the designed structure are optimistic. Displacement, though significant, does not

exceed the assumed values. The stresses in the ropes are twice smaller than the ones assumed, and thus the classification requirements will be met. ANSYS aqwa software allows you to quickly convert the behavior of the platform in different environmental conditions, but the process of data preparation is quite laborious.

 As part of further work, model tests are planned to validate calculations

References

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Turgut Sarpkaya (2010) Wave Forces on Offshore Structures,. Cambridge University Press, Cambridge