Numerical Analysis of Dynamics of Ship-OWT (Offshore Wind Turbine) Collision

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ABSTRACT

Offshore Structures supply vessels during operation are at risk of collision. The ship has random load, including offshore structures resistance is raised. In this paper, under the impact of a wind turbine offshore supply vessel with 5 different mass displacements are analyzed. Structural study examined the environmental conditions intermediate depth ocean water using ABAQUS finite element model of the software. The effects of static preload weight of turbine blades and environmental loads (wind, wave, sea current and the water pressure on the turbines) before hitting the ship dynamics, in terms of the structural behavior. Parameters such as power and momentum of support, around the turbine horizontal displacement, stress and strain Von-Mises different parts of turbines in different loading conditions (change in mass displacement of picky float) compared together and the results are discussed.

1. Introduction

The offshore environment can provide a variety of renewable energies by which communities can provide the energy required because of the marine environment, a lot of energy in the form of heat, wave, wind, tidal produces. The existing offshore structures in the present day mobile and fixed offshore wind turbines for optimal use of wind power, both inside and outside the country are very important.

These structures by the mechanical energy of the wind generator, the power required to transform communities. Therefore, careful analysis of collision is important. According to figures released by the Health and Safety [1] management on offshore installations in the UKCS 1975 to 2001, numbers of 551 incidents of collisions of ships with a variety of offshore installations have been registered [2].

Dealing with the causes of the accident are 5 main groups [3]:

- Estimates and false diagnosis captain (the main cause of collisions)
- The loss of equipment (e.g. power loss vessel dynamic positioning)
- Weather and environmental conditions
- Anchor problems running or cable anchoring (jams or stretching anchors and anchors)
- Others

This paper attempts to simulate offshore wind turbine with a constant supply vessel collision incident Monopole deals. In previous studies using the finite element method has been done, a lot of simplifying assumptions, especially with respect to geometric modeling turbine can be seen. Also, in previous studies to facilitate the issue is complex, dynamic and a quasi-static that could shed light on the exact mechanism of collision. But here is completely dynamic approach is investigated.

Literature Review

In this regard, Such work began in the early years and then with the development of computer software for numerical analysis and finite element methods in the analysis and comparison with experimental data was available simple laboratory model to help studying more complex finite element models.

Menkes [4] In experimental studies completely fixed on a beam that was equally affected by the impact load, showed that the severity of injury, damage distinguishable from each other three modes of structure completely that can be observed. The various modes of failure of the sheet are also examined.

They continued in the study by Smith and Nurick [5] the failure modes of the circular sheet and Olsen studies [6] square sheets of failure modes were found.

From 1990 onwards, the scientists investigated the effect of different boundary conditions, the reinforcement steel and different loading conditions were inclined to force to determine the deformation, to investigate the process of turbine as well as tear sheets.

Nurick and devices [7] experimental results on a square sheet steel fixed fines provided under impact loading. They showed phenomenon started tearing through the sides and across the border continues to the corners.

In 1998 Luca and Penn [8], analysis of dynamic elastic and non-reinforced sheet steel panels using simplified and advanced analytical techniques had taken.

Nurick [9] used to implement the rigorous test condition and the test is also consistent with the theory.

Geometric modeling of wind turbine

Dimensions and geometric parameters of the wind turbine fixed Mono-pile studied in this paper is specified in the table below.

Table1. Geometric characteristics of turbine

60	Turbine Blade weight (ton)
80	Diameter of turbine blades (m)
80	Height of horizontal axis of blades from the (m) water level
5	Base diameter of turbine (m)
0.05	Base thickness of turbine (m)
10	Diameter of energy absorber sphere (m)
0.1	Thickness of energy absorber sphere (m)
0.65	Drag coefficient of mono-pile cylinder
1.6	Inertia coefficient of mono-pile cylinder

One of the most important components of a wind turbine energy-absorbing steel spherical shell (with slippery surface mounted on the base) is just floating in the clash. The use of this butter, the creation of a centralized force on the floating turbine, protection of electronic equipment installed on the turbine, reducing the energy absorbed by the turbine during the process of collision and preventing collisions huge floating to the surface Turbine is.

The spherical shell is used to increase capacity to deal with its float, a ring with a thickness of 10 cm, the use and installation of the spherical shell and the base of the turbine. Below method of modeling the sphere and energy-absorbing ring, can be seen in software:

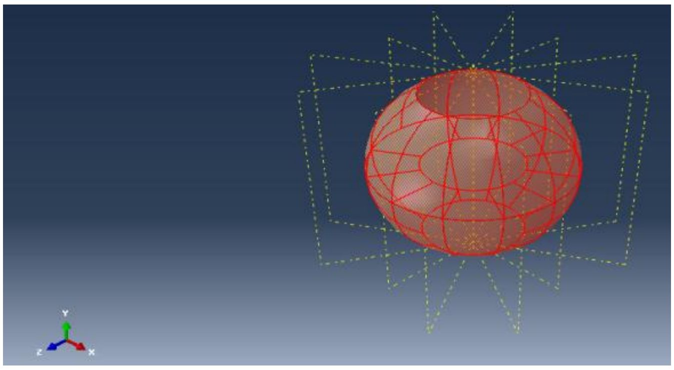

Figure1.modeling the sphere and energy absorber ring

Describing the collision

The main purpose of article is investigation on the dynamic fracture of offshore wind turbine structures due to the collision of floating to it. How to deal with a floating wind turbine is a complex nonlinear problem involving nonlinear dynamics and geometry of the problem is being encountered. Nonlinear finite element method is a useful method to solve this problem.

It is better to compare both the spherical shell and not have to use it. Studies show that the force of the collision on floating wind turbines to the main base of the turbine in the case of sphere, is about half. The energy absorbed by the turbine in the case of sphere, will be reduced significantly. Therefore, the spherical shell mentioned in the analysis of this deal will play an important role.

In general, the analysis of vessel collisions with turbines, based on the principle of conservation of momentum and energy based.

Local deformation in the collision is an example of this method.

The principle of conservation of momentum to the collision incident is written as follows [10]:

$$(m_s + a_s)v_s + (m_p + a_p)v_p = (m_s + a_s + m_p + a_p)v_c \quad (1)$$

In above relation m_s and m_p were floating mass and the mass of the turbine, a_s and a_p were added mass and added mass floating turbine, v_s and v_p and v_c respectively represent floating rate before hitting the structures, turbine speed before the collision float Subscribe to the vessel and the turbine speed collisions are traumatic.

The principle of conservation of energy for the collision incident is written as follows [10]:

$$\frac{1}{2}(m_s + a_s)v_s^{\,2} + \frac{1}{2}(m_p + a_p)v_p^{\,2} = \frac{1}{2}(m_s + a_s + m_p + a_p)v_c^{\,2} + E_s \quad (2)$$

In the above relation, E_s is depreciated strain energy of the system after the collision, which is defined as follows:

$$E_s = \frac{1}{2}(m_s + a_s){v_s}^2 \left[\frac{(1-\frac{v_p}{v_s})^2}{(1+\frac{m_s + a_s}{m_p + a_p})} \right] \quad (3)$$

Assuming the rest of the incident energy source for the body hit collision, kinetic energy is floating support. The total energy of the collision is due to the full integration method for solving the shell element is calculated using the following equation:

$$E_{total} = E_{kinetic} + E_{internal} + E_{slide} \quad (4)$$

Where $E_{kinetic}$ is kinetic energy of picky substance, $E_{internal}$ is internal energy of the body hit and E_{slide} by the sliding energy, obtained from contact between the two structures.

Environmental conditions in the study area

Information listed in the table below in relation to environmental conditions is derived from PETRONAS Company in Malaysia:

Table2. the environmental situation of case study area

28	Area wind speed at the height of 10 meters of static water level (m/s)
8	characteristic wave height (m)
9.4	characteristic wave period (s)
1.5	Sea flow speed at water level (m/s)
1.2	Sea flow speed at the height of 15 meters from sea bed (m/s)
0.3	Sea flow speed at the height of 3 meters from sea bed (m/s)
1025	water density ρ_{water} $(\frac{kg}{m^3})$
1225	weather density ρ_{wind} $(\frac{kg}{m^3})$
30	Water depth (m) d (m)

Investigation of the environmental forces on the turbine structures

Wind force on the structure of the surface water in the form of static and rotating horizontal axis turbines apply. Distribution of wind speed in the region is as follows [11]:

$$\frac{u_h}{u_H} = (\frac{h}{H})^{\frac{1}{n}} \quad (5)$$

Where u_h wind speed at height h from the surface of the water, u_H wind speed at an altitude of 10 meters above sea level, 1 / n is called the front, usually depending on the sea state, distance to the water and the wind continued between 1 / 13 and 1/7 respectively.

Power, for storm is equal to 1 / 13 for the issue in this project is considered equal to 1/8, H 10 cm, h is the height of the water level.

According to API regulations on turbines wind power per unit length is calculated as follows:

$$F_{wind} = \frac{1}{2}\rho_{wind}{u_h}^2 C_s A \quad (6)$$

Where ρ density of air around the structure, Cs cylindrical shape factor equal to 5.0 (depending on the shape of the body and air viscosity) and A is the projected area of the cylindrical structure per unit length is equal to 5 square meters.

The second force is the force of waves on structures.

The project for calculating the parameters of the wave, the wave theory of linear Airy will use Linear wave equation can be solved directly by the equations obtained. In this case, the speed potential of the equation can be written as follows [12]:

$$\phi = \frac{H_s g T_s \cosh(ks)}{4\pi \cosh(kd)} \sin\theta \quad (7)$$

Parameter represents the wave number k or the phase difference θ is:

$$\theta = kx - \frac{2\pi}{T_s} t \quad (8)$$

The dispersion relation to the value of k, we have:

$$\omega^2 = gk \tanh(kd) \quad (9)$$

To obtain a defined wavelength, we write the following relationship:

$$L_{wave} = \frac{2\pi}{k} \quad (10)$$

In general, continuity equation can be written as follows:

$$\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} + \frac{\partial^2\phi}{\partial z^2} = 0 \quad (11)$$

Therefore:

$$\frac{\partial^2\phi}{\partial t^2} + g\frac{\partial\phi}{\partial z} = 0 \quad (12)$$

In this theory, for profile of free surface of waves we have:

$$\eta = \frac{H}{2}\cos\theta \quad (13)$$

$$U = \frac{\pi H_s \cosh(ks)}{T_s \sinh(kd)} \cos\theta \quad (14)$$

U is the maximum angle θ equal to 45 °. Therefore:

$$U_{\max} = \frac{\pi H_s \cosh(ks)}{T_s \sinh(kd)} \times \frac{\sqrt{2}}{2} \tag{15}$$

Acceleration of fluid particles on the surface of the substrate s at the height of the turbines will be equal to:

$$\dot{U} = \frac{2\pi^2 H_s \cosh(ks)}{T_s^2 \sinh(kd)} \sin\theta \tag{16}$$

U is the maximum angle θ equal to 45 °. Therefore:

$$\dot{U}_{\max} = \frac{2\pi^2 H_s \cosh(ks)}{T_s^2 \sinh(kd)} \times \frac{\sqrt{2}}{2} \tag{17}$$

Based on Morison Equation, maximum wave force per unit length on the turbine structure consists of two drag Forces F_D, depending on the kinetic energy of water and the force of inertia F_I is associated with accelerated particles, respectively. The forces calculated by the following formula [13]:

$$F_I = \rho_{water} C_M \pi \frac{D^2}{4} \dot{U} \tag{18}$$

$$F_D = \rho_{water} C_D \frac{D}{2} U^2 \tag{19}$$

To obtain the wave forces on the structure of its length must be gathered drag with the force of inertia on the turbine [14]:

$$F_{wave} = F_I + F_D \tag{20}$$

The third force is the force of the sea on the structure. With regards to information about the environment is to calculate the force exerted on the structure we have:

$$F_{current} = \rho_{water} C_D \frac{D}{2} \left|U_{current}\right| U_{current} \tag{21}$$

The fourth force is the force of the collision floating turbine. In a simple way, the collision can be modeled by time point.

In this case, the force of the static water level to be considered contrary to the x-axis. According to DNV regulations to acquire the force of floating offshore wind turbines have a base:

$$F_{impact} = 2.5\Delta \tag{22}$$

Where Δ floating mass (including the added mass) in the formula of F, KN and unit of Δ also be considered. Time analysis of dynamic forces exerted on the structure is 200 ms (Time period = 200 ms). At the same time force 50 millisecond intervals and analyzing various parameters such as stress, strain, displacement, and is equal to 1 mili second.

Impact force in a triangular pulse is applied to the structure.

Fifth force is the weight of the turbine blades. As mentioned turbine blades weigh 60 tons is considered. Circular cross-section of the cylinder is equal to:

$$\pi D_{pile} = 15.7 \tag{23}$$

Thus, the weight per unit length of the turbine blades on the top of the cylinder enters will be achieved.

The last force is pressure around the turbine. The study projects non-viscous liquid water, is non-rotating and incompressible. The pressure changes in the water and its calculation formula is as follows:

$$p_{water} = \rho_{water} g h \tag{24}$$

Impact force, with the exception of floating dynamic forces is static. In order to calculate the maximum stress applied to the system, wind and wave forces and current research in this line and have to be considered. It is important that the effect of the wind and the waves to be coupled and at the same time (as a linear superposition) make relevant analysis.

Appropriate element for modeling the structure

It is appropriate to analyze the dynamic element, the element is Shell. After successive changes in the dimensions and layout of finite element and obtaining proper convergence solutions from Shell four-node elements (S4R) is used. In addition, the use of shell elements with respect to the dimensions of the sheet is perfectly logical assumption is appropriate.

Analysis of materials used in the manufacture of turbine

To analyze this ordinary steel marine grade E elastic properties - plastic liner that general properties of ABS are based on US regulations are as follows:

Table 3.materials used in manufacturing turbine

$\rho_{steel} = 7800\ \frac{kg}{m^3}$	Usual steel density
$\sigma_y = 242$ MPa	Yield stress of usual steel
$\sigma_{ult} = 531$ MPa	Plastic ultimate stress of usual steel
$\epsilon_{ult} = \frac{531 - 242}{\frac{E}{85}} = 0.12$	Plastic ultimate strain
$E_{steel} = 210$ GPa	Modulus of elasticity of usual steel
$\nu = 0.3$	Poisson coefficient
$H = E/85$	Rigidity of Plastic region

Defined support is for the problem of a cantilever support which is defined in connecting the turbine base to the seafloor base.Appropriate mesh for analysis of intended problem for Shell element is in the form of shell four-tied (Squad) of structural type.

Results

Here, the intended various points on the turbine is shown briefly as follows:

This Study in 5 different modes of the floating mass displacements in 2800, 8400, 16800, 28000, and 56000 tones will be investigated. In each of the important parameters such as reaction support, horizontal movements, stresses Von-Mises as well as elastic and plastic strains are calculated by the software between the different states performed in the form of (3) to (6), a comparison between the above parameters is shown in different positions.

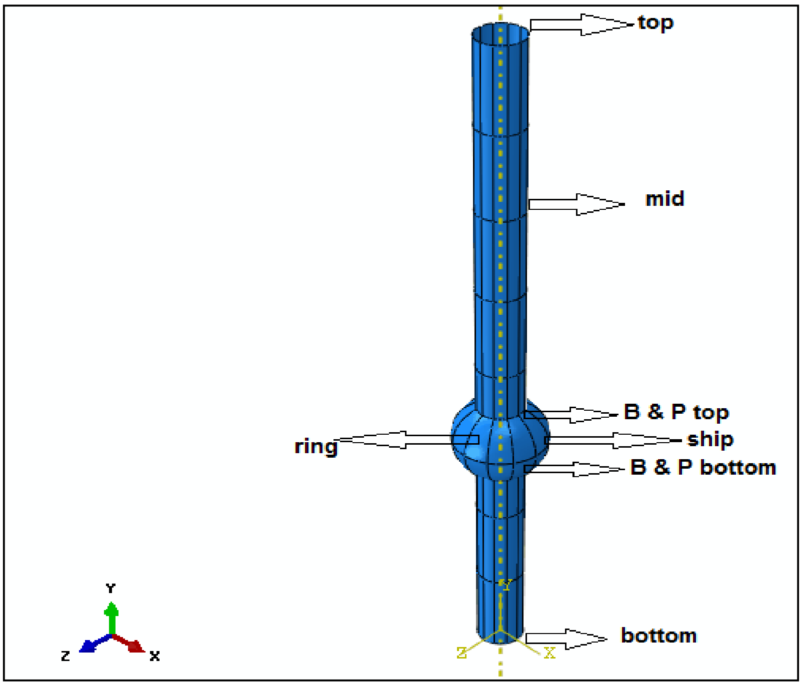

Figure2. Clarifying different points on the turbine

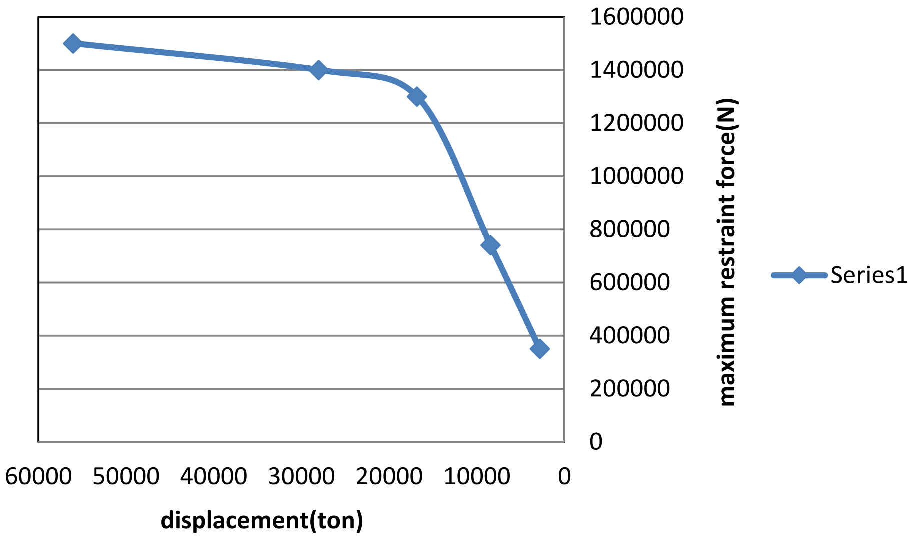

Figure 3. Comparison between maximum support forces in different cases of collision

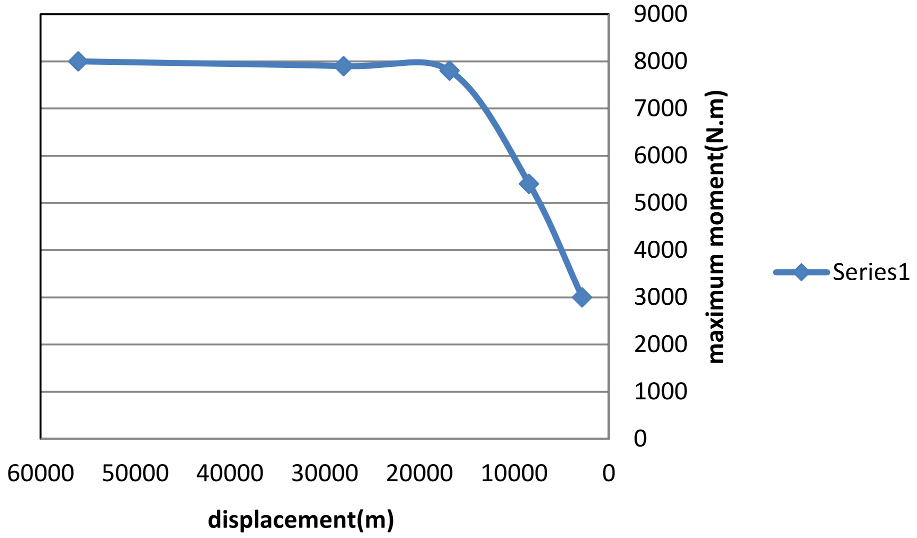

Figure 4. Comparison between maximum support moments in different cases of collision

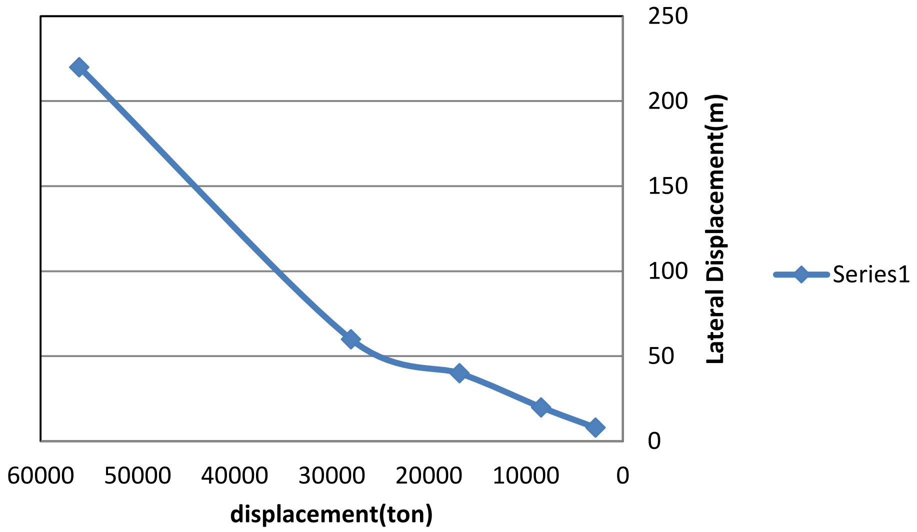

Figure 5. Comparison between maximum horizontal displacements of points on the structure in different case of collision

Comparing maximum horizontal displacement of turbine points in different cases

As the Figure 5 also suggests the maximum displacement of the top spot in the fifth turbine loading is equal to 220 cm.

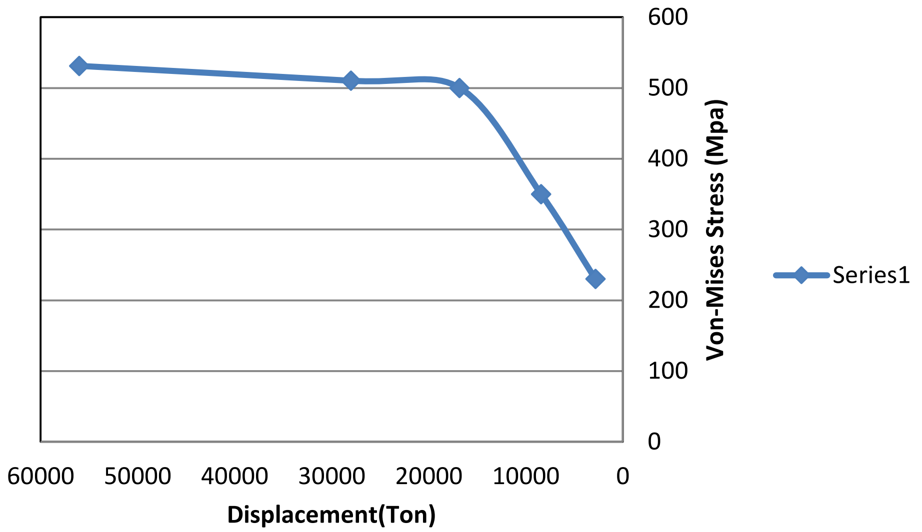

Figure 6. Comparison between maximum stresses of von-mises in different cases of collision

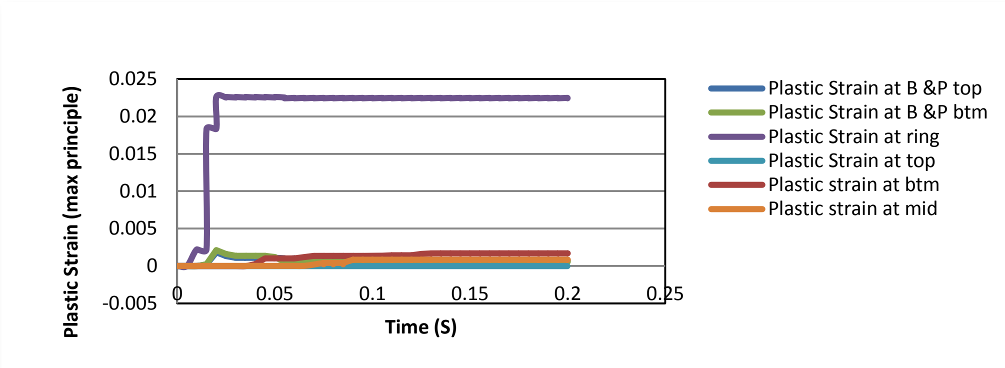

Figure 7. Elastic and plastic strains of points in the fifth case of collision

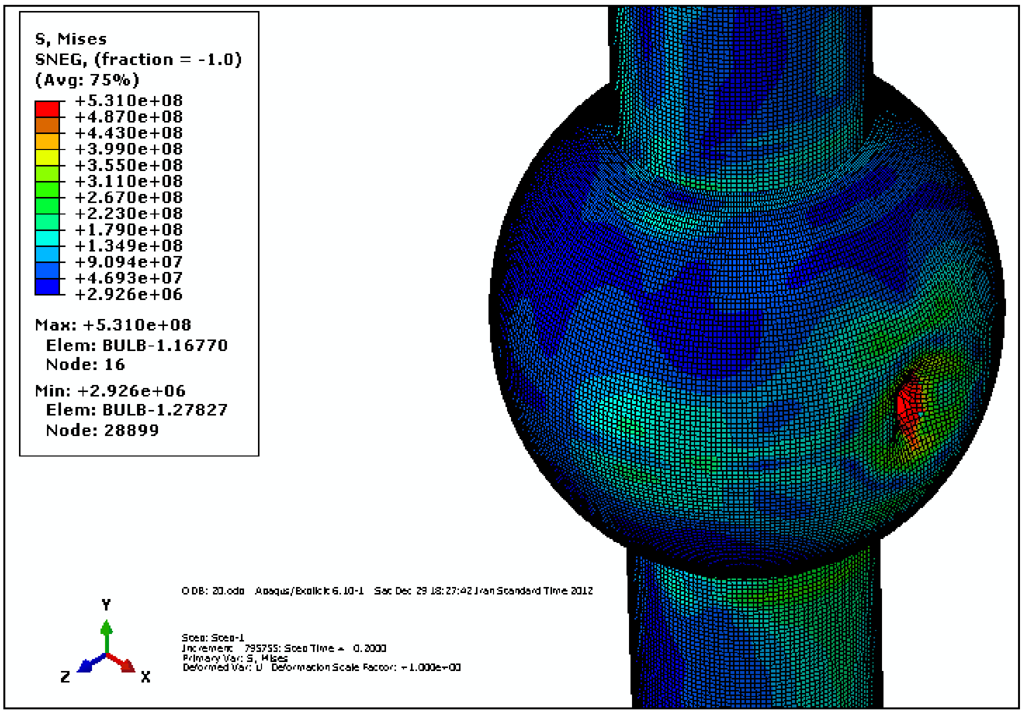

Figure 8. Contour of tensions on the turbine in the moment of t=200 ms and in the fifth case of collision

Conclusion

For observing the effect of mass floating movement on the output of the software in the process of treatment, the 5 different modes were investigated. After the software in different states came to the conclusion that the maximum forces and support reactions happen when a vessel is considered to have the largest mass movement.

However, the maximum displacement of different points along the x-axis and in the case of collision, it is important that only a fifth (to enter the field of plastic and structural failure) of maximum displacement, right at the point of impact.

While in four other cases, the maximum displacement is in the highest point of the turbine.

Finally, in the last case of collision, the point of contact with rot and compaction floating sphere that designs and principles of the turbine should be considered.

If this project in the future is to be continued to assess the following items, it can be more real output software solutions to help us.

- Flexible seabed soil intended to reduce the natural frequency of the system and finally Mono-pile turbines and soil interaction can also be calculated.
- Floating geometric model of ABAQUS software in order to ensure more accurate results.
- The effect of dynamic blade rotation and vibration are also taken into account.

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