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Offshore Structure Response due to Ship Collision on Jacket Legs

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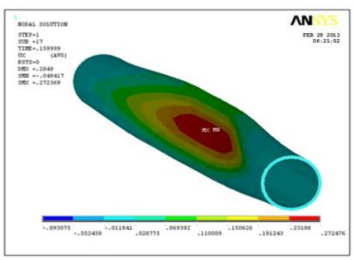
Graphical abstract



Abstract

This paper discusses graded and collision velocity supply vessel influence to local and global structure damage subject to collision. This case study for CONOCO BELANAK wellhead platform that approaching with of 2500 tonnes of supply vessel with tidal variation for each collision scenario. Deformation of the jacket leg occurs causes by material inability to proof against pressure. This paper uses 2 software are ANSYS LS-DYNA 9.0 to acquire local deformation and GT-STRUDL 27.0 version to acquire global deformation included dynamic transient analysis. Outside diameter of Jacket Leg is 1.651 m with wall thickness is 0.0381 m. Normal velocity in each sideway, stern; manoeuvring collision and extreme velocity is 0.28 m/s, 0.39 m/s and 0.74. Extreme velocity in each sideway and stern collision is and 10% exceedance velocity is 0.54 m/s, 0.73 m/s and 1.29 m/s. The result of this paper is dent of the landing platform for each normal and extreme is 0.2725 m, 0.2352 m, and 0. 3241 m/s it must be repaired or changed because of it is 30% larger than spacing frame. Maximum displacement x, y, z direction is 0.2423 m on 0.38 s, 0. 0559 m on 0.39 s, 0.7492 m on 0.41 s. The deformation in landing platform, jacket leg and jacket structure is smaller than research result indeed.

Keywords: Landing platform; impact; dent; eksplicit method; dynamic respons

1.0 INTRODUCTION

Development damage of offshore structure has been occurring for a long time. One of the large deformations is due to severe ship-platform collision. The ship-platform collisions are considered to be a dynamic phenomenon that has costly consequences in material, environmental, and human terms. The dynamic collision response of platforms should be analyzed at the design stage. This precaution ensures that the structure has sufficient strength to withstand impact and therefore has a low probability of severe collision damage.

There are so many incidents of collision at sea occurs. Kenny, 1988 has been reported 3 incidents of impact between very large vessel such as semi-submersible work barges or drilling rigs, and jacket under construction that considerable amount of information available regarding actual collision incident in the UK sector of North Sea, in China (Jin *et al.*, 2005) and this study case has been reported for Jacket-Leg of CONOCO BELANAK Wellhead Platform at Natuna Sea.

The frequency of collision incidents with all types of installations involving supply vessel which resulted in moderate or severe damage, has shown little variation with time. However, the total risk of supply vessel collision appears to have decreased with time, notably for fixed steel installations. Based on available evidence this restriction appears to reduce the number of minor impact, but not the serious incident, which are mostly caused by misjudgement.

In general, resistance to vessel impact is dependent upon the interaction of member denting and member bending. Platform global deformation may be conservatively ignored. For platforms of a compliant nature, it may be advantageous to include the effects of global deformation.

This paper discusses the effect of ship collosion on jacket leg. Detail flow chart of the study is shown in Figure 1. The flatform was analysed using ANSYS LS-DYNA with running scenario under normal and extreme conditions. Loading analysis was determined using GT-Strudle.

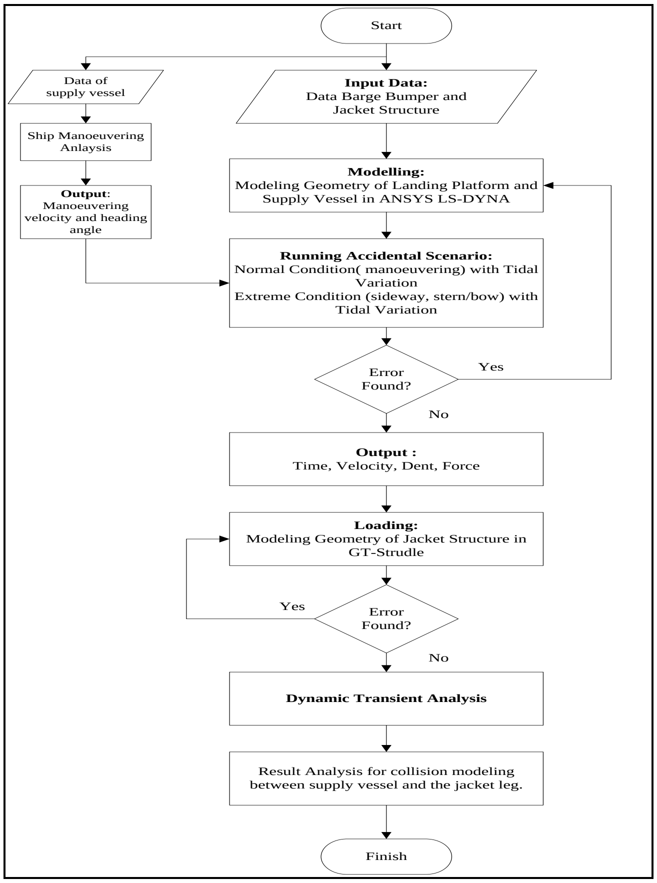


Figure 1 Flow chart of research activity

2.0 BEAM CENTERED IMPACT PROBLEM

Before studying the impact on the jacket leg due to ship collision, conducted the discussion centered on the beam impact problem as shown in Figure 2 (affected beam impact in the middle). It is assumed that the beam with a simple pedestal has a length L, which is exposed to impact loading in the middle by a rigid object with a moving mass mA constant initial velocity of vA.

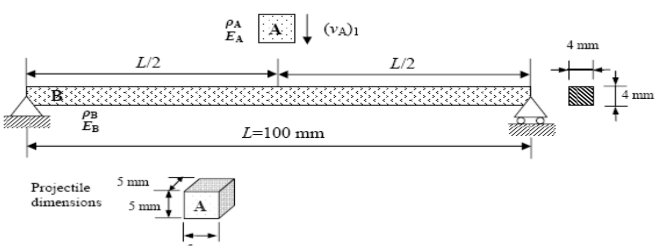


Figure 2 Beam impact problem

Because the impact occurred at one point, the problem can be solved by concentrating the whole mass of the beam at one point in the center of the beam, as shown in Figure 3.

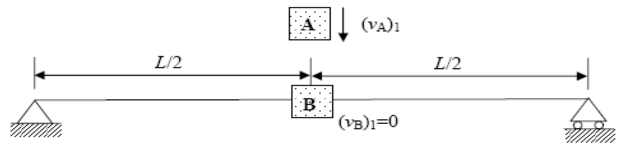


Figure 3 Simplification impact beam problem

Problem solution is divided into two stages. The first is the impact between two masses each have the early speed. At this level of impact force that occurs at the beam exactly equal to the force generated by the beam to an object against his fist. While the second stage is when the two move toward each other the mass and the same speed, for example at plastis perfect punches. Or in other words that the coefficient of restitution of the problem is e = 0. The determination of the restitution coefficient value has been paid to the concept of punching mechanism.

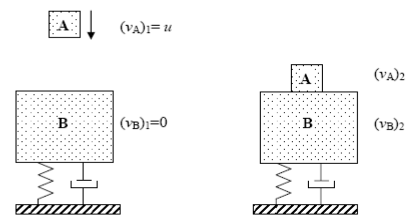


Figure 4 Plastic deformation after the collision

As shown in Figure 4, if the object is dropped from a height h, the speed of the object can be calculated with the energy conservation law, namely:

$$T_0 + V_0 = T_1 + V_1$$

$$0 + m_A gh = \frac{m_A v_A^2}{2} + 0$$

$$m_A gh = \frac{m_A v_A^2}{2}$$

So,

$$(v_A)_1 = \sqrt{2gh} \tag{1}$$

Then use the principle of impulse and momentum. Obtained by integrating the equation of motion with respect to time. Motion equation can be written using Newton's laws II:

$$\sum F = m \cdot a = m \cdot \frac{dv}{dt} \tag{2}$$

Multiplying dt on both sides and integrate anatra limit v = v 1 at t = t1 and v = v2 at t = t2.

$$\sum \int_{t1}^{t2} F dt = \int_{v1}^{v2} m dv = mv_2 - mv_1 \tag{3}$$

Particle initial momentum plus the total number of impulses that occur from t1 to t2 is equal to the particle momentum end. The principle of linear impulse and momentum in vector form is written with the following general equation:

$$\sum m_j \overline{vo_j} + \sum \int_{t1}^{t2} \overline{F} dt = \sum m_j \overline{vf_j} \tag{4}$$

Where $\overrightarrow{v_0}$ is the beginning of the velocity vector for mass j, $\overline{v_f}$ is the end of the velocity vector for mass j after the impact and $\overline{F}$ the force vector transmitted during impact. Impulse is a vector quantity equal to the extent of the area under the force-time curve in Figure 5.

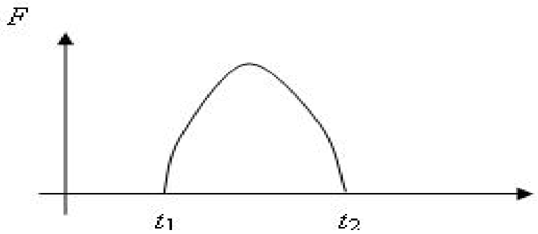


Figure 5 Impulse to force in function of time (Huertas Ortecho, 2006)

In general, impact force varies with time. However, the impact is very short and the style is considered constant, as shown in Figure 6. For reasons of time-average force F_{ave} formulated:

$$F_{ave} = \frac{1}{\Delta t}\int_{t1}^{t2} \vec{F}dt \qquad (5)$$

Where Δt = t2 - t1. So, the impulse equation:

$$I = \vec{F} \cdot \Delta t \qquad (6)$$

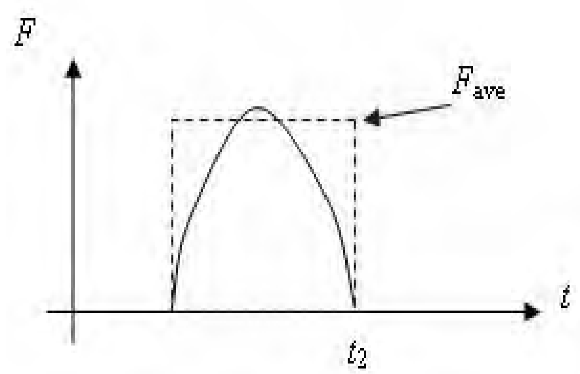


Figure 6 Average Impact Force (Huertas Ortecho,2006)

For this problem, the theory of impulse and momentum is divided into two parts, described in Figure 7:

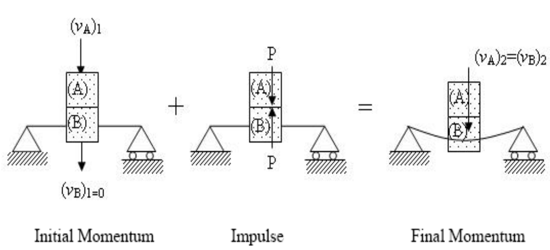


Figure 7 Visualization of the theory of impulse and momentum (Huertas Ortecho, 2006)

The visualization diagram above shows the direction and magnitude of the initial and final particle momentum. Particle initial momentum plus the total number of impulses from t_1 to t_2 is the final momentum.

$$\int \sum m_j (v_j)_1 + \sum \int_0^t \vec{F}dt = \sum m_j (v_j)_2 \qquad (7)$$

Where,

$$\int \; m_A(v_A)_1 + 0 + 0 = (m_A + m_B)\cdot(v_A)_2 \qquad (8)$$

A final velocity of the object beam is concentrated on the mass of B will be the same after the impact because the coefficient of restitution is zero is assumed for this problem. Final velocity can be calculated by:

$$(v_A)_2 = \frac{m_A}{(m_A + m_B)}\cdot(v_A)_1 \qquad (9)$$

As a result of the concentration of mass at the midpoint of the beam, the model is similar to a damped vibration system with one degree of freedom (one degree of freedom damped vibrating system) as shown in Figure 8.

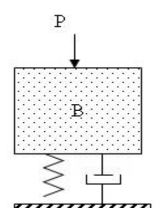


Figure 8 Damped vibration system with one degree of freedom (Huertas Ortecho, 2006)

The principle of impulse and momentum for the above system is formulated as follows:

$$\int_0^{t_0} F(t)dt - \int_0^{t_0} kudt - \int_0^{t_0} c\dot{u}dt = (m_A + m_B)\cdot(v_A)_2 \qquad (10)$$

Where t_0 is the duration of impact. Because the impact is infinitsimal, it was found that the limit t0 close to zero as in the equation below. Function F (t) is assumed as the impulse - an average constant force acting during the time of impact as shown in Figure 7. Containing integral damping and stiffness, for infinitesimal time, tends to zero. So the equation becomes:

$$F_{ave}\cdot t_0 - 0 - 0 = (m_A + m_B)\cdot(v_A)_2$$
$$F_{ave} = \frac{(m_A + m_B)\cdot(v_A)_2}{t_0} \qquad (11)$$

Substituting the final speed of the system $(vA)_2$ from equation 9, 10 into the equation yields:

$$F_{ave} = \frac{m_A(v_A)_2}{t_0} \qquad (12)$$

Above equation has two unknowns, the average force and the time of impact. The impact can be sought from the LS-DYNA

ANSYS software, so that force can be calculated using Equation 12.

3.0 IMPACT ENERGY

Impact is a collision or a collision between two objects that occur within a very short time interval, during which the two bodies pressing each other with a relatively large force. In accordance with the above basic physics concepts, then the amount of energy which resulted in impact between the supply vessel and the platform is proportional to the change in kinetic energy from the supply vessel as shown in Figure 9 (Kenny, 1988).

The highest value of accidents due to collision energy will be absorbed by the installation, with a probability of occurrence for each platform 10-3 every year, which is 4 MJ. This value depends on the size of the vessel as described in formula (Kenny, 1988):

$$\text{Energy absorbed} = 0.5 + m^2(4.2\text{x}10^{-7}\text{–}5.6\text{x}^{10\text{-}11}m)\ \text{MJ} \qquad (13)$$

Where m is displacement of the impacting vessel (tonnes).

Figure 10 shows simulation model scheme. The usefulness of the vessel displacement relationship and the absorbed energy can account for operational differences between areas in the North Sea. Since the serious events that occur because of errors in judgment, the size of the vessel is the most important parameter. Weather conditions did not become important due to the hard collision and are usually not included in the count on the installation of energy absorbed as a result of impact events.

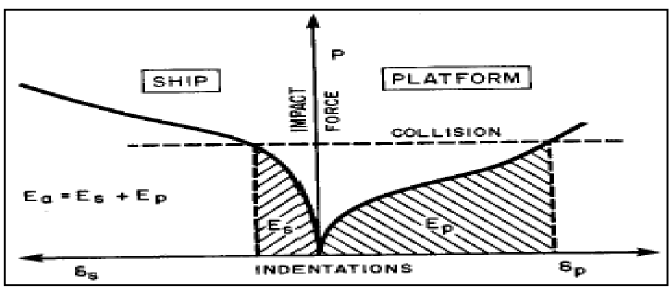


Figure 9 Tipical energi absorption (Kenny, 1988)

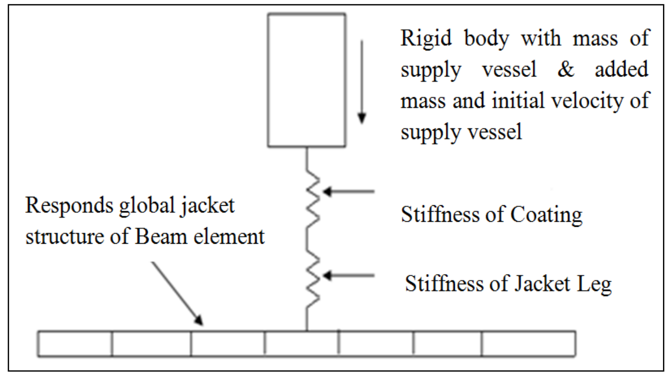


Figure 10 Simulation model scheme

4.0 ACCIDENTIAL IMPACT LOADING

Based on HSE, Load 2001, in cases where the stiffness of the impacted part of the Installation is very large in comparison to that of the impacting part of the vessel, as for example in collisions involving concrete Installations or fully grouted elements, the impact energy absorbed locally by the Installation may be very low and it is important to examine damage caused by the impact force.

In such cases, the impact force, F, may be taken as:

$$F = P_o \text{ or } V\sqrt{(cam)} \qquad (14)$$

Where P_o is the minimum crushing (punching shears as appropiate) of the impacting part of the vessel and the impacted part of the installation (MN), c is stiffness of the impacting part of the vessel (MN/m), V is impact speed (m/s), m is vessel displacement (kg), a is vessel added mass coefficient (1.4 for sideway collision and 1.1 for stern/bow collision).

5.0 SIMULATION OF A CASE STUDY

The impact energy is proportional to the impact velocity squared; hence it is important to predict this velocity as accurately as possible. Evidently, one cannot discard the possibility that a vessel may run into an installation at full speed, due to negligence by the ship crew or due to other reasons. However, it is not reasonable to design against such extreme situations. For this reason, attention has been concentrated on the collision velocities of attendant vessels, which are more likely to occur and can be rationally design against. The combination of collision velocities for each collision scenario is showed in Table 1.

Table 1 Combined collision velocities for each scenario

Collision Scenario	MSL		LWL		HWL	
	Normal Velocity (m/s)	Extreme Velocity (m/s)	Normal Velocity (m/s)	Extreme Velocity (m/s)	Normal Velocity (m/s)	Extreme Velocity (m/s)
Sideway Collision	0.28	0.54	0.28	0.54	0.28	0.54
Stern/Bow Collision	0.39	0.73	0.39	0.73	0.39	0.73
Manoeuvring Collision	0.74	1.29	0.74	1.29	0.74	1.29

According to the scenario above then continued to modelling geometry in ANSYSY LS-DYNA 9.0 version. Meshing and boundary condition of Jacket leg as shown in Figure 11.

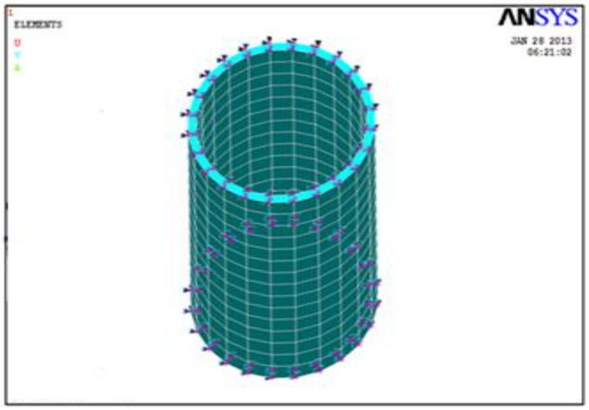


Figure 11 Meshing and boundary condition of jacket leg

Time duration during collision can be import to transient analysis in GT- STRUDL for global analysis. Modelling of Conoco Belanak Wellhead Platform in GT-Strudl as shown in Figure 12.

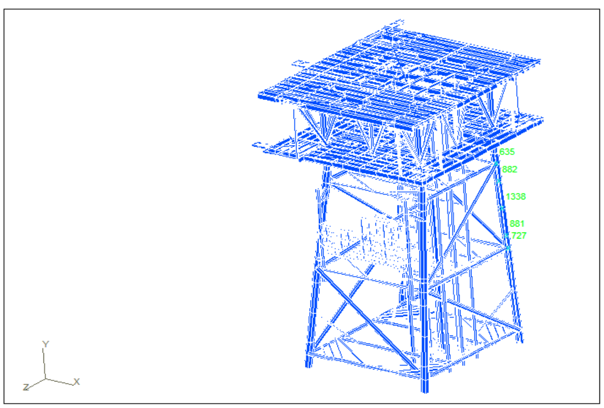


Figure 12 3D Modelling in GT-Strudl 27.0 version

6.0 SIMULATION RESULT AND DISCUSSION

6.1 The Jacket Leg Damage by Supply Vessel Collision

Based on simulation result obtained from ANSYS LS-Dyna software, contact stiffness for normal and extreme condition are showed in Table 2 and Table 3 repectatively.

Table 2 Contact stiffness of ANSYS result at normal condition

Type of Collision	Mass of vessel tonnes	Velocity of vessel m/s	Energy kinetics kJ	Dent Depth m	Stress *Impact* kN/m²	Stiffness kN/m
Sideway	2500	0.28	1345.932	0.2027	1.85E+05	9.13E+05
Stern/Bow	2500	0.39	2051.639	0.2246	1.96E+05	8.73E+05
Manouvring Drift	2500	0.74	9400.923	0.2740	2.96E+05	1.08E+06

Table 3 Contact stiffness of ANSYS result at extreme condition

Type of Collision	Mass of vessel tonnes	Velocity of vessel m/s	Energy kinetics kJ	Dent Depth m	Stress *Impact* kN/m²	Stiffness kN/m
Sideway	2500	0.54	52.0183	0.2352	2.27E+05	9.65E+05
Stern/Bow	2500	0.73	74.6929	0.2724	2.93E+05	1.08E+05
Manouvring Drift	2500	1.29	28568.437	0.3224	3.06E+05	9.49E+06

General provision of the jacket structure element such as diagonal braces, horizontal braces, columns, an if the member had a large dent over 10% of outside diameter, then the elements must be repaired or replaced. Dent that occurred depth lies in the impact site, as shown in Figures 13 and 14.

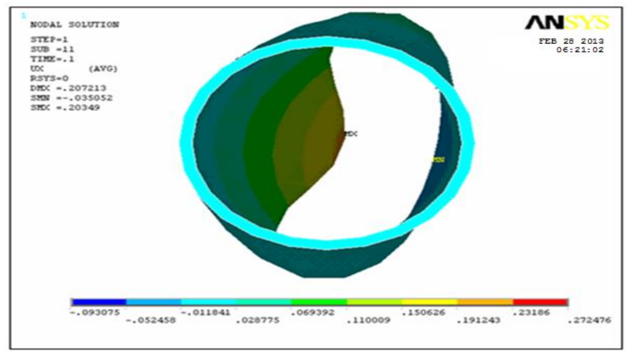


Figure 13 Maximum Dent (plan view x-y)

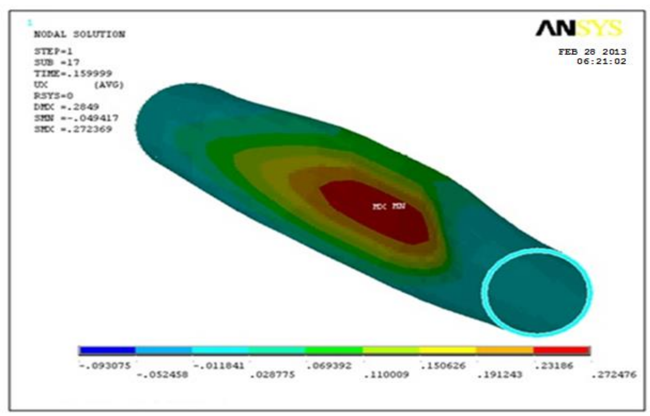


Figure 14 Maximum dent (plan view x-y-z)

The deformation at Jacket Leg due to collision can represent by Figures 15-20.

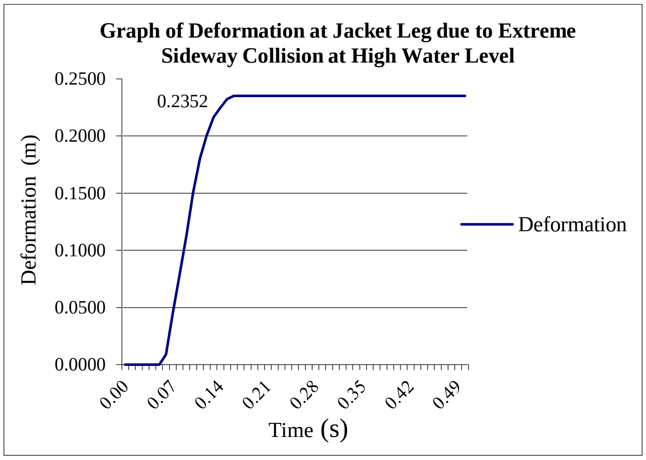


Figure 15 Graph of jacket leg due to extreme sideway collision at high water level

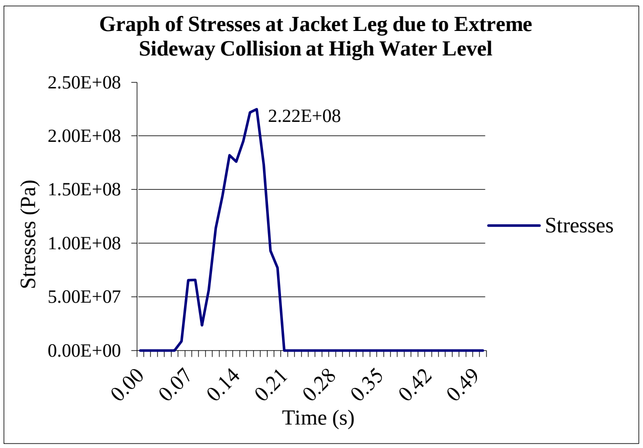


Figure 16 Graph of stresses jacket leg due to extreme sideway collision at high water level

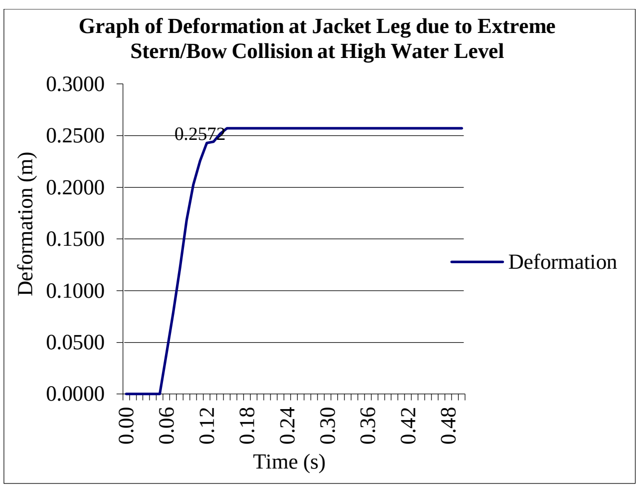


Figure 17 Graph of jacket leg due to extreme stern/bow collision at high water level

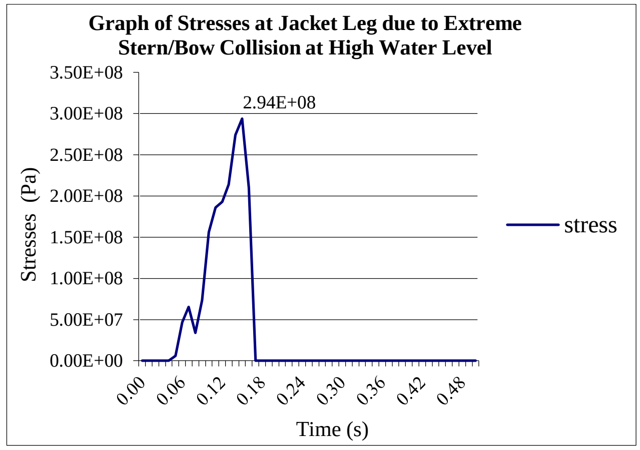


Figure 18 Graph of stresses jacket leg due to extreme stern/bow collision at high water level

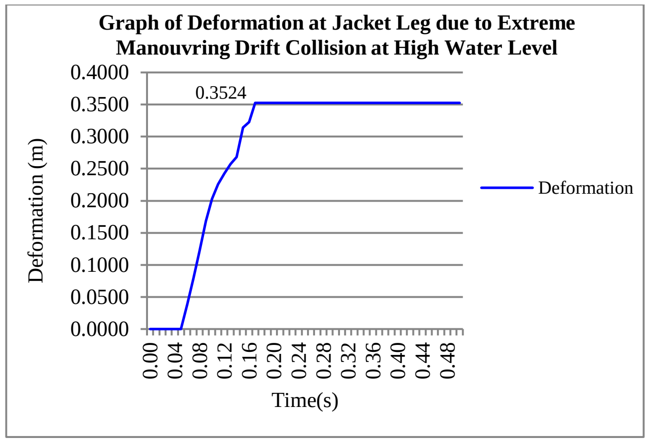


Figure 19 Graph of jacket leg due to extreme manoeuvring drift collision at high water level

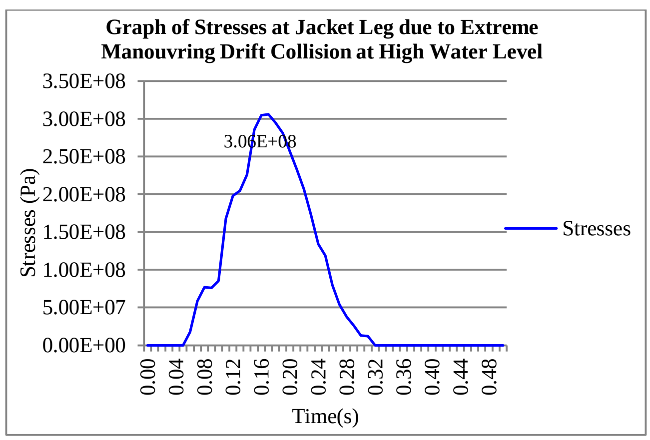


Figure 20 Graph of stresses jacket leg due to extreme manoeuvring drift collision at high water level

6.2 Response Analysis of Jacket Structure

Based on the output the GT-STRUDL software version 27.0, which occurred in this research on extreme condition that can be representing by High Water Level response structure. Jacket response that occurs in the load due to collision can be seen on the GT-SRUDL output version 27.0 as in Figure 21.

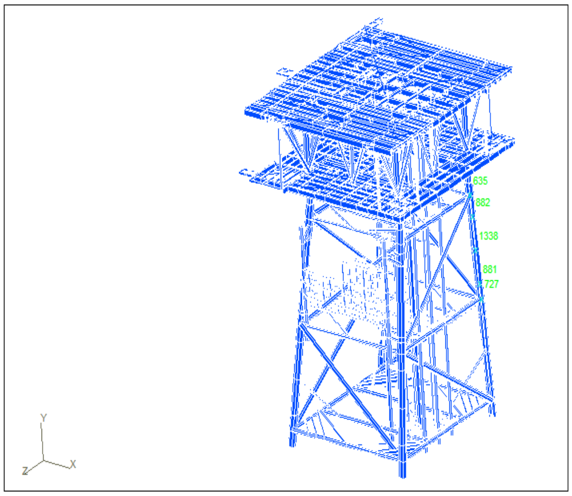


Figure 21 Determined joint (isometric view)

According to API RP 2A WSD, the allowable value unity check of jacket structure is less than equal 1.33 to extreme conditions and check the value of this research is still safe. The Tables 4-6 shows the unity check of selected jacket leg collision scanerio on extreme velocity at the high water level.

Table 4 List unity check jacket leg of sideways collision on extreme velocity at the high water level

CHORD	BRACE	JOINT	UNITY CHECK	REMARKS
JL-10	E15-1	635	0.4515	SAFE
JL-10	E15-2	635	0.5874	SAFE
JL-10	E15-3	635	0.4517	SAFE
JL-10	1767	635	0.2730	SAFE
JL-10	E15-3	635	0.2933	SAFE
JL-11	1767	635	0.5070	SAFE
JL-12	E50-2	809	0.1348	SAFE
JL-12	1472	809	0.7717	SAFE
JL-12	E50-104	809	0.6427	SAFE
JL-12	E50-2	809	0.3007	SAFE
JL-12	1472	809	0.3198	SAFE
JL-12	E50-104	809	0.2997	SAFE
JL-13	E50-2	809	0.8509	SAFE
JL-13	1472	809	0.7717	SAFE
JL-13	E50-2	809	0.3007	SAFE
JL-13	1472	809	0.3198	SAFE
JL-15	1741	1042	0.4239	SAFE
JL-16	E17-2	728	0.8500	SAFE
JL-16	E17-9	728	0.5050	SAFE
JL-16	1478	728	0.5477	SAFE
JL-16	1766	728	0.8258	SAFE
882	1473	882	1.3300	SAFE

Table 5 List unity check jacket leg of stern/bow collision on extreme velocity at the high water level

CHORD	BRACE	JOINT	UNITY CHECK	REMARKS
JL-10	E15-1	635	0.4515	SAFE
JL-10	E15-2	635	0.5874	SAFE
JL-10	E15-3	635	0.4517	SAFE
JL-10	1767	635	0.2730	SAFE
JL-10	E15-3	635	0.2933	SAFE
JL-11	1767	635	0.5070	SAFE
JL-12	E50-2	809	0.1348	SAFE
JL-12	1472	809	0.7717	SAFE
JL-12	E50-104	809	0.6427	SAFE
JL-12	E50-2	809	0.3007	SAFE
JL-12	1472	809	0.3198	SAFE
JL-12	E50-104	809	0.2997	SAFE
JL-13	E50-2	809	0.8509	SAFE
JL-13	1472	809	0.7717	SAFE
JL-13	E50-2	809	0.3007	SAFE
JL-13	1472	809	0.3198	SAFE
JL-15	1741	1042	0.4239	SAFE
JL-16	E17-2	728	0.8500	SAFE
JL-16	E17-9	728	0.5050	SAFE
JL-16	1478	728	0.5477	SAFE
JL-16	1766	728	0.8258	SAFE
882	1473	882	1.3380	SAFE

Table 6 List unity check jacket leg of manoeuvring drift collision on extreme velocity at high water level

CHORD	BRACE	JOINT	UNITY CHECK	REMARKS
JL-10	E15-1	635	0.4515	SAFE
JL-10	E15-2	635	0.5874	SAFE
JL-10	E15-3	635	0.4517	SAFE
JL-10	1767	635	0.2730	SAFE
JL-10	E15-3	635	0.2933	SAFE
JL-11	1767	635	0.5070	SAFE
JL-12	E50-2	809	0.1348	SAFE
JL-12	1472	809	0.7717	SAFE
JL-12	E50-104	809	0.6427	SAFE
JL-12	E50-2	809	0.3007	SAFE
JL-12	1472	809	0.3198	SAFE
JL-12	E50-104	809	0.2997	SAFE
JL-13	E50-2	809	0.8509	SAFE
JL-13	1472	809	0.7717	SAFE
JL-13	E50-2	809	0.3007	SAFE
JL-13	1472	809	0.3198	SAFE
JL-15	1741	1042	0.4239	SAFE
JL-16	E17-2	728	0.8500	SAFE
JL-16	E17-9	728	0.5050	SAFE
JL-16	1478	728	0.5477	SAFE
JL-16	1766	728	0.8258	SAFE
882	1473	882	1.3428	SAFE

6.3 Push-over Method due to Collision Application

As the load is incrementally increased, structural elements such as member, joints, or piles checked for inelastic behavior in order to ensure proper modeling. In this research would show the increasing load due to manoevring drift collision until collapse. The deformation of the structure as shown in Figure 22 to Figure 25. Graphs of push-over analysis were shown in Figures 26-27.

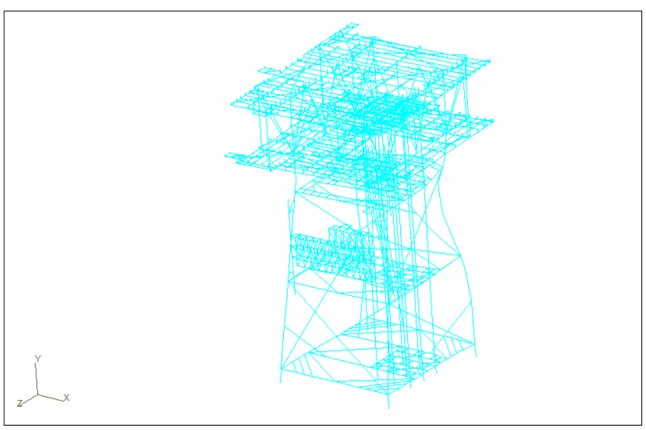


Figure 22 First collision on high water level on manoeuvring drift collision

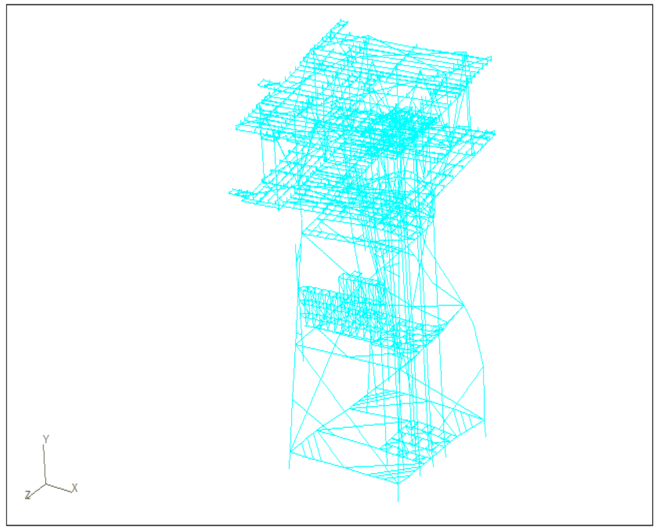


Figure 23 Thirteenth collision on high water level on manoeuvring drift collision

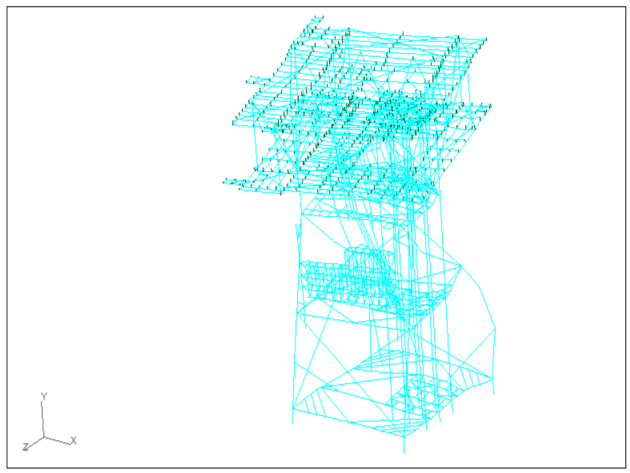


Figure 24 Twenty-fifth collision on high water level on manoeuvring drift collision

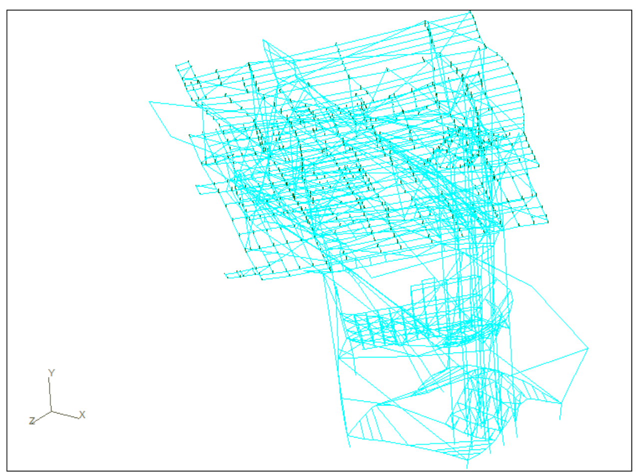


Figure 25 Thirty-seventh collision on high water level on manoeuvring drift collision

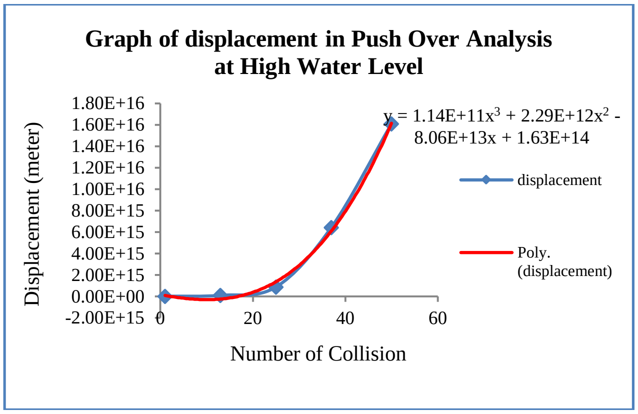


Figure 26 Graph of displacement in push-over analysis at high water level

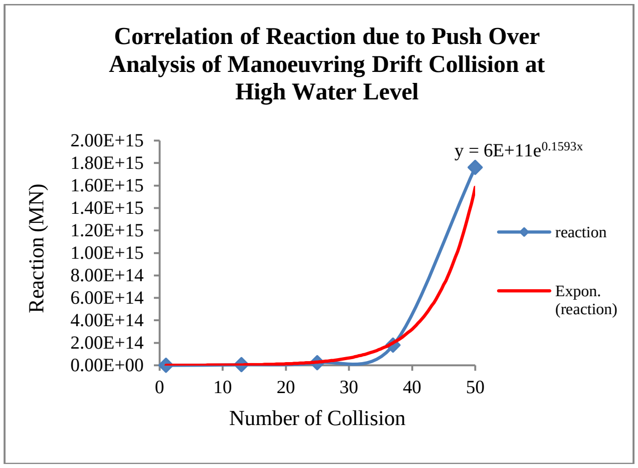


Figure 27 Graph of reaction doe to push-over analysis at high water level

7.0 CONCLUSION

After analyzing the local structure and global structure of the jacket can be concluded that:

- Dent shape at jacket leg is ellipse
- Dent dept due to normal sideway, ster/bow and manoeuvring drift collision is 0.2027 m, 0.2246 m and 0.2740 m.
- Dent dept due to extreme sideway, stern/bow, and manoeuvring drift collision is 0.2352 m, 0.2724 m, and 0.3234 m.
- On Push-over analysis, jacket structure would be collapse at fifty increased collision.
- The prediction of displacement can be calculate by this equation:
  $y = 1.14E{+}11x^3 + 2.29E{+}12x^2 - 8.06E{+}13x + 1.63E{+}14$
- The prediction of displacement can be calculate by this equation:
  $y = 6E{+}11e^{0.1593x}$

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