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Numerical Model of Spherical Storage Tank and Structural Strength Analysis

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Abstract

This research is aim to study of the spherical pressure tank behavior in any operating condition due to the product changed. The finite element analysis technique is used to analyze the static and dynamic structural responses in terms of the stress distribution, deflection, and modal analysis of the tank. The design concept of such spherical pressure tank design is based on the American Society of Mechanical Engineers code, namely ASME Section VIII. Verification and approved of mechanical structural strength of existing tank shell and weld joint through the numerical model under various loading conditions using a finite element software.

Keywords*:* Finite Element Method, Stress Analysis, Spherical Storage Tanks.

1. Introduction

Spherical storage tanks in refineries and chemical plants contain large volumes of flammable and hazardous chemical products. Slight leakage of such chemical products from the tank may lead to a drastic consequence causing not only to environmental impact but also to unforecastable failure of the plant. To avoid the appearance of severe accidents and damages during the plant operation, design and maintenance procedures are strictly basThe dynamical behaviour of elevated liquid storage containers is mainly studied because of the interest in their response to seismic loads (e.g., in petrochemical industry) or in the connection with the structural integrity and reliability analysis of diverse shell componentsed on the engineering design codes of practice including ASME and API codes.

To achieve the operating cost effectiveness, several petrochemical companies turn to reuse the existing spherical tank for storage of liquid hydrocarbon product. In this study, a 20-year used tank but still in a good structural condition has been renovated for the interior as well as exterior walls in order to improve its service lifetime. However, current liquid temperature in the tank is approximately less 17°C. This low-temperature operation level may has a role on tank structural strength in particular for fracture toughness of the weld joint. It is widely agreed that design procedure of such tank shall meet the ASME SEC. XIII, DIV 2, 1995 Edition for the tank material which is JIS G 3115: grade SPV 490Q steel.

The dynamical behavior of elevated liquid storage containers is mainly studied because of the interest in their response to seismic loads (e.g., in petrochemical industry) or in the connection with the structural integrity and reliability analysis of diverse shell components. [12]. Amin Paykani [13] studied the finite element analysis of a thin-walled pressure vessel under simultaneous thermal and static loading is investigated using both analytical and simulation-based methods (ANSYS). He had the results obtained by proposed method are compared by that of purely numerical "finite difference" method calculated by ANSYS. Two types of analysis are commonly applied to pressure vessels. The most common method is based on a simple mechanics approach and is applicable to thin-walled pressure vessels which by definition have a ratio of inner radius, r, to wall thickness, t, of $r/t \geq 10$. The second method is based on elasticity solution and is always applicable regardless of the r/t ratio and can be referred to as the solution for thick-walled pressure vessels. Finite Element Analysis (FEA) is a practical tool in the study of pressure vessels, especially in determining stresses in local areas such as cavities, O-ring grooves and other areas difficult to analyze manually.

Fig.1 Spherical Tank

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2. Specification and Applied Loads

2.1 Structural design criteria

The Spherical Tank was design as following the ASME standard (Section VIII division 2) [1]

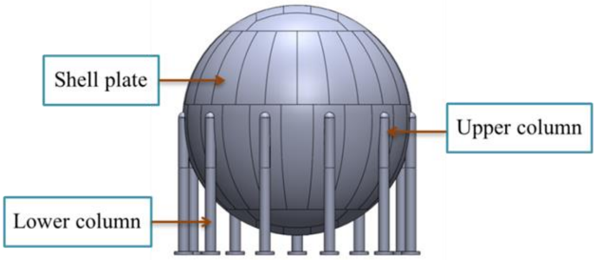

Fig. 2 Location of tank material

2.1.1 Material Specification and Design of Data

Table. 1 Material specification of spherical storage tank

Tank Component	**Material specification**
1.Shell Plate	JIS G 3115: Grade SPV 490Q
2.Upper column	JIS G 3115: Grade SPV 490Q
3.Lower column	JIS G344 STK400

Design spherical storage tank incorporated with the site meteorological data is given in Table. 2.

Table. 2 Data for the design of spherical storage tank [3]

Design data	**Value**
1.Design Internal Pressure,[MPa]	0.883+D.L.L.
2. Design Liquid Level,[mm.]	16,548
3.Wind Pressure,[kg/m^2 max]	160
4.Hydrostatic test Pressure,[MPa]	1.108+D.L.L.
5. Inside Diameter,[mm.]	21,900
6.Specific Gravity	0.920
7. Corrosion Allowance,[mm.]	1.5

Note: D.L.L = Design Liquid Level

Table.3 Mechanical properties of material-JIS G 3115: SPV 490Q : Shell Plate

Properties of materials	**Value**
1.Yield strength of steel, σ_{yield} [MPa]	490
2.Ultimate tensile strength, σ_u [MPa]	650
3.Density, ρ [kg/m^3]	7,850
4.Modulus of elasticity, E [GPa]	200
5.Poisson ratio	0.3

Table.4 Mechanical properties of material - JIS G344 STK400 : Lower column

Properties of materials	**Value**
1.Yield strength of steel, σ_{yield} [MPa]	235
2.Ultimate tensile strength, σ_u [MPa]	650
3.Density, ρ [kg/m^3]	7,850
4.Modulus of elasticity, E [GPa]	200
5.Poisson ratio	0.3

According to Table 2. The calculation of tank thickness can be determined as follows [1]

$$t = \left[\frac{0.5PR}{(S-0.25P)}\right] + CA \qquad (1)$$

When
t = minimum required thickness of shell (mm.)
P = design internal pressure plus any pressure due to the static head of fluid at the point under consideration, (MPa)

$$P = wh + P_d \qquad (2)$$

when
Pd = design internal pressure (MPa) = 0.883 MPa
R = inside radius of the tank shell (mm) = 10,950 mm.
S = membrane stress intensity limit (MPa)
w = Specific gravity = 0.920
h = liquid depth at the point considered (mm)

The membrane stress intensity limit can be written as

$$S = Sm \times Ki \qquad (3)$$

When
Ki = stress intensity factor = 1.0
Sm = design stress intensity value at design temp.
Material specification = SPV490Q at 60 Deg.C.
The minimum tensile strength = 650 MPa
The minimum yield strength = 490 MPa
So, Sm = (1/3 x Tensile or 2/3 x Yield, whichever is smaller)
Sm = (1/3 x 650MPa or 2/3 x 490 MPa, whichever is smaller)
Sm = 216.67 MPa
Thus, $S = 216.67 MPa \times 1.0 = 216.67$ MPa

Table A1 Pressure calculation for the point of consideration in any liquid depth

Point	Angle (deg)		Liquid depth (mm.)	Liquid head (MPa)	Total Pressure (MPa)
1	$\theta 1$	180.0	16,548	0.149	1.029
2	$\theta 2$	157.4	15,706	0.142	1.022
3	$\theta 3$	140.9	14,910	0.127	1.007
4	$\theta 4$	84.3	4,518	0.040	0.920
5	$\theta 5$	39.1	0	0	0
6	$\theta 6$	30.5	0	0	0

Table A2 Thickness calculation for the point of consideration in any liquid depth

Point	Plate No.	Calculation Thickness, mm.
1	No.1 & No.2	29.322
2	No.3	29.116
3	No.4 & No.4P	28.725
4	No.5	26.392
5	No.6	25.292
6	No.7 & No.8	25.292

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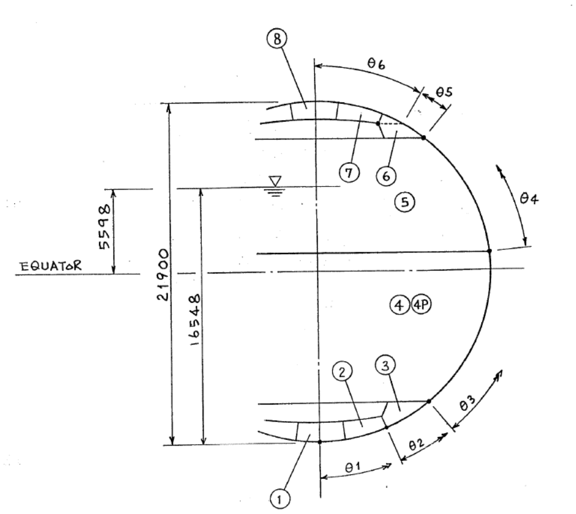

Fig. 2A Point consideration at liquid depth

2.1.2 Wind load determination

The standard for calculating structural loads is ASCE 7 [6], Minimum Design Loads for Buildings and Other Structures. This standard is referenced by many model building codes, and consequently its provisions are the law in many jurisdictions. The standard contains provisions and commentary relating particularly to the estimation of wind loads. Equation (4) below is provided in ASCE 7 to calculate wind loads on "other structures" and has been adopted by ASCE's guide, Wind Loads and Anchor Bolt Design for Petrochemical Facilities (1997) for application to petrochemical structures.

The design wind load, Fw, on spherical tank is determined by the following formula:[2]

$$Fw = qz \times Gh \times Cf \times Af \qquad (4)$$

Where

qz is evaluated at height z above ground = 160 kg/m^2
Gh is gust response = 1.18
Cf is force coefficients for tank = 0.5
Af is projection area of spherical tank = 412 m^2

So, $Fw = 160\dfrac{kg}{m^2} \times 1.18 \times 0.5 \times 412 m^2$ = 38,893 kg.

2.1.3 Tank Column design

The column design is performed axially compression load in accordance with AISC 5-19[2]
Allowable compressive stress is determined by the following formula:[2]

$$Fa = \frac{\left[1 - \dfrac{\left(\dfrac{KL}{r}\right)^2}{2Cc^2}\right]Fy}{\left[\dfrac{5}{3} + \dfrac{3\left(\dfrac{KL}{r}\right)}{8Cc} - \dfrac{\left(\dfrac{KL}{r}\right)^3}{8Cc^3}\right]} \qquad (5)$$

$$Cc = \sqrt{\frac{2\pi^2 E}{Fy}} \qquad (6)$$

When
Fa is Allowable compressive stress; kg/mm^2
Fy is Minimum Yield Stress of column 23.96 kg/mm^2
E is Modulus of elasticity = 2.1 x10^4 kg/mm^2
K is Effective Length Factor = 1.0
r is Radius of Gyration = 816 mm
L is Effective length of column = 12,750 mm
Cc is The largest Effective column Slenderness Ratio
A is Cross sectional area of column = 50,265 mm^2

$$Cc = \sqrt{\frac{2\pi^2 \times 2.1 \times 10^{-4}}{23.96}} = 131.53$$

And

$$\frac{KL}{r} = \frac{1 \times 12{,}750}{816} = 15.62$$

$$Cc > \frac{KL}{r} \qquad \text{Satisfied}$$

Allowable Compressive Stress;

$$Fa = \frac{\left[1 - \dfrac{(15.6)^2}{2(131.53^2)}\right](23.96)}{\left[\dfrac{5}{3} + \dfrac{3(15.6)}{8(131.53)} - \dfrac{(15.62)^3}{8(131.53^3)}\right]} = 13.89 \text{ kg/mm}^2$$

Allowable Compressive Stress is to be increased by multiplying the following factor for each loading condition.
1.0 for Normal condition (Product 85% of tank volume)
1.33 for the wind condition
1.33 for the hydrostatic test condition

Table 5. The compression stress analysis in tank column for each column

Loading condition	Axially compression Stress (kg/mm^2)	Allowable compressive stress (kg/mm^2)
1.Normal condition (Product 85% of tank volume)	8.53	13.89
2.Under the hydrostatic test condition	8.76	18.52
3.Under wind condition (Storage product 85% of tank volume)	10.70	18.52

3. Methodology of Finite Element Analysis

The spherical tank operate liquid product in high internal pressure. Tank dimension has diameter 21.90 m. and the spherical tank leg high 12.75 m. from ground level that constructed from thin plate. [3]

3.1 Tank structural modeling

The geometry of tank create with Solidworks, the dimension as following in the manufacture drawing. [3]

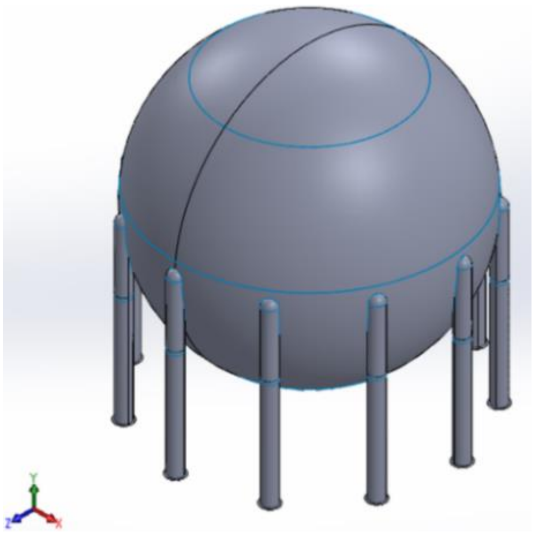

Fig. 3 3D modeling of spherical Tank

3.2 Meshing

The spherical tank model created mesh in shell, leg support were shell element type with ANSYS. The node quantities 19,074 nodes and element quantities for this model 15,761 elements.

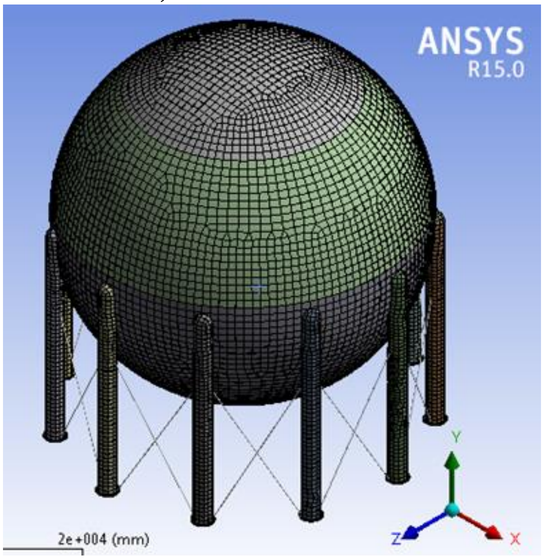

Fig. 4 Meshing of spherical tank model

3.3 Material properties

Refer to Table 3 to Table 4. The material properties are tank shell, and lower column.

4. Analysis of spherical tank at various state

The tank structure are include top shell, bottom shell, top side shell, bottom side shell, and column that effected by the internal pressure. The internal pressure are include design pressure and hydrostatic pressure. In the tank support such as column, bracing have the load from all tank structure.

Table.6. Loading data of spherical tank

Design condition	Total Load (kg)	Pressure (MPa)
1.Normal condition (Product 85% of tank volume)	4.715×10^6	0.88253
2.Under the hydrostatic test condition	5.914×10^6	1.32379
3.Under wind condition		
3.1) Tank empty	4.53×10^5	0
3.2) Storage product 85% of tank volume	4.754×10^6	0.88253

5. Local Stress Simulation

5.1 The Simulation of weld joint at bottom shell plate section of spherical tank

In tank structure, the weld joint is important to determine the strength occurred in this part because it was jointed between any parts of tank body. The maximum load was occurred in the bottom section of shell plate that came from the internal pressure and the hydrostatic of liquid level.

The analysis of weld joint should be consider in the flange to shell plate at bottom section that is the maximum load was occurred.

5.1.1 Structural Modeling

The model was created by 3D model from Solidworks as per the manufacture data sheet [3].

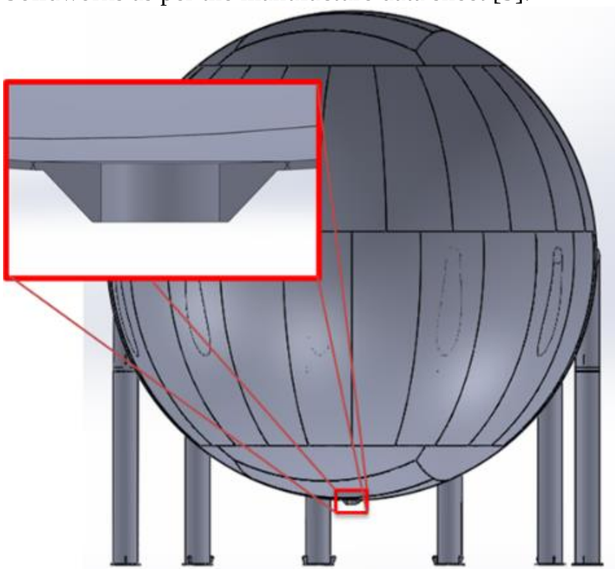

Fig. 5 The 3D model of tank body and the flange component

5.1.2 Meshing

Mesh was created by the discrete model to small element with ANSYS. In this model consider to shell body include bottom flange component. The element type is solid element that have element 240,279 elements and total node 85,986 nodes.

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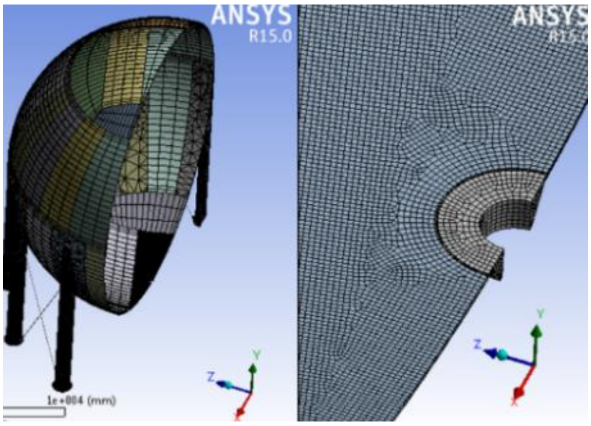

Fig. 6 The element type of tank body

5.1.3 Material Properties

Refer table 3 and 4 the material properties is JIS G 3115: SPV 490Q for tank shell, JIS G344 STK400 for lower column and the welding material is AWS A5.5: E9016-G as table 7

Table 7. Material properties of welding Electrode

Material Properties – AWS A5.5 : E9016-G	
Property	**Value**
Modulus of Elasticity, E [GPa]	200
Density, ρ [kg/m^3]	7,850
Poisson's Ratio, ν	0.3
Yield strength, σ_{yield} [MPa]	590
Ultimate tensile strength, σ_u [MPa]	705

5.1.4 Boundary Conditions

A – Fixed Support
B – Hydrostatic Pressure
C – Design Pressure : 0.88253 MPa
D – Standard Earth Gravity : 9.81 m/s^2

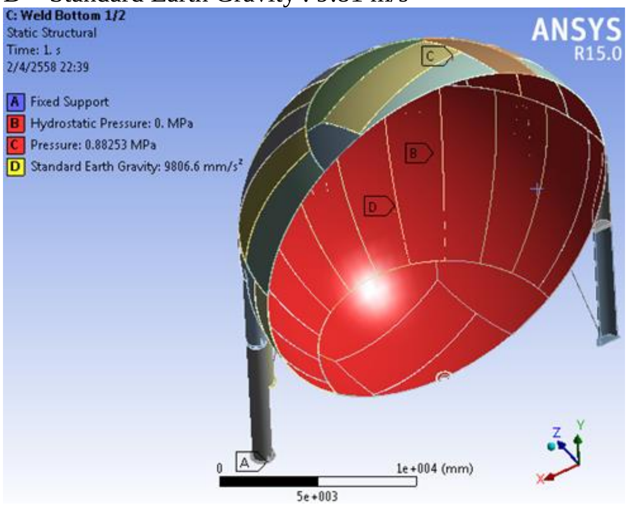

Fig. 7 Boundary Conditions of tank body (Symmetry)

5.2 The Stress in Shell plate of spherical tank

5.2.1 Consideration of the stress in shell plate

This object consider to liquid level of tank 3 level; 25% liquid level, 55% liquid level, 75% liquid level.

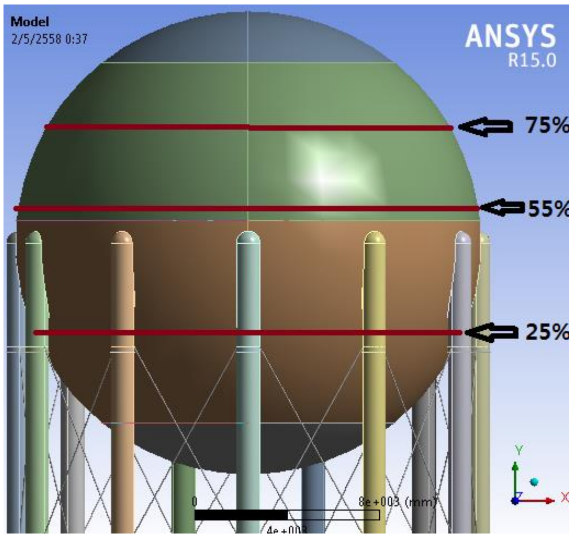

Fig 8 Levelling line for consideration

5.3 Simulation of the spherical tank column

One problem faced in the design of structures is buckling, in which structural members collapse under compressive loads greater than the material can withstand. In this research, performing linear buckling analyses in simulation.

5.3.1 Structural Modeling

The model was created by 3D model from Solidworks as per the manufacture data sheet [3].

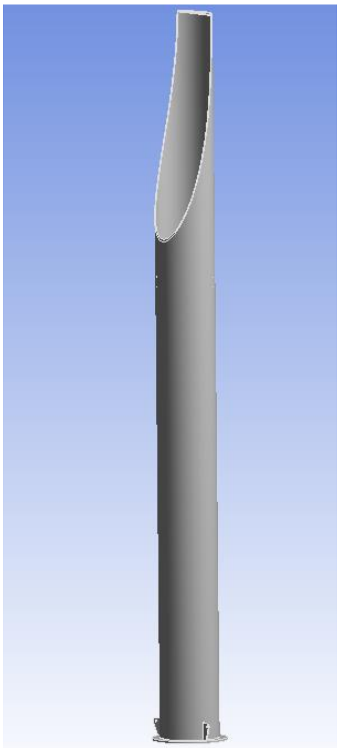

Fig. 9 3D modeling of spherical Tank Column

5.3.2 Meshing

Mesh was created by the discrete model to small element with ANSYS. In this model consider to solid body .The element type is solid element that have element 30,407 elements and total node 106,821 nodes.

5.3.2 Material Properties

Refer table 4 the material properties is JIS G344 STK400 for lower column

Table 8. Analysis buckling of tank column at various state

Design condition	Load (kg/column)[3]
1.Normal condition (Product 85% of tank volume)	4.285×10^6
2.Under wind condition with product 85% of tank volume	4.401×10^6
3.Under the hydrostatic test condition	5.376×10^6

6. Natural frequency response of spherical tank in various state

6.1 Modal analysis

The goal of modal analysis in structural mechanics is to determine the natural mode shapes and frequencies of an object or structure during free vibration. It is common to use the finite element method (FEM) to perform this analysis by ANSYS.

6.1.1 Boundary Condition

Condition (1) No liquid product condition

- Fixed Support

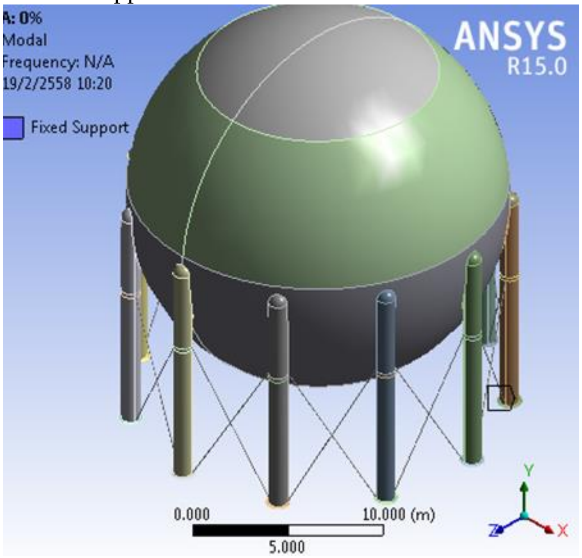

Fig. 10 Boundary condition without liquid product

Condition (2) Liquid product volume condition

A – Fixed Support

B – Point Mass

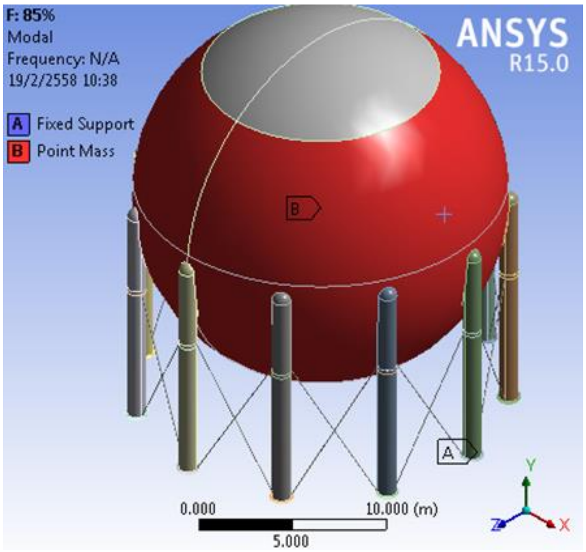

Fig. 11 Boundary condition with liquid product

7. Result and Discussion

7.1 Analysis of spherical tank at various state result

7.1.1 The result of normal condition (Product 85% of tank volume)

A) The Deformation: while the spherical tank stored 85% of tank volume that had the pressure came from the high of liquid level. The maximum deformation approximate 9.63 mm. at the center of the bottom of spherical tank as show in Fig.12.

B) Stress: the stress generate in tank body during operate show in Fig. 13 that found the stress distribute all tank shell not exceed 200 MPa

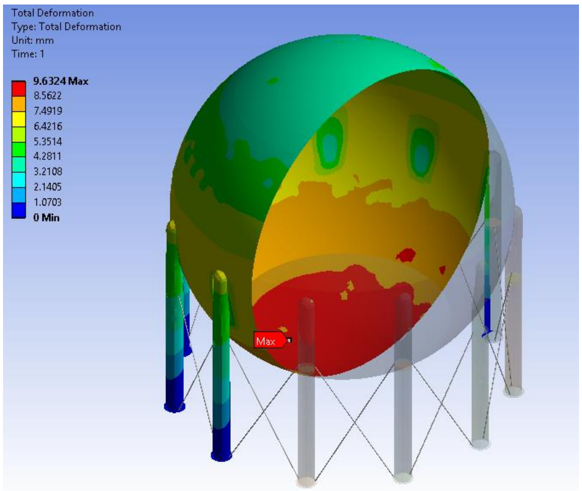

Fig. 12 Deformation of spherical tank during stored 85 % of tank volume

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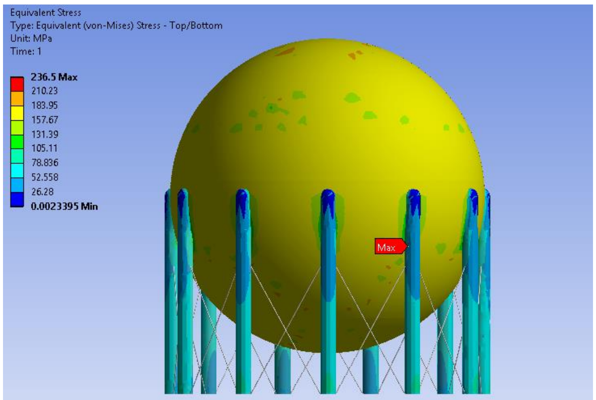

Fig. 13 Stress Distribution in tank shell

7.1.2 The result of hydrostatic test condition

A) Deformation: during hydrostatic test of this tank by filled water full tank. The maximum deformation approximate 12.963 mm. at the center of the bottom of spherical tank as show in Fig. 14

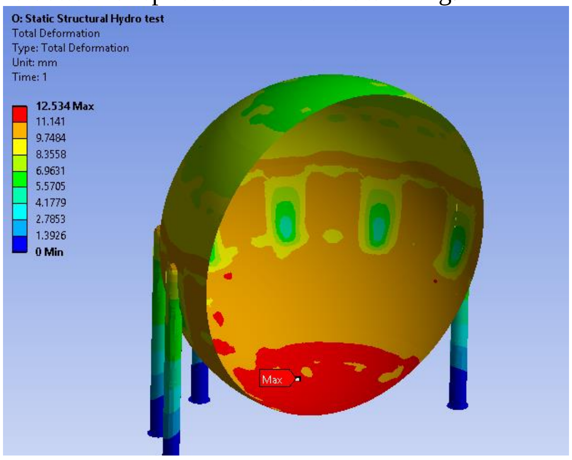

Fig. 14 Deformation of spherical tank during under hydrostatic test

B) Stress: the stress generate in tank body during operate show in Fig.15 that found the stress distribute all tank shell not exceed 300 MPa

7.1.3 The result of tank empty under wind condition :

A) Deformation: the empty tank has been the load from wind velocity that deformed by wind load. The maximum deformation approximate 1.73 mm. at +X direction as show in Fig. 16

B) Stress: the result of stress when considered wind load with empty tank in +X direction show in Fig.17 that found the stress distribute all tank shell to low stress distribution.

7.1.4: The result of tank storage product 85% of tank volume under wind condition

A) Deformation: the tank has been the load from wind velocity that deformed by wind load with 85% of liquid volume. The maximum deformation approximate 9.98 mm. at +X direction as show in Fig. 18

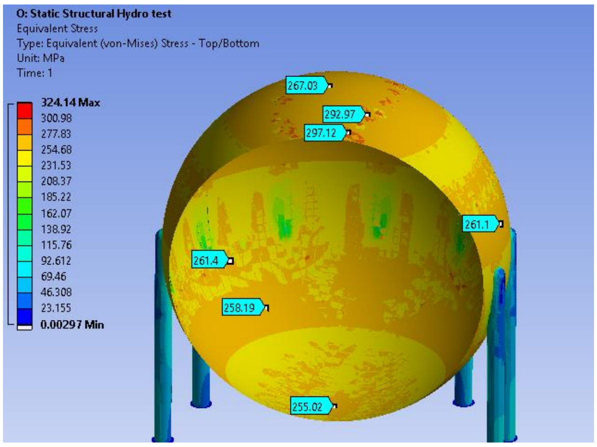

Fig. 15 Stress Distribution in tank shell under hydrostatic test

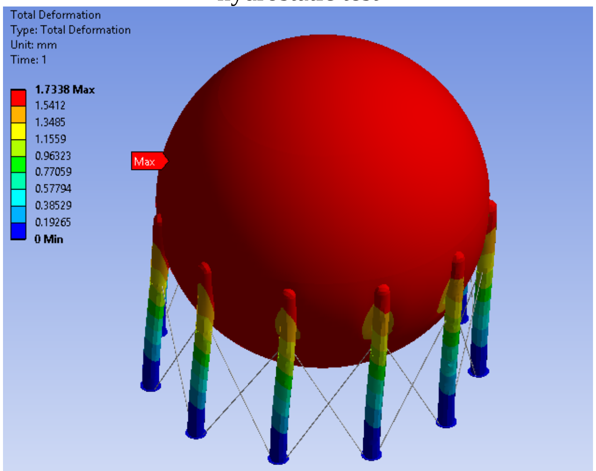

Fig. 16 Deformation of spherical tank under wind load condition and no liquid inside

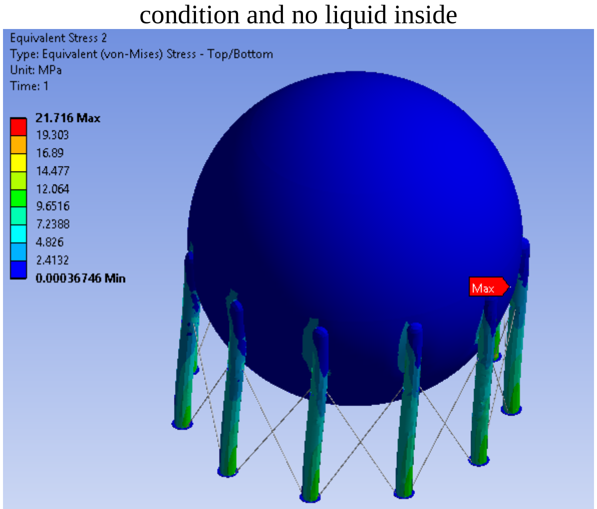

Fig. 17 Stress Distribution in tank shell under wind load condition and no liquid inside

B) Stress: the stress generated in tank body during operate show in Fig.19 that found the stress distribute all tank shell not exceed 200 MPa.

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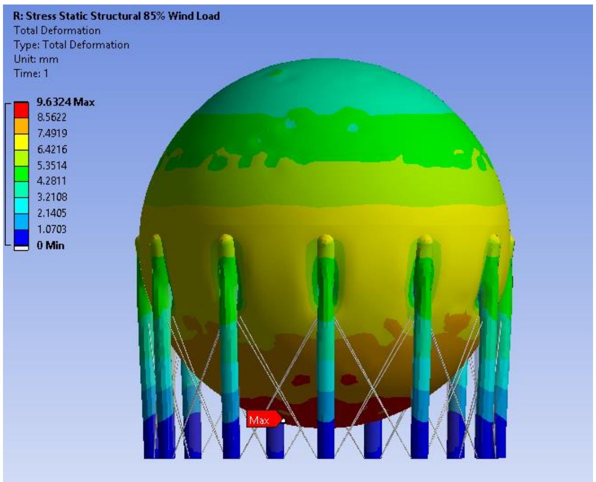

Fig. 18 Deformation of spherical tank under wind load condition with 85% of liquid volume

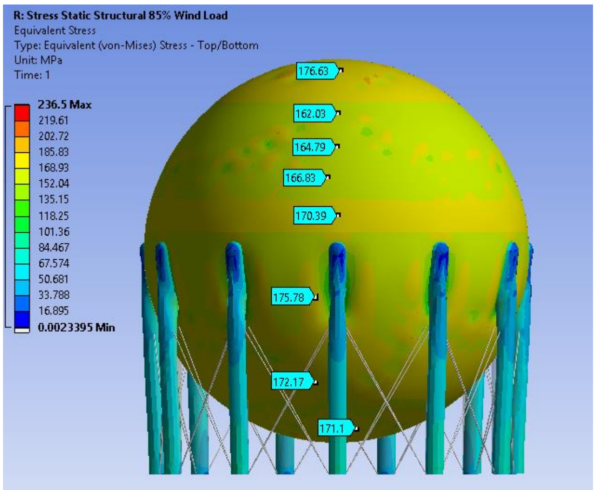

Fig. 19 Stress Distribution in tank shell under wind load condition with 85% of liquid volume

Table 9. Summary of study in various conditions

Condition	Deformation (mm.)	Max. Stress (MPa)	Aver. Stress (MPa)
1.Normal condition (Product 85% of tank volume)	9.63	200	90
2.Under the hydrostatic test condition	12.963	300	260
3.Under wind condition			
3.1) Tank empty	1.73	20	20
3.2) Storage product 85% of tank volume	9.98	200	160

7.2 Local Stress Simulation result

7.2.1 Result of the Simulation of weld joint at bottom shell plate section of spherical tank

A) Deformation: the deformation was occurring in bottom section as show in Fig. 20 at point 1 was minimum deformation, point 2 was the maximum load and has maximum deformation <9 mm.

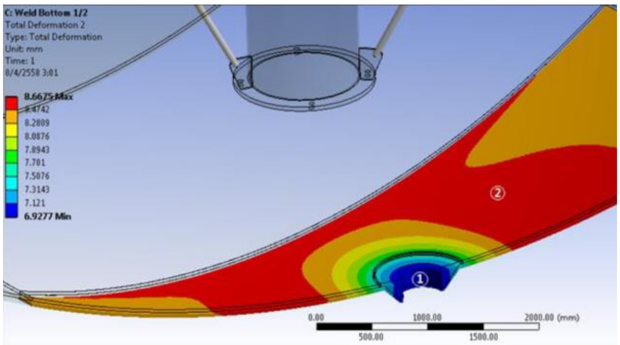

Fig. 20 Tank deformation at the bottom section

B) Factor of safety (FOS) : The Bottom Shell Plate, FOS less than 3.5 find at the edge of flange 2.022 as show Fig.21. Normally the pressure vessel has to be the FOS >3.5 when compare with The Ultimate Strength of material according to ASME Sec. II Part D standard.[4],

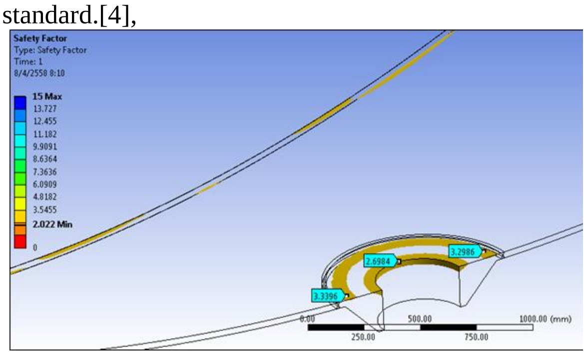

Fig. 21 Factor of safety in the bottom shell plate section

Weld Bead; The bottom shell plate has thickness 30 mm. when design of weld joint should be design with double V groove type that welded inside to 10 mm. and outside to 20 mm. The stress distribution is showing in Fig.22 (a) and maximum stress was found in point 1.

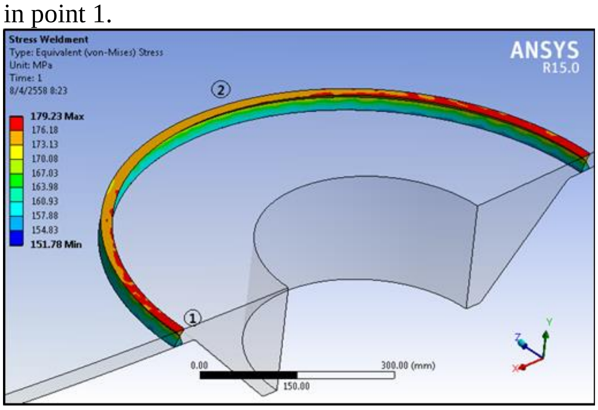

Fig. 22 (a) Stress distribution in weld joint

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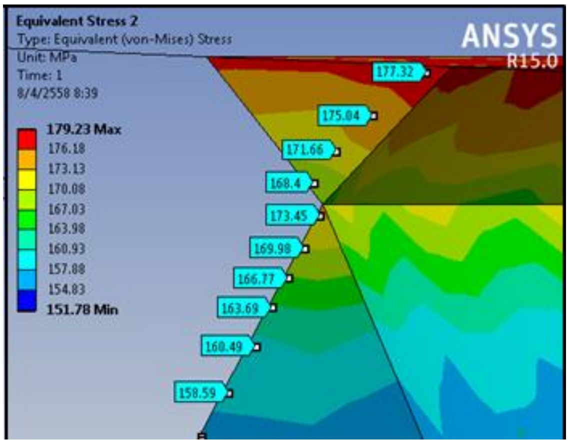

Fig. 22 (b) Section area of the stress at point 1

The maximum stress find in weld joint 179 MPa. and reduce from inside tank to outside tank. The minimum stress was found 151 MPa. at outside tank, the average stress is 165 MPa. For the welding material E9016-G has the yield strength 590 MPa. this determine the factor of safety (FOS) as

$$F.O.S = \frac{\sigma_{yield}}{\sigma_{actual}} \tag{6}$$

$$= \frac{590\text{MPa}}{179\text{MPa}} \quad \text{So,} \; F.O.S = 3.3$$

For the factor of safety (FOS) by FEM is 3.58 that suitable to operate of this spherical tank.

7.2.2 Result of the Stress in Shell plate of spherical tank

The stress had considered to 3 type; Equivalent Stress, Circumferential Stress (Horizontal direction and Vertical direction) that compare to the stress occurred in tank circumferential. The coordinate from Cartesian was Cylindrical to consider of stress in the same axis on tank circumferential.

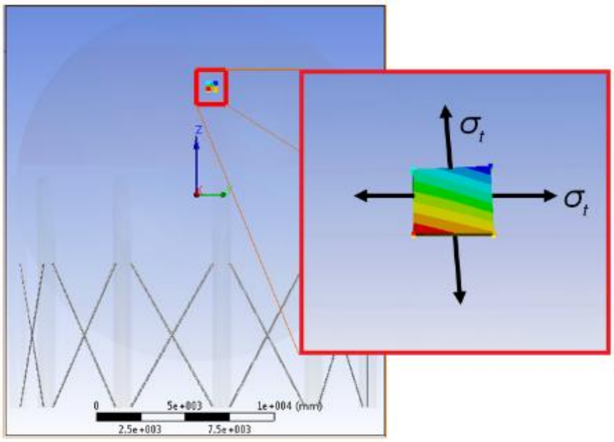

Fig. 23. The stress in element

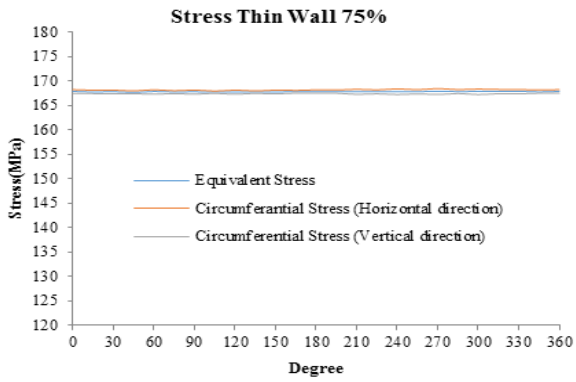

Fig. 24 The stress in various location of 75% of tank high

From the graph of thin wall stress (Fig.24, Fig.25, Fig.26) were found Equivalent Stress, σ_{VM} Normal Stress Horizontal direction, σ_t Normal Stress Vertical direction, σ_t that result closed to the theory of stress in spherical shell as

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2 - \sigma_2\sigma_3 - \sigma_3\sigma_1} \tag{7}$$

For element not consider to shear stress and the circumferential stress equal to the principle stress, so $\sigma_1 = \sigma_2 = \sigma_t$ and $\sigma_3 = \sigma_r = 0$

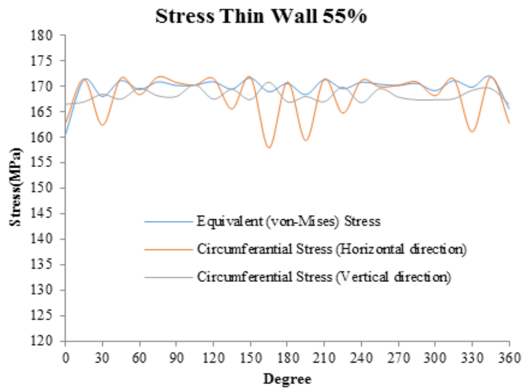

Fig. 25 The stress in various location of 55% of tank high

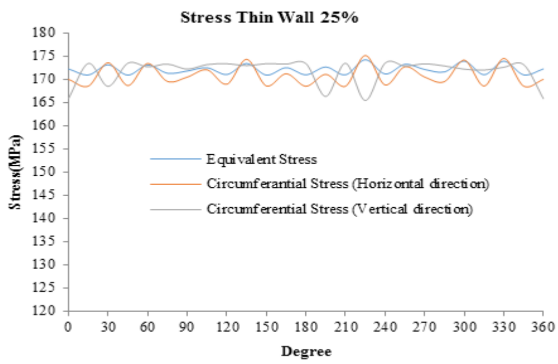

Fig. 26 The stress in various location of 25% of tank high

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2} \tag{8}$$

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7.2.3 Result of the simulation of the spherical tank column

A) Normal condition (Product contain 85% of tank volume). The deformation, while the spherical tank contain the product 85% of tank volume that has the total load as per each column apply to the top of column in Fig.27. The maximum deformation approximate 2.89 mm. at the top of column

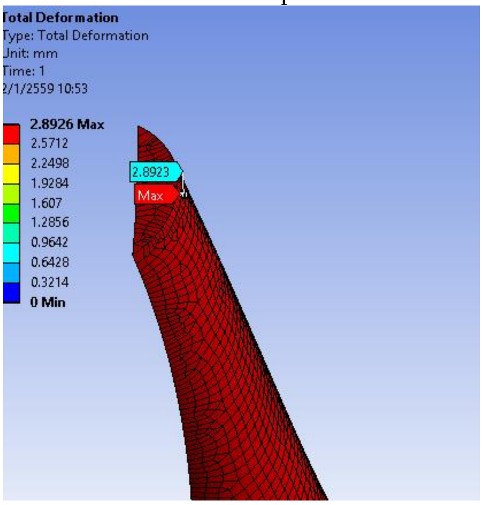

Fig. 27 The deformation of tank column in the normal condition (Product 85% of tank volume).

The stress distributed in the column during operate show in Fig.28 that found the stress distribute in tank column not exceed 138.9 MPa is the allowable Compressive Stress of this structure.

B) To under the wind condition with product contain 85% of tank volume. The deformation, while the spherical tank contain the product 85% of tank volume include the wind load in +X direction that has the total load as per each column apply to the top of column. The maximum deformation approximate 2.97 mm. at the top of column in Fig.29.

The stress distributed in the column during operate with the wind load in +X direction show in Fig.30 that found the stress distribute in tank column not exceed 138.9 MPa is the allowable Compressive Stress of this structure.

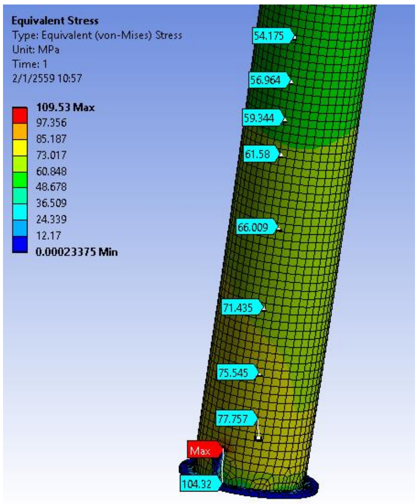

Fig. 28 The stress distribution in the column in the normal condition (Product 85% of tank volume).

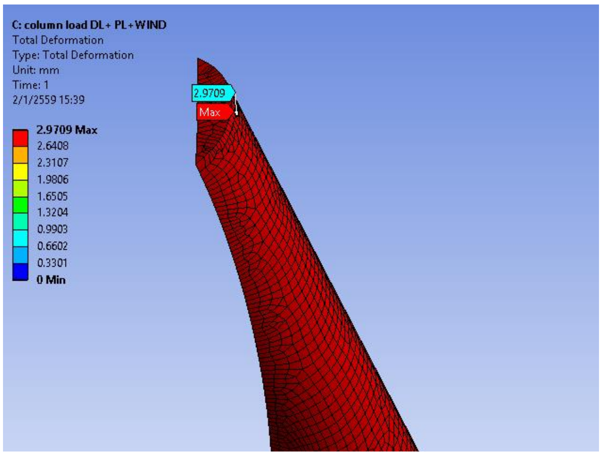

Fig. 29 The deformation of tank column under wind condition with product 85% of tank volume

C) To under the hydrostatic test condition. The deformation, during hydrostatic test of this tank by filled water full tank that has the total load as per each column apply to the top of column. The maximum deformation approximate 3.63 mm. at the top of column in Fig 31. The stress distributed in the column hydrostatic test of this tank by filled water full tank show in Fig.32 that found the stress distribute in tank column not exceed 138.9 MPa is the allowable Compressive Stress of this structure.

7.2.4 Result of simulation of the spherical tank column

A) Natural frequency response of spherical tank in various conditions. This analysis consider to 6 case of tank volume to contain product 85%, 65%, 50%, 35%, 20% and 0%. The natural frequencies are find as show in Table.11

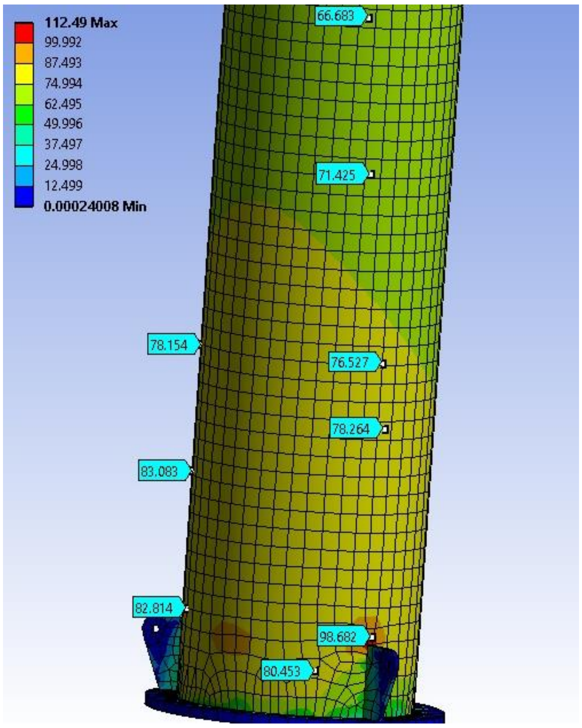

Fig. 30 The stress distribution in the column under wind condition with product 85% of tank volume

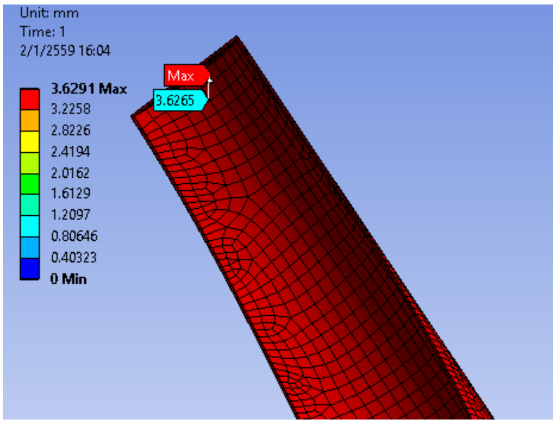

Fig. 31 The deformation of tank column under the hydrostatic test condition

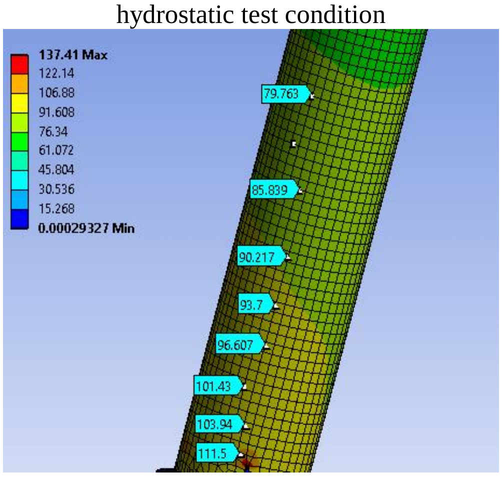

Fig. 32 The stress distribution in the column under the hydrostatic test condition

Table 10. Summary of study spherical tank column in various condition

Design condition	Deformation (mm)	Max. Stress (MPa)	Load multiplier
1.Normal condition (Product 85% of tank volume)	2.89	109.53	14.87
2.Under wind condition with product 85% of tank volume	2.97	112.49	14.47
3.Under the hydrostatic test condition	3.63	137.41	11.849

Table 11. The natural frequencies response in various conditions of product contain in mode shape 1.

Product Contain (% of tank volume)	**Frequency (Hz)**
0%	4.504
20%	2.1631
35%	1.7206
50%	1.4763
65%	1.3088
85%	1.1592

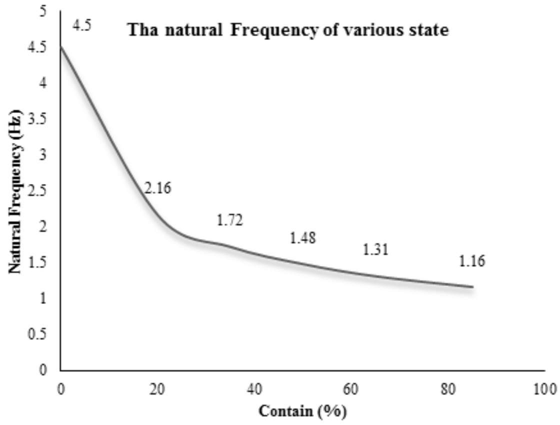

Fig. 33 The natural frequencies vs product contain in spherical tank

The natural frequencies depends on the volume of tank or mass product that following in the equation;

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \qquad (9)$$

When
f is the natural frequencies (Hz)
k is the spring constant (N/m).
m is the mass of tank (kg)

8. Summary and Conclusion

This study is analytical of strength of the spherical tank. The impact test was considered to the behavior of tank material have to stored liquid product at low temperature. Material thickness 32 mm. was done in impact test at –20ºC that result of impact test was satisfied

1) Analysis of spherical tank in various condition

a) The deformation of this study in tank normal condition has deform to any direction that effected from the internal pressure and mass of tank body include product storage. The result of study is satisfy condition that no damage or leakage to tank body.

b) The deformation of this study in tank hydrostatic test condition has deform to the bottom section of this tank that effected from the internal pressure and mass of tank body include hydrostatic pressure. The result of study is satisfy condition that no damage or leakage to tank body.

b) The analysis in the wind load condition has deform to wind velocity direction. The wind load in this study not effect to the tank support.

d) The buckling load multiplier is more than 14. The can be viewed as a safety factor as far as bucking is connected. It predicts that more than10 times of design load will initiate a buckling. The conclusion is that the structure won’t buckle under the design load.

2) The strength of material in tank bottom was focused on the weld joint in the flange component that had maximum load at that location. Maximum

deformation in this location is 7.5 mm. However, when compared with dimension of this tank that is not effect to tank structure. The maximum stress is 165 MPa. and factor of safety (FOS) is 3.58 that enough to operation of tank system.

3) The stress of tank shell plate in difference liquid level found the value of simulation were closed to the theoretical.

4) The modal analysis to find natural frequency in difference liquid level that inverse variation to natural frequencies.

6. Acknowledgement

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