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Assessment of Buckling Failure in Oil Storage Tanks: Finite Element Simulation of Combined Internal and External Pressure Scenarios

Themba Mashiyane[1*], Lagouge Tartibu[1], Smith Salifu[2]
[1]*Department of Mechanical and Industrial Engineering Technology, University of Johannesburg, Johannesburg, South Africa.*
[2]*Centre for Nanoengineering and Advanced Materials, University of Johannesburg, South Africa.*

Abstract

Investigating the structural behaviour and buckling susceptibility of cylindrical oil storage tanks is crucial for ensuring their safe and reliable operation. In this study, the structural behaviour and buckling susceptibility of closed roof-top cylindrical oil storage tanks under combined internal and external pressure scenarios were investigated using the finite element analysis (FEA) technique. By utilizing the FEA technique, the combined effect of wind-induced pressure of 250 Pa, applied on the outer surface of the tank and internal pressure of 0.5 MPa, applied on the outer surface of the storage was analysed. The result reveals significant stress concentrations and deformation patterns, particularly on the windward side of the tank, thus, emphasizing the susceptibility of the storage tank to buckling under the specified operating conditions for both the filled and half-filled tank; with internal pressure emerging as the primary contributor to mechanical strain and deformation experienced in the tank, while the wind load plays a secondary but significant role in the deformation of the tank. The fe-safe predicted useful life shows that under the specified operating conditions, the filled storage tank will survive 1 429 hours (2 months) while the half-filled tank will survive 3 551 hours (5 months) before failure due to buckling. Thus, the useful life estimation results show the importance of varying oil levels and operating conditions in the structural assessments of storage tanks.

Keywords: *Abaqus, buckling, external pressure, internal pressure, storage tank, fe-safe.*

1. Introduction

The global energy demand has driven the expansion of oil and gas infrastructure, thus, resulting in the widespread usage of large-scale storage tanks for the safe storage of petroleum products [1]. Among these storage vessels, oil storage tanks play a crucial role in maintaining the stability and integrity of the oil reserves [2]. Since these tanks are subjected to a myriad of environmental and operational conditions, their structural reliability becomes an important factor to consider when ensuring the safety of both the stored contents (oil) and the surrounding environment [2]. One of the critical failure modes that pose a significant risk to oil storage tanks is buckling, and this becomes pronounced when the tank is subjected to combined internal and external pressure scenarios [3].

In storage tanks, failure by buckling occurs when the applied load exceeds the structural capacity of the tank, thus, leading to a sudden and catastrophic collapse. Oil storage tanks are thin-walled cylinders and their buckling can manifest as deformation, distortion, or outright rupture of the tank walls, and these potentially result in environmental contamination, loss of valuable resources, and posing a threat to human safety [1]. Understanding and preventing the risks associated with storage tank buckling is imperative for storage tank users, be it the oil and gas industry or the powder generation industry, as

Corresponding author: *Themba Mashiyane (tmashiyane12@gmail.com)*
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doing this ensures the reliability and longevity of these essential storage facilities [4-6].

Given the nature of the large storage tanks, a good understanding of the combined effect of internal and external pressures on storage tanks is very crucial. Internal pressures in the storage tanks arise from the stored contents, while external pressures may result from factors such as wind loads, seismic events, or adjacent storage tank operations. Investigating the interaction between these pressure scenarios is essential for accurately assessing the structural vulnerabilities of oil storage tanks and implementing robust design and maintenance strategies [7].

The buckling behaviour of oil storage tanks has been the subject of extensive investigation by various researchers over the past decades [8]. In the year 1950, Donnell and Wan [9] researched on the impact of imperfections on the buckling behaviour of thin cylinders, by employing large-deflection shell theory. Their findings indicated that buckling may manifest with an elastic response or be triggered by yielding. In a related study, Miller [10] conducted a comparative analysis of small-scale ring-stiffened steel cylinders and larger-radius fabricated ring-stiffened steel cylinders. The study provided elastic buckling coefficients for both small and large-scale cylinders and plasticity factors for those undergoing inelastic buckling. In 1999, an experiment conducted by Singer [11] revealed that cylindrical shells tend to buckle locally, particularly when initial geometric imperfections are substantial. Seung-Eock and Chang-Sung [12] explored the buckling behaviour of cylindrical shells, and they highlighted a significant decrease in buckling strength as the amplitude of initial geometric imperfections increases.

Buckling in storage tanks is commonly associated with external forces such as wind and earthquakes [13, 14]. Uematsu et al. [15-17] made notable contributions to understanding wind-induced buckling in storage tanks. Their work involved wind tunnel experiments used in the investigation of pre-buckling deflections and critical buckling wind pressure for closed-top tanks [16], by considering the influence of stiffeners [17]. Over the years, several studies based on numerical simulations were also conducted. In one of such study, Schmidt et al. [18] performed both experiments and finite element analyses, thus, providing recommendations for an economic post-buckling strength design strategy for storage tanks. Sosa and Godoy [19] in another study implemented a lower-bound approach for the buckling of imperfection-sensitive shells using finite element simulations. In a related study, Jaca and Godoy [20] focused on the buckling of steel tanks during construction, with emphasis on the inadequacy of design steps in predicting wind-induced buckling during construction. Utilizing the finite element method, Zhao and Lin [21] examined the linear and nonlinear buckling of storage tanks, by considering different sizes and height/diameter ratios with imperfections. Based on their findings, they concluded that the buckling resistance of storage tanks under wind loads is approximately 25–50% higher than under uniform external pressure. By studying the impact of simplified rooftop and wind girder modelling [22]; and wind pressure distribution on tanks shielded by other tanks [23], Burgos et al. [22, 23] also contributed to the understanding of storage tank buckling behaviour. Shokrzadeh and Sohrabi [24] investigated the effect of external and internal corrosion on wind buckling resistance, by considering the reduction of critical buckling loads due to these damages. More recent publications have explored wind turbulence dynamic characteristics [25], wind girders' effects [26, 27], and buckling analyses based on the American and European design codes [8, 28].

This study utilizes finite element analysis (FEA) techniques in the simulation and assessment of the buckling behaviour of cylindrical closed roof-top filled and half-filled oil storage tanks when subjected to internal and external pressure loads, thus, providing valuable insights into the dominant factor influencing buckling susceptibility of storage tanks.

Table 1. Oil Storage Tank Dimension.

Tank Parts	Height (m)	Outer Diameter (m)	Inner Diameter (m)	Thickness (m)
Cone shape top	0.770	0.975	1.015	0.01
Cylindrical section	10.077	7.076	7.096	0.01
Vent	0.156	0.100	0.120	0.01

2. Methodology

In this study, a finite element analysis (FEA) approach is employed to assess the structural behaviour of an oil storage tank under combined internal and external pressure scenarios, specifically by incorporating the effect of wind-induced pressure on the outer surface of the tank. The primary objective is to investigate the tank's response to both internal pressure and external pressure due to wind loading, thus, providing comprehensive insights into the stress, strain, displacement, and buckling characteristics of the tank under typical operating conditions. The analysis is carried out using commercial finite element analysis software, Abaqus, while the computational post-processing of the FEA result is performed by utilizing fe-safe software.

2.1. Model development

The model of the oil storage tank is developed using FEA software, Abaqus. Figure 1 illustrates the tank model, which is based on the design commonly utilized in oil storage applications in the power generation company. The dimensions of the S355 low-carbon steel utilized in the development of the oil storage tank are provided in Table 1, while its material properties and the properties of the diesel oil stored in the tank are detailed in Table 2.

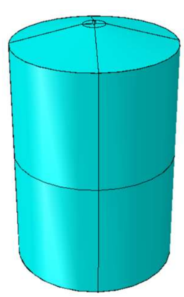


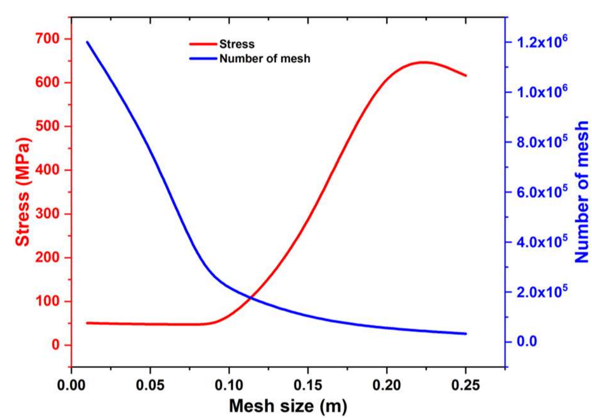
Figure 1. Developed model of oil storage tank.

2.2. Mesh convergence study and mesh type

To ensure the accuracy of the FEA, a mesh convergence study is required to determine the optimal mesh size [31-35]. Figure 2(a) displays the results of the mesh convergence study which was conducted by gradually reducing the mesh size until the desired results with a reasonable computational time was obtained. A free text mesh type with 400,872 nodes and 201,023 quadratic tetrahedral elements of type C3D10, utilizing a mesh size of 0.10 m, is found to be suitable for the analysis, as this mesh size resulted in a balance in the computational efficiency and result integrity. The mesh model of the oil storage tank is presented in Figure 2(b).

Table 2. S355 low-carbon steel material properties used for the oil storage tank [29] and properties of diesel oil [30] stored in the tank.

Property	Value
Modulus of Elasticity (GPa)	202.60
Poisson's Ratio	0.277
Yield Strength (MPa)	1139.30
Density (kg/m^3)	781.30
Thermal Expansion (K^{-1})	1.296×10^{-5}
Thermal Conductivity (W/(mK))	14.85
Specific Heat Capacity (J/kgK)	531.40
Density of diesel (kg/m^3)	840.00 [30]
Specific volume of diesel (m^3/kg)	1.18×10^{-3} [30]



(a)

(b)

Figure 2. (a) Plot for mesh convergence study and (b) oil storage tank mesh model.

2.3. Loading and boundary conditions

Incorporating external pressure from wind and internal pressure due to the height and density of the liquid (diesel) stored and any possible pressure build up in the tank due to vacuum, and during discharge in the tank, the loading and boundary conditions are defined to mimic the realistic operational conditions of oil storage tanks. Based on the density and the level of fluid in the storage tank and other conditions such as faulty vent and pressure build-up during discharge, an internal pressure load of 0.5 MPa was specified in the interior surface of the filled and half-filled tanks while an approximate pressure of 250 Pa, due to wind velocity at 20 m/s computed using Equation 12 was specified on the outer surface of the tank in windward direction for both scenarios considered as illustrated in Figure 3.

Similar to the other closed rooftop storage tanks, the boundary conditions applied to the tank are such that the top of the tank is subjected to displacement/rotational boundary conditions in the X and Z axes, thus, allowing displacement in the Y axis, (X=0, Y=1 and Z=0), while the base of the tank is fixed (Encastre) (X=0, Y=0 and Z=0) as depicted in Figure 3.

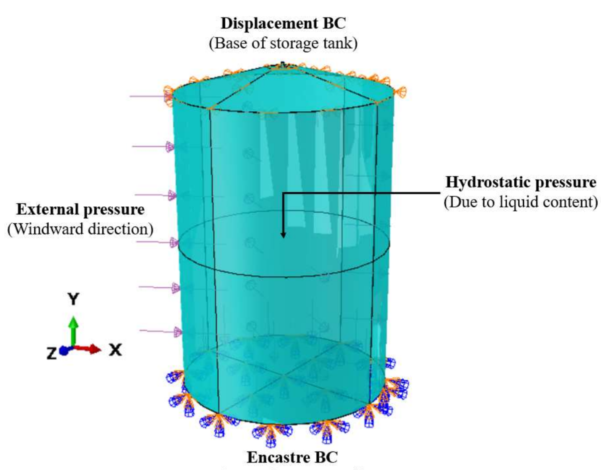


Figure 3. Storage tank loading and boundary conditions.

2.4. Analysis steps

Two distinct steps are specified in Abaqus to analyze the tank's behaviour. A static general step is designated to determine stress and strain under the stated operational conditions, while a buckling step is introduced to identify potential mode shapes and the buckling pattern induced by the combined internal and external pressure scenarios.

2.5. Useful life

To evaluate the useful life of the tank under the specified conditions, fe-safe, a post-processing software is utilized. The output database (.odb) obtained from the stress analysis is imported into fe-safe and the nodal stresses and strains are then employed to predict the lifespan of the tanks under the combined effects of internal pressure, external pressure from wind, and the tank's design parameters.

3. Tank Buckling Analysis and Mathematical Expressions

3.1. Structural prototypes

The analysis focuses on a fixed roof tank with a cone-like top shape, a common design found in power generation industries in South Africa for oil storage.

3.2. Internal and external loads/pressure on Tanks

The internal pressure (P_I) in a cylindrical tank, caused by the liquid it contains, is calculated using the formula:

$$P_I = \rho g h \qquad (1)$$

where ρ is the liquid density, g is the acceleration due to gravity (9.8 m/s²), and h is the height of the cylindrical tank.

For external pressure, the applied pressure is divided into wind load (P_w) and uniform external pressure. The wind pressure distribution on cylindrical tanks is expressed as:

$$P_w = c_p q(z) \qquad (2)$$

where c_p is the wind pressure coefficient, and $q(z)$ is the wind velocity pressure, varying with the tank's height. The wind pressure coefficient is further defined by a Fourier series decomposition (Equation (3)) [3, 36].

$$c_p(\theta) = \sum_{i-0}^{m} a_i \cos(i\theta) \qquad (3)$$

For open-top tanks, an additional negative wind pressure coefficient is subtracted using Equation (4), accounting for internal suction pressure [3, 36].

$$c_p(\theta) = \sum_{i-0}^{m} a_i \cos(i\theta) - \begin{cases} 0.8 & H/D \geq 2 \\ 0.5 & H/D \leq 1 \end{cases} \qquad (4)$$

where the height and diameter of the open-top storage tank are represented by H and D, respectively.

3.3. Linear buckling analysis

Utilizing linear elasticity theory, the analysis of the linear buckling of small displacement and strain under external/internal forces is possible, and a sudden jump in the configuration of the tank under one or the combination of these forces, termed buckling, occurs when the applied load reaches a critical value. This study focuses on stress/strain development and buckling due to combined internal pressure and external pressure in the windward direction.

3.4. Analytical calculation of uniform pressure on storage tanks

For tanks subjected to external uniform pressure, the developed critical pressure can be calculated using various methods. According to GB50341-2014, the critical pressure (P_{UT1}) is determined as follows [3]:

$$P_{UT1} = 16000 \times \frac{t_{min}^{2.5}}{D^{1.5}H} \quad (5)$$

Another method, for the calculation of the critical pressure, is based on Donnell's numerical calculation, and it can be expressed as [3]:

$$P_{UT2} = 2.59 \times \frac{Et^2}{HD \times \sqrt{D/t}} \quad (6)$$

According to GB150-2011, the critical pressure (P_{UT3}) is calculated as [3]:

$$P_{UT3} = 2.60 \times \frac{(D/t)^{-2.5}}{(H/D) - 0.45(H/t)^{-0.5}} \quad (7)$$

Nevertheless, for tanks with stepped shells, the equivalent height (H) and thickness (t) are computed using Equations (8) and (9) [3].

$$H = \sum h_i \sqrt{\left(\frac{t_{min}}{t_i}\right)^5} \quad (8)$$

$$t = t_{min} \quad (9)$$

where, t_{min} is the thinnest shell thickness, D is the diameter of the tank, h_i is the height of the shell course, and t_i is the thickness of the shell course.

3.5. Stress developed in thin-walled cylinder

As the considered oil storage tank has a diameter-to-thickness ratio exceeding 20, it is classified as a thin-walled cylinder. Based on these, the hoop/circumferential stress (σ) in a thin-walled cylinder is determined by [37]:

$$\sigma = \frac{P_I d}{2t} \quad (10)$$

while the stress developed in the longitudinal direction in the cylinder is given as [37]:

$$\sigma = \frac{P_I d}{4t} \quad (11)$$

where P_I is the internal pressure, d is the diameter, and t is the thickness of the cylinder or tank.

3.6. Wind pressure

The force exerted by wind on a structure such as a cylindrical tank due to the movement of air molecules is termed wind pressure. The pressure often causes structural deformation, stress, and even failure if not properly accounted for in design and construction. The expression for computing the pressure exerted on a structure due to the wind speed, V is given as follows:

$$P = 0.0025 \times V^2 \quad (12)$$

where V is the wind speed in miles per hour (mph), and P is pressure in pounds per square foot (psf).

4. Results and Discussion

4.1. Stress and strain developed in the storage tank

The result of the finite element analysis (FEA) in Figure 4 (a) provides crucial insights into the structural behaviour of the filled oil storage tank under combined loading conditions. In the windward direction, a significantly high von Mises stress of 485.4 MPa was obtained, and the value of this stress exceeds the yield strength of the tank material, while a maximum principal strain of 2.095×10^{-3} was obtained. The high stress and strain developed in the tank indicate a high likelihood of plastic deformation under the specified operating conditions. This implies that the tank, subject to an internal pressure of 0.5 MPa and a relatively low external wind pressure of 250 Pa, experiences significant mechanical strain, primarily due to the internal pressure. The stress concentration from the contour plot on the windward side of the storage tank confirms that this region encounters the maximum combined effect of internal and wind pressures which results in high stress and strain levels observed in the region. The pattern of stress and strain distributions on the tank such that the least stress was found on the side opposite the windward direction shows the contribution of wind pressure to the stress and strain developed on the filled tank [26].

When the analysis was conducted on the tank when half-filled as depicted in Figure 4(b), The contour plot of stress distribution reveals critical points, with the maximum stress of 388.7 MPa concentrated at the base of the tank near the windward side. Thus, indicating the vulnerability of this region of the tank to failure especially when the maximum developed stress exceeds the yield strength (355 MPa) of the tank material under the stated loading conditions. Just like the stress pattern, the strain distribution of the contour plot indicated that the highest strain (1.778×10^{-3}) occurs at the base of the oil storage tank. The observed location of the stress and strain concentrations on the storage tank aligns with theoretical expectations for thin-walled cylindrical pressure vessels, where the windward side experiences elevated external pressure that results in an outward deformation and increased stress and strain in the region, while the opposite side experiences minimal loading effects [26, 38].

Comparing the FEA results of the filled and half-filled oil storage tanks, notable differences in stress and strain distributions under the stated loading conditions were observed. While both tanks experience significant mechanical strain due to internal pressure and wind load, the filled tank exhibits a higher maximum von Mises stress of 485.4 MPa compared to 388.7 MPa for the half-filled tank. Additionally, the filled tank demonstrates a slightly higher maximum principal strain of 2.095×10^{-3} compared to 1.778×10^{-3} for the half-filled tank. Despite these disparities, both tanks exhibit stress concentrations on their windward sides, indicating the combined effect of internal pressure and wind load. However, the stress developed in the half-filled tank is concentrated at the base, thus emphasizing the vulnerability when the developed stress exceeds the yield strength of the tank material. Furthermore, the result of the analysis highlights the dominant role of internal pressure in contributing to the overall stress developed in the tank.

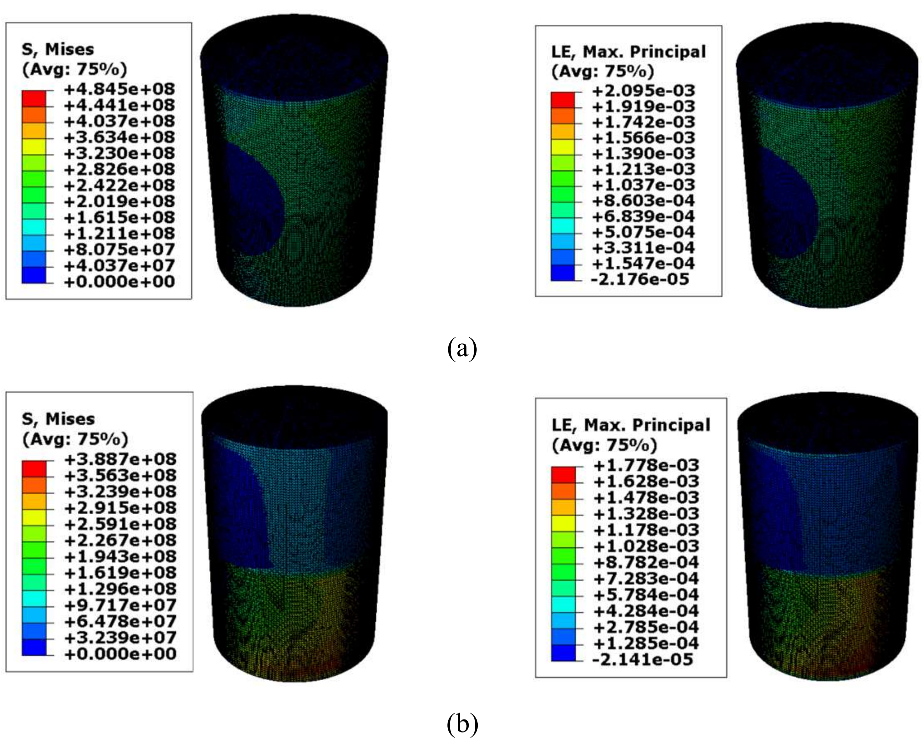
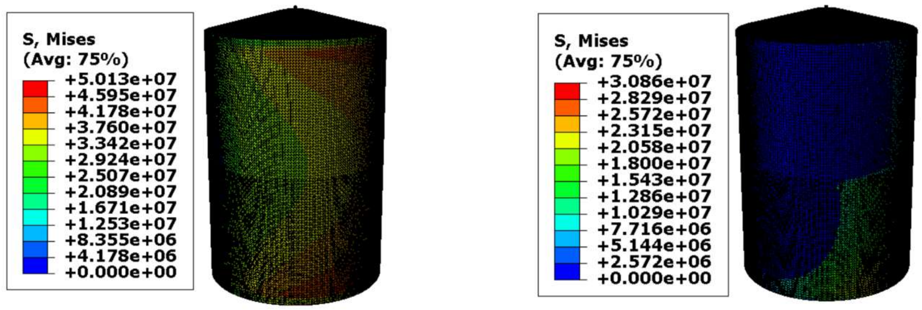


Figure 4. Stress and strain developed on (a) filled and (b) half-filed oil storage tank under external wind pressure and high internal pressure.



(a) (b)

Figure 5. Hydrostatic stress developed in the oil storage tank when the tank is (a) filled and (b) half-filled with oil.

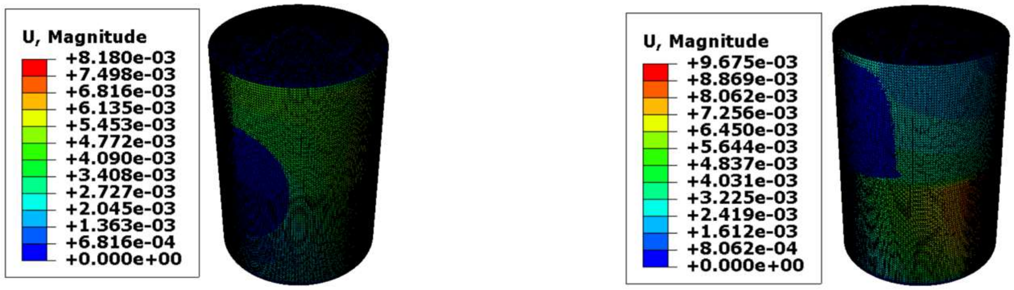
While the wind pressure was discovered to amplify the stress levels, its impact is comparatively low compared to the internal pressure. Hence, the difference between the internal pressure applied and the hydrostatic pressure due to the stored liquid suggests that other potential factors such as thermal expansion or gas evolution during product discharge, or faulty valve etc could be responsible for the high stress induced in the tank. Due to the complexity of the tank and the operating condition it is subjected to during service, validating the results obtained analytically becomes practically difficult. In order to accurately validate the results of the developed model, the complexity of the operating conditions needs to be reduced. Thus, only the hydrostatic stress induced in the tank due to the hydrostatic pressure exerted on the tank by the liquid it contains was used as the basis for the validation of the developed model. Figure 5 (a) and (b) depict the stress developed in the storage tank when it is filled and half-filled, respectively. For the filled tank, the maximum hydrostatic stress developed due to the level of the oil it contains is 50.13 MPa while the maximum hydrostatic stress developed when the tank is half-filled is 30.86 MPa.

4.2. Displacement in the Storage tank

In the filled oil storage tank scenario depicted in Figure 6(a), the finite element analysis revealed that the deformation of the tank is primarily due to the internal pressure rather than the external wind load, and the maximum displacement (0.00818 m) occurred in the windward direction due to high internal pressure. Conversely, the leeward side of the tank experienced minimal displacement due to the lower external pressure. The significant difference between the internal and external pressures favours the dominance of internal pressure in influencing the deformation of the tank [26].

On the other hand, the FEA result of the half-filled oil storage tank (Figure 6(b)) shows that both internal pressure and wind load were considered and the internal pressure which was significantly higher than the hydrostatic pressure of the liquid was the predominant factor responsible for the pattern of displacement obtained. Despite the relatively small external wind pressure as compared to the internal pressure the tank was subjected to, the external pressure still contributed to the overall loading behaviour of the tank. The displacement pattern of the half-filled tank showed that the maximum displacement (0.009675 m) occurred towards the bottom of the tank in the windward direction, while minimal displacement occurred towards the top in the leeward direction, thus, conforming to the expected behaviour of thin-walled cylinders under wind-loading.

Comparatively, while both tank configurations experienced displacement towards the windward direction due to the applied pressure differentials, the filled tank exhibited a more pronounced response to internal pressure, with wind load playing a secondary role. In contrast, the half-filled tank demonstrated a more balanced interaction between internal pressure and wind load, with both factors contributing to the observed displacement pattern. Despite these differences, both tanks displayed deformation characteristics which are consistent with their loading conditions.



(a) (b)

Figure 6. Displacement in (a) filled and (b) half-filed oil storage tank under external wind pressure and high internal pressure.

4.3. Buckling behaviour of tank

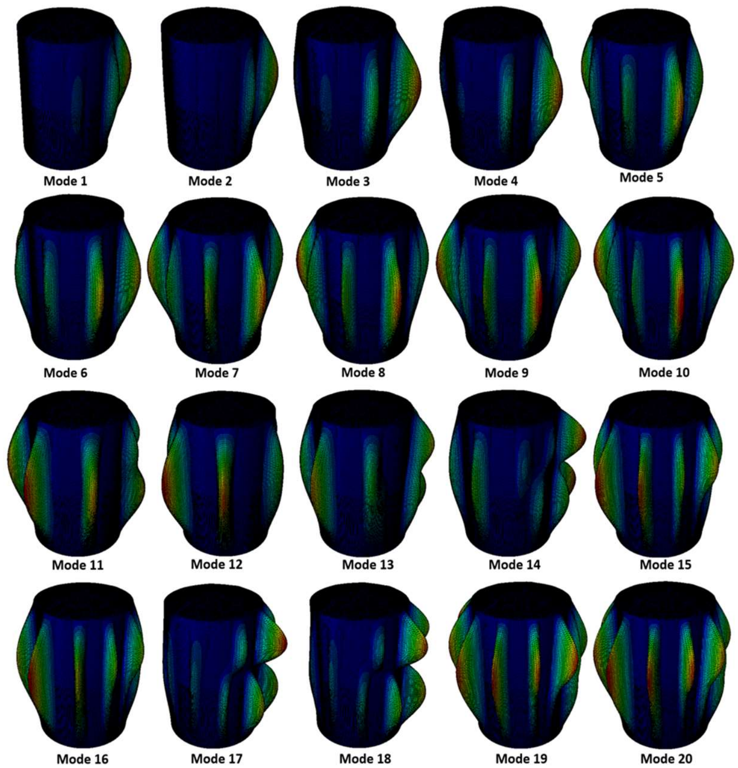
Figure 7 depicts the FEA results for the buckling contour plots of the first 20 eigenvalue buckling mode shapes for the filled and half-filled oil storage tanks under combined high internal pressure and wind-induced external pressure, and the plot provides crucial insights into the buckling behaviour of the storage tank under the specified loading conditions. The results of the analysis reveal that both tanks are susceptible to buckling under the specified loading conditions, and the initiation of buckling observed when the tank is filled and half-filled is predominantly in the windward direction.

The first 20 modes of both the filled and half-filled tank provide valuable insights into the deformation patterns exhibited by the tank under the two oil levels. As expected, the first four modes showcase an outward bulging which is particularly prominent on the windward side of the tanks. This phenomenon arises from the significant pressure gradient that emanates from the high internal pressure and the low external pressure induced by wind velocity on the tank [38]. This gradient from the difference in both induced pressures results in a net force acting on the tank walls, thus, causing the tank to deform towards the higher pressure region. Consequently, the high internal pressure exerts an outward force on the interior surface of the tank, while the wind-induced low external pressure pulls inward on its exterior surface. The combination of these forces results in a net force directed outward on the windward side of the tank such that it causes the tank to bulge in the windward direction as it seeks to relieve the pressure differential between its interior and exterior surfaces [38]. This initial deformation creates stress concentrations that propagate across the tank in subsequent modes, leading to more complex buckling patterns as experienced in the higher modes (mode 5 to mode 20).

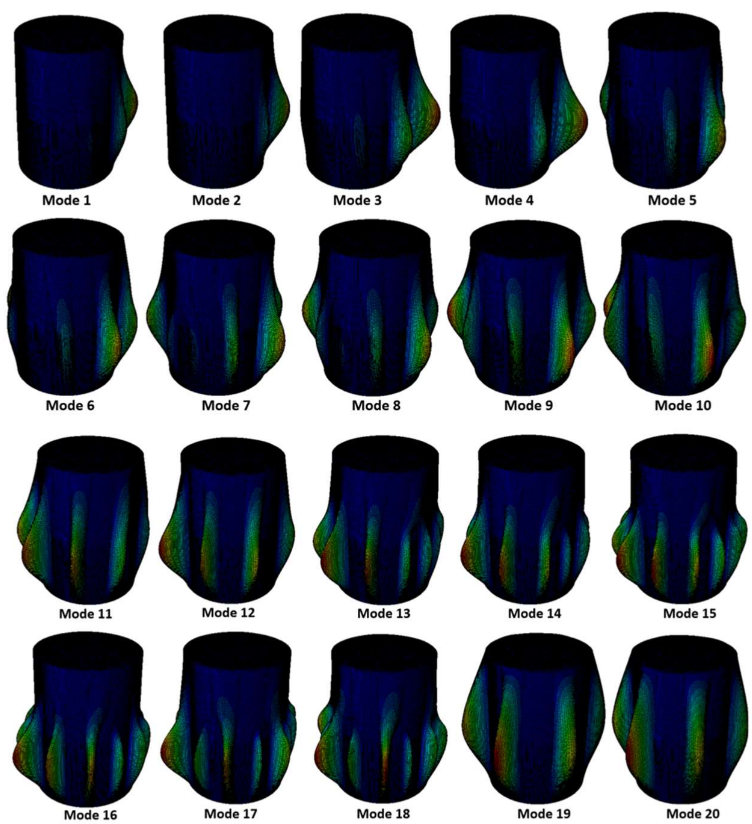
The comparison buckling behaviour of the filled and half-filled tanks offers valuable insights into how the buckling behaviour of storage tanks is affected by the level of fluid they contain. Despite similarities in the initiation of buckling in the windward direction for both tanks, notable differences were observed in the distribution and severity of their deformation. In the case of the half-filled tank (Figure 7 (b)), the bulging is more pronounced between the middle and bottom sections as compared to the more centralized buckling observed in the filled tank. This discrepancy highlights the influence of fluid distribution on the structural response because the presence of fluid has been discovered to alter the stress distributions and deformation patterns within the tanks.

4.4. Useful life estimation

The ability to accurately determine the useful life of oil storage tanks when subjected to varying oil levels and operating conditions is crucial for ensuring safety, reliability, and cost-effectiveness in industrial operations. To determine the useful life of the tanks under the specified operating conditions, the stress and strain results obtained from the stress analysis were exported and used in fe-safe postprocessing software. Based on the processed stress and strain results, the fill storage tank is expected to survive 1429 hours before failure while the half-filled tank is expected to survive 3551 hours before failure, as shown in Figure 8.

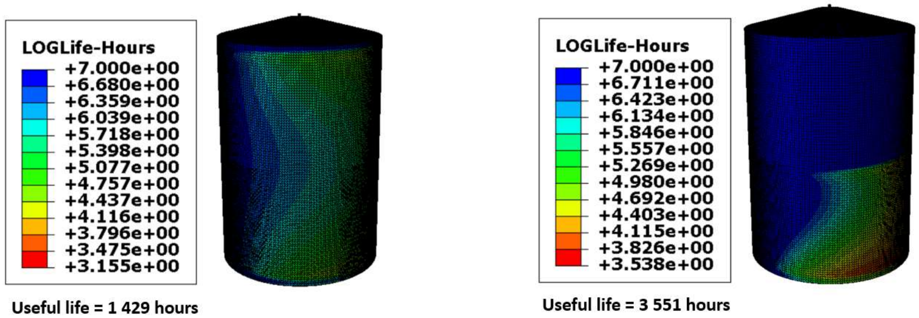


(a)



(b)

Figure 7. First 20 buckling mode shape of storage tank when (a) filled and (b) half-filled with oil, and under the influence of high eternal wind pressure in the windward direction and high internal pressure.



(a) (b)

Figure 8. Useful life of oil storage tank under specified operating conditions when (a) filled and (b) half-filled.

The contour plots of the useful life for both tanks show that the worst life was obtained towards the bottom of the tank in the windward direction. The disparity in the useful life of the tanks under the different operating conditions suggests that the structural integrity and durability of the tank are heavily influenced by the distribution of internal and external stresses, which are inherently different under the operating conditions considered. The analysis of the contour plots of both tanks shows that the red regions located toward the base of the tank in the windward direction on the plot represent the areas with lower useful life and are more prone to failure while the blue region indicates the area with higher useful life [39].

4.5. Validation of FEA results

Owing to the complexity of the tank model when subjected to loading conditions other than the hydrostatic pressure due to the liquid it contains, the validation of the model becomes practically impossible. However, the stress developed in the tank when subjected to only hydrostatic stress is used as the basis for the validation in this study. Employing analytical techniques with expressions shown in Equations (1 and 10-11), the finite element analysis (FEA) results for the hydrostatic pressure developed in the oil storage tank as shown in Figure 5 were appropriately validated. The obtained analytical results exhibit strong agreement with the FEA results. Thus, increasing the confidence, reliability and accuracy of the computational model employed in the simulations. Such alignment between analytical predictions and FEA results further substantiates the robustness of the approach used and enhances the credibility of the results presented in the study. Table 3 shows and compares the FEA and analytical stress results obtained for the oil storage tank for the two different hydrostatic pressure (filled and half-filled) conditions considered.

Table 3. Analytical validation FEA results of the oil storage tank.

Tank	Computed Stress (MPa)		Percentage Deviation (%)
	Numerically	Analytically	
Filled tank	50.13	52.10	3.78
Half-filled tank	30. 86	29.35	5.14

5. Conclusion

The structural integrity of filled and half-filled oil storage tanks subjected to a combined internal pressure and external pressure in the windward direction was determined using FEA technique. Through these techniques, the stress, strain, displacement, buckling behaviour and useful life of the cylindrical storage tank were determined for the two oil level conditions, and under the specified operating conditions. The FEA results revealed significant stress concentrations and deformation patterns, particularly on the windward side of the tank, thus, indicating the susceptibility of such structures to buckling under specified operating conditions.

Furthermore, the results of the analysis provided valuable insights into the factors that influence buckling susceptibility in the storage tank. Internal pressure was identified as the predominant factor contributing to mechanical strain and massive deformation experienced in the tanks, while wind load was identified to play a secondary but significant role in the deformation of the tank. The fe-safe estimated useful life of the storage tank under the specified operating conditions shows the role of varying oil levels and operating conditions in the structural assessments of thin-walled cylinders, as the fluid distribution and stress levels tend to significantly affect the useful life of the structures. Finally, the hydrostatic stress developed in the storage tank when filled and half-filled was validated analytically and the FEA computed results and the analytically calculated results are in good agreement, thus, giving credence to the developed model and the FEA technique used in this study.

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Author contributions

This work was carried out in conjunction with all authors. The role of each author is as listed below:

Themba Mashiyani: Conceptualization, Methodology, Software, Investigation, analysis, Writing − original draft preparation. Lagouge Tartibu: Supervision, analysis, Writing − review & editing. Smith Salifu: Analysis, Writing − review & editing

Availability of Data and Materials

Data will be made available upon request.

Competing Interests

No potential conflict of interest was reported by the author(s).

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