

# Analysis of Hydrodynamic Performance in Flexitank Applications with Varying Strap Configurations Using CFD

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## Abstract

Liquid sloshing is a fundamental challenge in the structural design of flexitank used for liquid transportation. Thus, flexitank is one of the alternative ways for transporting the fluid package. However, there are some cases reported by industry regarding the leakage of the flexitank during transportation. The purpose of this study is to analysis of hydrodynamic performance in flexitank application with varying straps configurations using CFD. In this study, the straps act like a baffle in the ISO tank. There are several types of straps configurations in this study which are the number of straps and depths of straps likes one strap, two straps and three straps for the number of straps, while the depts of straps are 1/3, 1/2 and 2/3 of height the flexitank. Hydrodynamic measurements of pressure and wall shear stress established the ideal strap arrangements for latex-based flexitank storage systems. The results showed that different strap arrangements modify the hydrodynamic behavior of flexitanks, that increasing both depth and strap concentration results in altering the flexitank structure negatively. Since the acceleration phase of condition, the flexitank's elastic equivalent pressure reaches its highest value at its back-top location.

## 1. Introduction

Supply chain operations put the most importance on transportation development because it handle product movement from production to end-use demand locations. The transportation process moves products from manufacturing locations to customer demand destinations [1]. Transportation effectiveness determines the success of supply chain operations through chosen modes of movement between shipment points. Proper transportation choices are vital because they directly determine supply chain operational efficiency and associated cost effectiveness [2].

Bulk liquid transportation stands as a significant mode for fluid package distribution through either maritime or surface routes. The shipping method for bulk liquid supplies tankers the liquid in a tank truck without tanks or drums. These tanks receive the same transportation services as ordinary truckload shipments. The principles behind liquid transport demand careful attention to multiple performing aspects. Liquid cargoes comprised of chemicals and liquefied natural gas and crude oil are transported through automated systems. packaged. Loadmaster operatives conduct both the holding procedures and vacuuming processes for big liquid storage areas on Parcel Tankers which professionals. Bulk liquids transportation occurs through standard International Standardization Organization (ISO) containers together with plastic flexicontainers which operate

through multiple different trailer types. Bulk tankers remain the main storage method for all types of liquids within the shipment transportation sector.

The flexitank is available in different shape and capacities to meet various application depending on the mode or transport. For instance, the Middle-Duty (K-LEX) used in the research is made by LiquA Europe SLU, the R-Flex (20ft) used is produced by DHL Logistics, while the E-Flex used is manufactured by Liqua Europe [3,4]. Industrial products that can be conveyed using flexitanks include detergents, lubricants, fertilizers, latex and paints with the size depending on the density or specific gravity of the liquid [5]. They are also equally appropriate for disgusting food grade liquids such as oils, milk, juices, wines, and fructose syrups that may call for special coatings to counteract microbial intrusion. The most common product being transported through flexitanks is latex since the production of flexitanks mode of transport is cheaper. Also, because they are single-use, the latex used is never compromised thus its quality and properties remain intact [6].

Another interesting feature that is usual in tanks, including the ISO has, baffles are in purpose to increase safety and stability by decreasing movement of the stowed liquid (sloshing). These internal plates or partitions partition the tank into compartments so there will be interrupting of the momentum of liquid in the tank as well as enhancing balance especially in the half filled tanks [7]. Like belts in flexitanks, straps are used in the same way to prevent the movement of liquid within the transport tubes. Though, baffles and straps operates in distinct ways, they are made for the purpose of controlling movement of liquids properly. Belts fix the external frame of the flexitank to the interior of the container so that it cannot move or stretch inside. On the other hand, baffles in iso tanks subdivide the tank into smaller sections to minimize surging of liquids and control sudden heave [8].

Previous research investigated how different flexitank capacities with various liquid densities affect hydrodynamic performance. Hydrodynamic studies compared the flexitank model at three different filling levels which exceed Container Owner Association (COA) recommended rated capacities by 1% and 2% and 3%. Results demonstrate how changes in liquid filling threshold influenced flexitank hydrodynamic response behavior. Post these quantitative boosts water-filled flexitanks demonstrated three percent additional structural harm while latex-filled flexitanks plus CPO required a single percent elevated total deformation during testing. During braking events the front-top area of the flexitank structure experiences its maximum elastic equivalent strain condition [9].

Hydrodynamics is highly important to engineers when dealing with water flow through pipelines and structure like the tank baffles. It assists in forecasting customary flow disruptions like turbulence and congestion that is significant in different applications like in the development of water dams. Previous research mostly centered on two-dimensional studies of inviscid fluids with original  $\sigma$ -transformed mappings and numerical methods such as the pseudo-spectral and finite element [10].

The Blender is a software which performs 3D creations which includes modeling, animation, simulation, rendering and motion tracking. This proof is its flexibility in sharp application, and the ever-growing number of users that have been lively to its modernization. Blender is applied in industrial design to establish virtual models of the products to be manufactured and used in product emulation for marketing purposes slashing the time and cost of physical modeling. Computational Fluid Dynamics (CFD), based on accurate measurements of flow velocity profiles, can be used to assess the discharge coefficients for a relatively low cost compared to physical experiments. Interestingly, CFD has been an empirical substitute for experiments to give accurate and useful information [11].

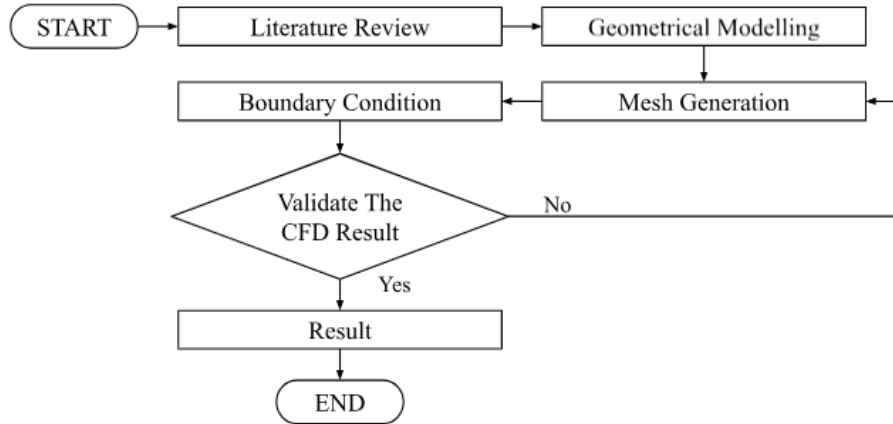
In this study, the strap layout of the flexitank is given special attention as the research investigates one-strap, two-strap, and three-strap solutions with strap lengths of 1/3, 1/2, and 2/3 of the flexitank's height. Geometry modeling is carried out using Blender, while the hydrodynamic pressure and analysis of the sloshing effects are carried out using Computational Fluid Dynamics Analysis using ANSYS. CFD is then shown to offer a more sound methodology for evaluating sloshing behavior and the related hydrodynamic effects such as turbulence in the flexitank. The study also seeks to advise on the most appropriate strap positioning that would reduce the impacts of sloshing and guarantee the efficiency of the flexitank in transit.

The study aims at solving crucial issues arising from leaks that are caused by movement of contents in flexitanks. For example, MY Flexitank Industries Sdn Bhd in 2021 received over 50 cases of latex failures as a result of wrong manipulate and large fluid transfers [12]. In contrast to ISO tanks equipped with baffles to minimize rolling, flexitanks rely upon straps, for best configurations of which have yet to be most thoroughly determine. The objective of the study is to design a flexitank with straps and its hydrodynamic characteristics compared with the straps are compared; in addition, an optimal strap layout is suggested.

## 2. Methodology

### 2.1 Research Flowchart

Figure 1 illustrates a process flowchart, illustrating the research process from start to finish, using symbolic shapes and arrows to indicate decision points. The chapter also includes a literature review of relevant journals, research papers, and articles on flexitank simulation.



**Fig. 1:** Research Flowchart of The Study

### 2.2 Flexitank Geometry

MY Flexitank Industries Sdn Bhd uses flexitanks with a thin, linear-low density polyethylene (LLDPE) package with a 21,000-liter filling volume. The 3D model was created using Blender 4.1, and the dimensions of the flexitank are shown in table 1. The thin layer thickness reduces interaction between bodies.




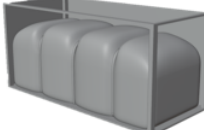
**Table 1:** The dimensions of the flexitank

Description	Specification
Length	3,028 mm
Height	2,362 mm
Width	2,223 mm

### 2.2 Configurations of Strap on Flexitank

The study investigated the use of straps as baffles around a flexitank to minimize sloshing. Different configurations of straps were used, one strap, two straps, and three straps with depths ranging from 1/3, 1/2 and 2/3 from the height of the flexitank. The straps were made of lightweight polypropylene webbing, with a breaking strength of at least 5,000 kg. The study also examined the effects of free surface wave elevation and hydrodynamic pressure on the tank wall. The results are presented in Table 2.

**Table 2:** The Configuration of the straps that will to the flexitank

Description /Depths	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{2}{3}$
	x	x	x
Flexitank with no strap			
	✓	✓	✓
Flexitank with one strap			
	✓	✓	✓
Flexitank with two straps			
	✓	✓	✓
Flexitank with three straps			

### 2.3 Geometry meshing

The figures 2 show 3D model of flexitank was imported from Blender 4.1 software and the geometry mesh was created in ANSYS software. Meshing is a crucial step in flow simulation analysis, and the mesh quality determines the outcome. The tetrahedral element was used due to its ability to mesh complex 3D shapes efficiently, making it suitable for engineering models with intricate designs. Regular grid elements like hexahedrons or quadrilaterals are not suitable for this purpose.

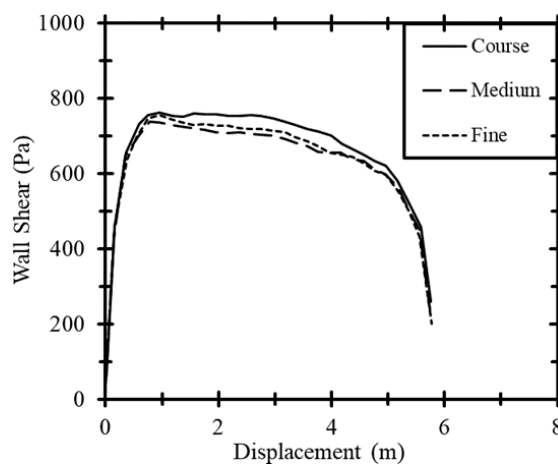
**Fig. 2:** Meshing of the geometry

A grid independence test is in fact, a procedure that checks how the computed solution depends on the mesh density. Table 3 display three mesh resolutions: coarse, medium, and fine. Just like mesh type, each of the parameters enjoys a standard value that may differ depending on the kind of mesh in use. The experiment carried out for evaluating the present grid-independent library of solvers involved a reference model which gave an average absolute error less than 1 percent by solving a test problem with 75-500 thousand organizations of node meshes.

**Table 3:** The three mesh resolutions with the associate parameters

Parameters	Coarse (1)	Medium (2)	Fine (3)
Face Element Size (mm)	50	40	30
Growth Rate	1.5	1.2	1.0
Defeature Size (mm)	0.15	0.15	0.15
Total Elements Number	390,00	830,000	1,620,000
Total Nodes Number	75,000	150,000	450,000

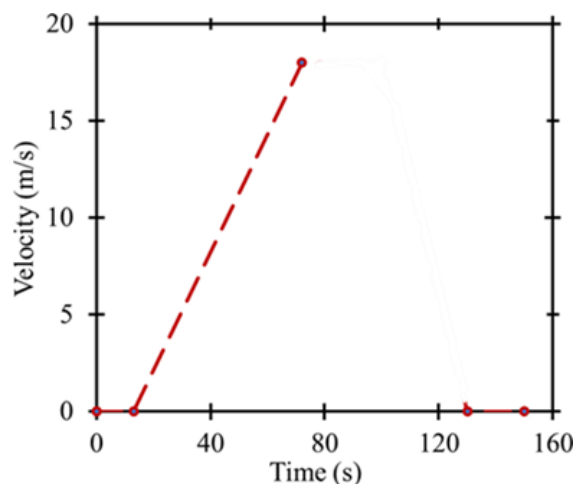
Figure 3 demonstrates results from simulations conducted on 21,000 L flexitank size models utilizing the mesh settings presented in Table 3. The research team expanded mesh size nodes by 375 K from 75 K to 450 K to monitor significant velocity changes. According to the grid independence analysis wall shear numbers exhibit minimal variation when the results from medium mesh resolution (150 K nodes) are compared to fine mesh resolution (450 K nodes) resulting in an average velocity comparison error below 1%. Several subsequent simulations use node settings that are equivalent to 150 K nodes or higher. The model has reached grid independence therefore cell size needs to decrease for reducing discretization errors then utilizing this mesh scheme for subsequent models.



**Fig. 3:** Grid independence test result for three different mesh parameters

### 2.4 Speed Profile

Figure 4 shows driving cycle in the WVU 5-Peak Drive Cycle. Due to computational constraints, the real driving profile and entire driving cycle speed profile were not feasible. To make the study feasible, a new speed profile was created alongside the origin speed profile. The new profile was created by taking the final cycle of the complete profile, consisting of acceleration, steady velocity, and braking. The highest velocity is 64.37 km/h, or 18 m/s.



**Fig. 4:** The driving profile generates from the WVU 5-Peak drive cycle [13]

## 2.5 Fluid Properties

The study focuses on the physical properties of fluids, specifically latex, to predict their hydrodynamic performance in flexitank. The properties latex, was 950 kg/m<sup>3</sup> for the density and 0.042 kg/m. s for the viscosity as a well-defined and consistent rheological model, was the main product used by MY Flexitank Industries Sdn Bhd, with its flow behavior adhering to constant viscosity characteristics [14].

## 2.6 Mechanical Properties of Flexitank Package

Flexitanks stem from different materials produced by multiple manufacturers operating throughout various nations. For this study the producer selected Low-Linear Density Polyethylene (LLDPE) as the material which they use. This classification is known as LLDPE, which is also used for packaging purposes due to properties like low shear sensitivity, easy process ability, and higher fluidity. The properties of LLDPE in term of physical in addition to mechanical properties are summarized in table 4.

**Table 4:** The LLDPE properties [15]

Physical Properties	Units	Tolerance ±	Values	Testing Methods
Thickness	mil	2	12	Thickness gauge
Density	Kg/m <sup>3</sup>	-	920	ASTM D-1505

## 2.7 Analysis

This study examines the impact of fluid in flexitanks with different strap configurations. Wall shear and pressure are interrelated and contribute to fluid-structure interaction, affecting velocity profile and energy dissipation. They need optimization for safe and efficient transport. The study aims to determine the optimal design for a flexitank based on different boundary conditions using a reference design and CFD software. The model will be prepared for flow simulation, with boundary conditions similar to the prior study fluent.











## 3. Result and Discussion

In this chapter will be the explanation of the result of flexitank's geometry with varying configurations of straps and analysis results obtained from the CFD simulation. The results are presented in graphs and figures to illustrate the readers better.

### 3.1 Flexitank Model with Configurations of Straps

Creating a flexitank model before the simulation with strap configurations in Blender involves several key steps which are modelling the flexitank itself, setting up the straps, and configuring the necessary materials. A flexitank is a large, flexible container designed to hold liquids in a shipping container. It is usually made from flexible materials like low-density polyethylene (LLDPE), and it requires proper design to simulate both the flexible tank body and the straps that secure it. The result of model will be one strap, two straps, and three straps with different depths which are 1/3, 1/2 and 2/3 from the height of flexitank. Table 5 presents the design results generated using Blender Software.

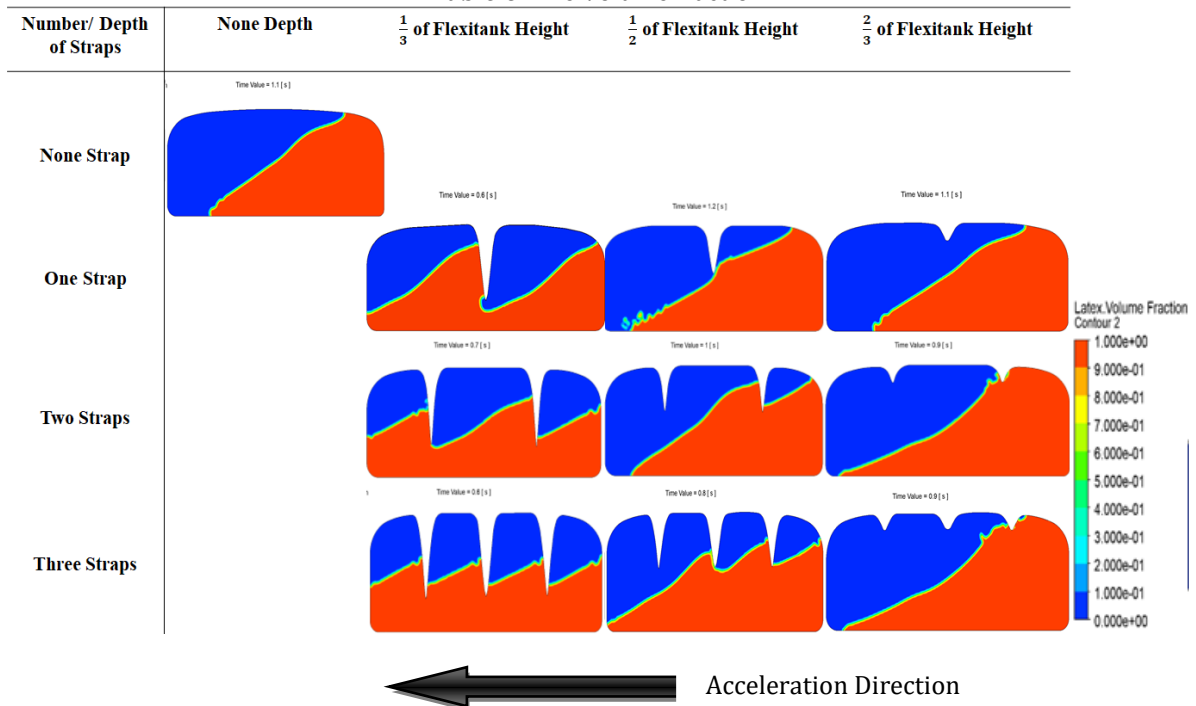
**Table 5:** The design results generated using Blender Software

Number/ Depth of Straps	None Depth	$\frac{1}{3}$ of Flexitank Height	$\frac{1}{2}$ of Flexitank Height	$\frac{2}{3}$ of Flexitank Height
None Strap				
One Strap				
Two Straps				
Three Straps				

### 3.2 Volume Fraction

Table 6 displays the volume fraction contour of a flexitank's sloshing behavior during a CFD analysis under a sub-urban driving cycle speed profile. The study found that adding straps significantly minimizes the liquid's motion. Without straps, the liquid moves with high amplitudes, causing instability. A single strap attenuates sloshing action by absorbing half of wave energy, but is not fully stable. Using two straps reduces oscillation even further, as they add more restraints and absorb more energy. For three straps, the sloshing phenomenon is reduced to the maximum level possible, as the straps reduce tank sections and minimize wave activity and energy, resulting in smaller oscillations.

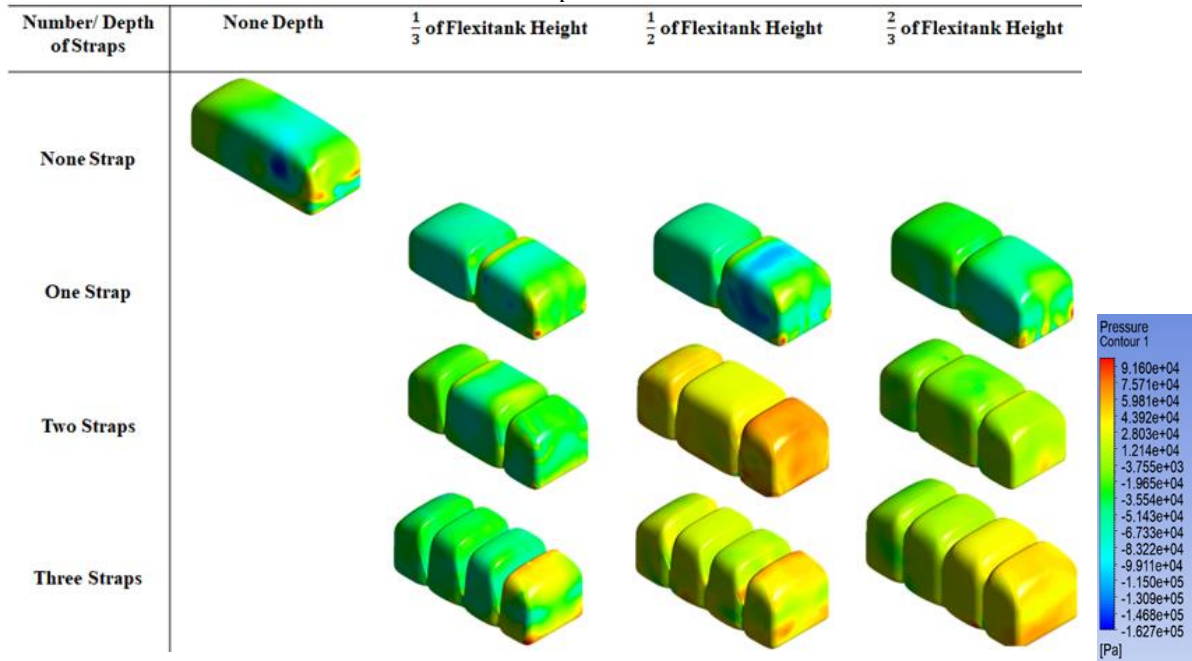
**Table 6:** The Volume fraction



### 3.3 Pressure Distribution on Flexitank Structures During Acceleration

The inertia of a latex flexitank can impact its pressure distribution when a vehicle accelerates. This can lead to the flexitank stretching or bulging, potentially causing leakage or damage. The pressure on the front of the tank is higher than the pressure on the back. Simulation results show that no-strap and one-strap configurations are effective in managing pressure distribution in the flexitank. The no-strap setup is suitable for demanding situations where no restrains are allowed and for applications promoting free and equal flow of liquids. Applying one strap enhances stability while keeping pressure concentrations low. Table 7 shows the positioning one strap at 1/3 of the height up to the base helps contain movements causing waves at the base of the tank. A strap at 1/2 height targets the middle part, providing both low pressure and high stability. A strap at 2/3 height controls heaving action on the surface and provides consistent pressure on the tank body. However, two and three strap arrangements can cause problems. Two strap placements at 1/3 and 1/2 heights create high pressure concentrations, causing material stress and uneven pressure distribution. These locations also amplify this effect, especially at the middle and upper part of the tank, leading to decreased flexibility and potential structure fatigue risk. Straps placed at 1/3 and 2/3 provide lower and upper constraints, resulting in high-pressure concentration without managing central forces of conversation and sloshing. Three straps eliminate splashing but produce excessive constraints, leading to poor pressure distribution and material damage. Overall, no-strap and one-strap configurations are most effective in balancing stability and pressure management, while two-strap and three-strap configurations create undesirable localized pressure issues.

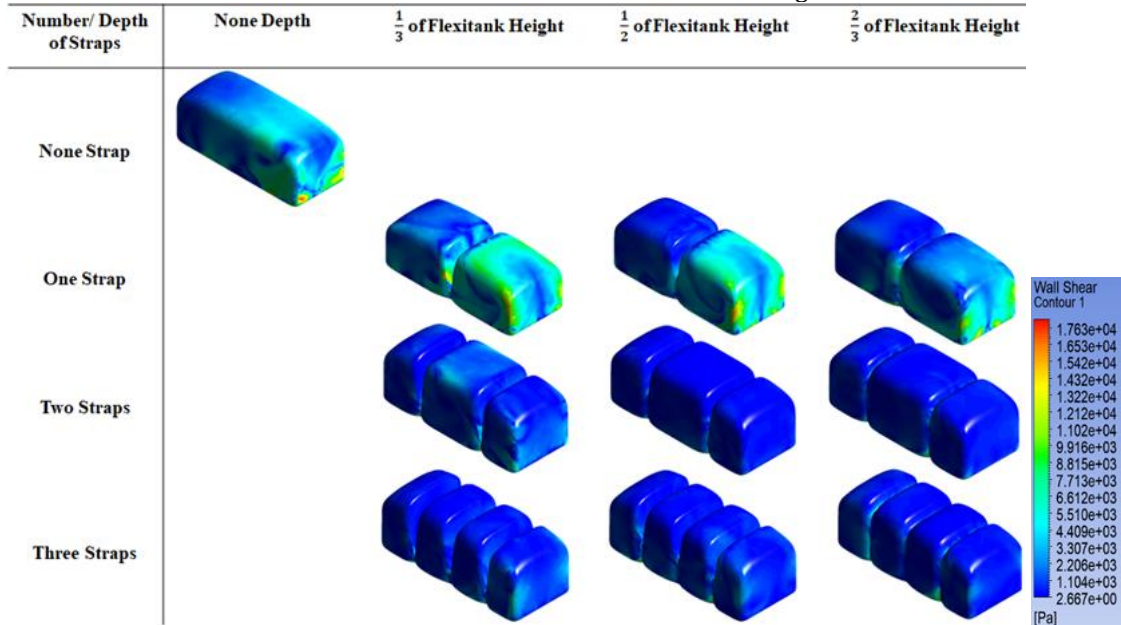
**Table 7:** The pressure distribution



### 3.4 Wall Shear Distribution on Flexitank Structures During Acceleration

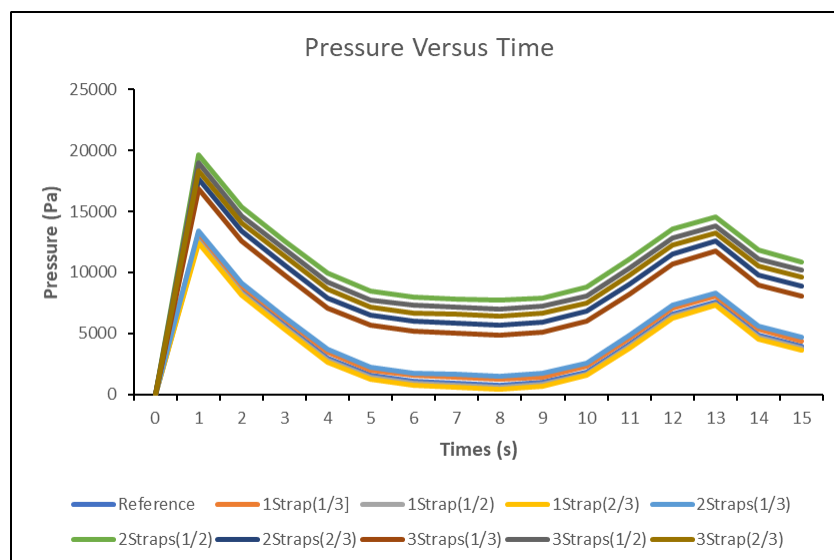
Wall shear is a frictional force that opposes fluid flow against a solid boundary. It occurs on a flexitank structure due to fluid movement within the container, creating a shearing force against the container's walls. The amount of wall shear depends on the liquid's velocity and viscosity, with higher velocities and lower viscosities resulting in greater shear. Multiple straps provide the best solution for wall shear stress during acceleration, avoiding stress concentrations around specific parts of the flexitank. Table 8 display the best configuration is three straps placed 2/3 of the height of the flexitank, reducing stress area and distributing pressure equally throughout the tank's walls. Even two straps at 2/3 of the tank height can reduce stress while maintaining strength. No straps result in poor performance, with significant stress concentrations potentially affecting the tank.

**Table 8:** The wall shear distribution on flexitank during acceleration



### 3.5 Validation Analysis of Pressure Behavior in Flexitank with Different Strap Configuration Over Time

Figure 5 illustrates the relationship between pressure and time in a flexitank configuration. The reference line (no strap) shows moderate pressure levels over time, while the one-strap configurations significantly affect pressure levels. The strap at 1/2 height performs best, reducing fluctuations and balancing liquid motion across the tank. The strap at 1/3 height reduces pressure in the lower section but does not manage upper motion well. The strap at 2/3 height stabilizes upper-level motion but allows higher pressures at the lower section. The two-strap configurations, such as 1/3 and 1/2, have higher pressure levels than the one-strap configurations, creating localized pressure spikes due to the liquid's interaction with multiple barriers. The 1/3, and 1/2 combination provides slightly better control due to broader coverage of the lower and middle sections. The three-strap configurations generate the highest peak pressures, hindering free flow of liquid and leading to localized pressure maxima around the straps. These configurations manage sloshing but do not allow liquid energy discharge, resulting in constant high-pressure levels. The best solution depends on the relative importance of pressure reduction and the requirement for minimum sloshing. The one strap with a depth of 2/3 times that of the flexitank setup is the most reasonable, as it provides the smallest peak pressures and uniform pressure over time.



**Fig. 5:** The graph relationship between pressure and time for different strap configurations in a flexitank

### 3.5 Summary

After considering the hydrodynamic performance with varying straps analysis configurations in this study, the suitable number of straps and depth of straps can be determined. The determination is being made, as shown in table 9.

**Table 9:** The Suitable configurations straps for application flexitank

Number/ Depth of Straps	Pressure Conclusion	Wall Shear Conclusion	Best Use Case
<b>No Strap</b>	Broad, even distribution but lacks control over sloshing; localized peaks occur.	High and uneven due to unrestricted liquid motion, leading to wear over time.	Suitable for applications requiring natural flow and minimal complexity.
<b>One Strap with 1/3 of Depths</b>	Improves lower pressure management but does not address upper areas effectively.	Moderate reduction in lower sections but uneven elsewhere.	Good for controlling lower sloshing but lacks balance for overall stability.
<b>One Strap with 1/2 of Depths</b>	Balanced pressure distribution with the lowest peaks and effective sloshing control.	Best setup for even stress distribution and reduced shear forces.	Optimal for balancing pressure, sloshing control, and wall stress reduction.
<b>One Strap with 2/3 of Depths</b>	Manages upper-level sloshing but leaves lower regions less controlled.	Effective for reducing stress in upper sections but less control over lower areas.	Ideal for surface stability but leaves structural vulnerabilities below.
<b>Two Straps with 1/3, 1/2, and 2/3 of Depths</b>	Reduces pressure in lower and middle sections but creates uneven distribution.	Balanced reduction in lower and middle sections but stagnation zones appear.	Better for upper stability; less suited for comprehensive control.
<b>Three Straps with 1/3, 1/2, and 2/3 of Depths</b>	Minimizes sloshing but introduces high localized pressure due to over-restriction.	Lowest stress but creates stagnation zones and reduces operational efficiency.	Best for wall protection but compromises flow dynamics and operational flexibility.

Looking at the table, One-Strap Configuration at 2/3 of height comes out as the most effective. This pressure distribution imparts the best performance since it reduces pressure peaks, provides pressure equitability and minimizes the wall shear stress. Where other configurations are feasible for certain circumstances, they create localized problems including high pressure or flow stagnation that may be disadvantages.

### 4. Conclusion

In conclusion, the suitable configurations of straps in that regard, the choice of one strap configuration at the 2/3 height flexitank is the most suitable. This delivers the optimal performance because it allows pressure peaks and their distribution presses to be kept to the lowest while also reducing wall shear stress significantly. Some other configurations which are good for certain applications create local problems like high pressure or zones of flow separation detrimental to the operations. Blender Software is performed to design a 3D model and export it to computational fluid dynamics (CFD) analysis is done on the varying configuration of straps, ANSYS software is used to analyze the hydrodynamics performances of pressure, volume fraction, and wall shear stress at the flexitank. The study showed that, concerning hydrodynamics at the flexitank, configuration of straps has the ability to cause variation. The prediction should enable the engineers to enhance the hydrodynamics design application.

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## References

- [1] "MYFlexitank-Your Bulk Liquid Packaging Specialist." <https://www.myflexitank.com/>.
- [2] Aaltonen, A. 2015. How are Flexible Tanks Becoming a Solution for Wine in Bulk Transportation? Lahti University of Applied Sciences, Business Faculty, Bachelor Thesis.
- [3] All You Need to Know about Reefer Flexitanks <https://www.dhl.com/my-en/home/global-forwarding/freight-forwarding-education-center/reefer-flexitanks.html> DHL Global Forwarding
- [4] "T-FLEX-LiquaTrans-TechnologyLeaderintheFlexitankIndustry." [https://www.liquatrans.com/products/t-flex\\_VFryzD3\\_WwNoSaPIG5bqJFUIsaAvetEALw\\_wcB/](https://www.liquatrans.com/products/t-flex_VFryzD3_WwNoSaPIG5bqJFUIsaAvetEALw_wcB/)
- [5] "Trust Flexitanks. European manufacturer of flexitanks," <https://www.trustflexitanks.com/>
- [6] "Blue whale. [https://www.bluewhalepack.com/Flexitank-for-20-Foot-Container\\_pd44767319.html/#5\\_uses\\_for\\_a\\_flexitank/](https://www.bluewhalepack.com/Flexitank-for-20-Foot-Container_pd44767319.html/#5_uses_for_a_flexitank/)
- [7] Eswaran, M., Saha, U. K., & Maity, D. (2009). Effect of baffles on a partially filled cubic tank: Numerical simulation and experimental validation. *Computers & Structures*, 87(3-4), 198-205. doi:10.1016/j.compstruc.2008.10.
- [8] Menon, H. (2024, May 2). What is Flexitank in Shipping? *Marine Insight*. <https://www.marineinsight.com/maritime-law/what-is-flexitank-in-shipping/>
- [9] Azahar, N. M. a. R., Darlis, N. N., Hassan, N. N., Salleh, N. Z. M., Azam, N. S. R. S., Taib, N. I., Ngali, N. M. Z., Mustaffa, N. K. N., & Hashim, N. M. M. (2023). CFD analysis on different filling volume capacity and fluid density for flexitank application. *CFD Letters*, 15(1), 115-126. <https://doi.org/10.37934/cfdl.15.1.115126>
- [10] J. B. (2003). Sloshing motions in excited tanks. LA 70803 USA: Department of Mechanical Engineering
- [11] Zhang, J., Wu, W., & Hu, J. (2016). Parametric studies on nickel ore slurry sloshing in a cargo hold by numerical simulations. *Ships and Offshore Structures*, 12(2), 209-218. doi:10.1080/17445302.2015.113100
- [12] P. K. Panigrahy, U. K. Saha, and D. Maity, "Experimental studies on sloshing behavior due to the horizontal movement of liquids in baffled tanks," *Ocean Eng.*, vol. 36, no. 3-4, pp. 213-222, 2009, doi: 10.1016/j.oceaneng.2008.11.002.
- [13] "Sci-Hub | Use of the West Virginia University Truck Test Cycle to Evaluate Emissions from Class 8 Trucks. SAE Technical Paper Series | 10.4271/951016." <https://sci-hub.ru/10.4271/951016>
- [14] "Neoprene Vs. Natural Rubber." <https://sciencing.com/neoprene-vs-naturalrubber-7443733.html>
- [15] L. Hynčik et al., "Identification of the LLDPE Constitutive Material Applications," *Polymers (Basel)*.