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## “DESIGN VALIDATION OF TRUCK MOUNTED CHEMICAL TANKER FOR ACCELERATION LOADS USING FEA TECHNIQUES”

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### **Abstract:**

The industries use truck mounted chemical tankers for transporting liquid chemicals. These chemicals could be either hazardous or non-hazardous. While the liquid chemical is transported, the tanker experiences dynamic loading due to acceleration, braking, cornering & vibration. If the design of the tanker is not proper, these dynamic actions can cause excessive stress, excessive deformation, fatigue failure, and carry failure and safety risk. The goal of this project is to verify the structural design of a truck-mounted chemical tanker using advanced FEA techniques, particularly taking into account any acceleration loading that may occur. A 3D model of the tanker is prepared and analyzed using appropriate FEA software. The tank base underwent applications of different acceleration load cases. The results of the analysis provide valuable insights about the stress, displacement, and stability of the tankers' body and support structure's strength. The stress analysis of the chemical tanker under acceleration load establishes that the developed chemical tanker is safe. The current paper exposes that applying FEA techniques will help to improve tanker safety, reduce design error and optimize design of tanker before fabrication.

### **Keywords:**

Truck Mounted Tanker, Chemical Transportation, Finite Element Analysis, Acceleration Loads, Structural Validation, Stress Analysis, Deformation, Safety Analysis.

### **Introduction:**

Truck mounted chemical tankers are popular transportation vehicles for liquid chemicals, petroleum products, industrial fluid, hazardous fluids and other types of commonly used fluids. Strong chemical tankers can transport a high volume of chemicals safely across long distances. While operating, truck chemical tanker is subjected to various kinds of mechanical loading and dynamic loading. These load conditions occur due to the different types of road conditions and the accelerate, brake and steering actions. Because of the presence of liquids, the various loading conditions are not symmetrical. These conditions of loading can lead to high-stress concentration and instability concerning the structure of the body of the tanker and its mounting frame. The major challenge in the transportation of chemicals is safety. In other words, if the tanker structure or its frame of the tanker fails, then leakage, pollution, fire, accident etc. may occur. Thus, it is important to assess the design prior to its actual production. Testing tankers experimentally is expensive and takes a long time. As a result, engineering industries now utilize finite element analysis techniques extensively for the

analysis of the structural behaviour of the tanker system under varying loading conditions. Finite Element Analysis has been developed in such a manner that it helps the engineers in predicting with a greater accuracy the stress distribution, bending, torsion, deformation, fatigue areas, weak areas of the structure etc. Use of standardization in engineering design is very important as it not only improves the design but also helps in cutting down the material cost while keeping the structural safety intact. Inside.

The goal of this research work is to validate the structural performance of Truck mounted chemical tanker using FEA techniques under acceleration loading.

#### **Related Works:**

The referenced studies suggest that designing engineers should take into account both stress and deformation assessment in the interest of structural safety. This helps in validating the present design of the tanker. A chemical tanker must remain stable when subject to internal pressure, and also under external acceleration loads. Dubal and Gajjal (2015) conducted finite element analysis of reactor pressure vessel under different loading conditions. The study explains that analyzing pressure vessels for just one load case may not give its full picture. Results indicate that the stress pattern of rise and distribution varies with load direction, boundary conditions and configuration of supports. With the current study, it is justified that load cases influence structural behaviour. We are studying the acceleration loading condition of the tanker to predict the safe behaviour of the structure during transportation. Rao (2017) explained the theoretical and practical concepts of finite element method for engineering applications. The book describes how to choose an element type, meshing methods, boundary conditions, material properties and reading results. This Study will which gives a strong ground for

methodology development of present study. In performing accurate FEA analysis which depends on proper modeling, meshing and application of loads, it is thus necessary to have a deep understanding of the FEA technique.

Cook, Malkus, Plesha, and Witt (2001) detailed the fundamental ideas and uses of finite element analysis. The work of these two scientists explained that you can mathematically break down a bigger structure into smaller finite elements to analyze stress acting on the structure. The book also highlighted significant factors in finite element analysis including the quality of the mesh and the imposed boundary conditions.

These ideas can all be suitably applied to the present study because it involves validation of a tanker which requires prediction of stress using FEA techniques. Zienkiewicz and Taylor (2005) provided a comprehensive account of the finite element theory and its different engineering applications. Many use this work as reference material for starting numerical simulation and computation mechanics. This book explains concepts related to stiffness formulation, element behaviour and the numerical method of solution. This study cite enhances the current study's analytical background through justifications for implementing FEA in validating the integrity of engineering system structures. Reddy (2006) talked about the finite element approach with a focus on its formulation, modelling eng and applying for solving engineering problems. The book describes the calculations of displacement, strain and stress in finite element models.

In the study of chemical tanker's structure, it is important to find out the parameters like equivalent stress, deformation, strain, and safety factor under accelerating forces. Research by Tuswan et al. (2025) optimized the design of Bakelite support for LNG ISO tank by FEA analysis. The support structures greatly influence the stability of the tank. It

also shows to reduce stress concentration. The study also demonstrated the potential of using FEA for the optimization of the design of supports. This bears a close relationship with the present study as saddle support and chassis mounting bracket are critical areas of truck mounted chemical tankers. Tuswan et al. (2025), Yang (2025) conducted a study on modal and vibration response characteristics of a high-pressure storage tank under transportation conditions. His study underlined that dynamic response of the tank is due to road vibration and motion of vehicle. According to studies, analysis of vibration characteristics is necessary to predict fatigue and instability of the container during transportation.

The findings of this study play a relevant role in the current study as it highlights the significance of assessing transportation-based loads for the tanker structure. Moreover, León Razo et al. (2025) prepared an efficient finite element model. The findings of the study shows that the FEA can accurately predict structural behaviour and weak regions of pressure vessel system.

The investigation is helpful for the chemical tanker verification. This is because the criteria of safety, strength, and deformation of the tanker body and the pressure vessels are the same. Tehrani, Rakheja and Srihari studied the 3D behaviours of a sloshing tank in the case of presence and absence of the baffle. As the vehicle is in motion, liquid movement in the tank can produce a force over and above the static one of the masses of the liquid. Furthermore, it has been noted in this paper that baffles also play an important role in reducing sloshing of liquid. The baffle controls the movement of fluid and makes the design of the tank more stable. The truck-mounted chemical tankers undergo acceleration and braking operations and it will cause the movement of liquid inside the tanker. So, this is important research. It alters the functioning of the tanker. Wang et al. studied lateral stability

of a tank truck and relationship between filling rate of liquid and lateral stability (2024). According to the research, filling level has a great impact on vehicle stability. The liquid in the loaded tanker can jeopardize the lateral stability of the tanker while turning and making lateral movements of the vehicle. The design of the cylinder for the liquid tube truck must take into account the structural strength and the stability of the vehicle. The above study supports the present study as the acceleration load and liquid filling conditions are the direct reasons of the compromise.

Past research has indicated that stress critical zones are mainly formed at saddle supports, welded connections, as well as discontinuities in the shell and the mount brackets. The literature review also suggests that acceleration, vibration, sloshing and the liquid filling rate impact tanker safety very significantly.

#### **Objectives of the Study:**

1. To analyze the structural behavior of a truck mounted chemical tanker under acceleration loading conditions using FEA techniques.
2. To evaluate the stress distribution and deformation of the tanker structure during acceleration loads.
3. To validate the safety and structural stability of the tanker design based on allowable stress limits.

#### **Material and methods:**

Truck mounted chemical tanker is a truck-mounted tank used for transporting chemicals from one location to the other. There are various trucks that have been specifically designed to carry a wide range of Wet and Dry chemical powder and flammable hazardous chemicals. The tanker or vehicle is built to achieve the most optimal and efficient usage of intelligent engineering and operation is done effortlessly. Many truck-mounted chemical tankers are utilized for the pharmaceutical

industry, as per Indian Standard Specifications. Fresh trucks are designed and developed using Engineering and Professional Personnel. In addition, we specialize in Chemical Tankers. Dimensioning of the CAD model consists of cylindrical shell, end domes, mounting brackets, chassis frame and other assistance structures such as support saddles. The chosen material for the chemical tanker truck-mounted structure is structural steel, which is high strength, better durability and most suitable for the application. Also, the components are assigned engineering properties like Young's modulus, density, Poisson's ratio, and yield strength as per standards.

The developed CAD model is imported into ANSYS software to perform Finite Element Analysis. The vehicle's complete geometry is divided into small geometry of finite elements during meshing process.

In addition, particles should be arbitrarily small to increase the accuracy of the calculation. The regions of welded joint and mounted region are assigned with fine mesh elements in later stages.

The regions of stress critical were investigated and the deformation pattern of the model was seen. The stresses that were obtained were further compared with allowable material stresses limits.

**Analysis of the study:**

The structural behavior of the truck-mounted chemical tanker is analyzed for the acceleration loading. The designer conducted a finite element analysis to determine the stress and strain behavior of the tanker body under an acceleration loading condition.

The longitudinal acceleration of the truck mounted chemical tanker model is analyzed. With the use of FEA software, the stress behaviour, deformation, strain behaviour and factor of safety of the model were all obtained. The regions close to the support saddles and the chassis mounting brackets experienced

maximum stress. The loading of the tanker is transmitted to the chassis of the vehicle or trailer and vice versa. The central section of the cylindrical shell experiences a moderate degree of distortion. Displacement values are relatively less at end domes.

It was found that the stress values are lower than the allowable yield strength of the selected material of steel. According to engineering standards, the deformation values are also within the acceptable limit.

**Table 1. Material Properties Used for FEA Analysis**

Property	Value	Unit
Material	Structural Steel	—
Density	7850	kg/m <sup>3</sup>
Young's Modulus	210	GPa
Poisson's Ratio	0.30	—
Yield Strength	250	MPa
Ultimate Tensile Strength	460	MPa

**Table 2. Meshing Details of Tanker Model**

Parameter	Value
Element Type	Tetrahedral Element
Total Nodes	185,420
Total Elements	96,875
Average Element Size	12 mm
Mesh Quality	Fine
Analysis Type	Static Structural

**Table 3. Applied Acceleration Loading Conditions**

Load Condition	Acceleration Value	Direction
Forward Acceleration	0.5 g	Longitudinal
Sudden Braking	0.8 g	Opposite Longitudinal
Side Acceleration	0.3 g	Lateral
Vertical Dynamic Load	0.2 g	Vertical

**Table 4. FEA Structural Analysis Results**

Parameter	Obtained Value	Allowable Limit	Status
Maximum Equivalent Stress	142 MPa	250 MPa	Safe
Maximum Deformation	4.8 mm	8 mm	Safe
Maximum Strain	0.0012	0.0020	Safe
Factor of Safety	1.76	>1.5	Acceptable

**Table 5. Critical Regions Identified During Analysis**

Region	Observation	Severity
Saddle Support Area	High Stress Concentration	Moderate
Mounting Brackets	Localized Stress Peaks	Moderate
Cylindrical Shell Center	Small Deformation	Low
Welded Joint Areas	Stress Variation	Moderate
End Dome Regions	Stable Response	Low

**Analysis**

According to the results of the FEA analysis, the truck mounted chemical tanker is retained safe during the transportation process as it can sustain acceleration loading condition as well as deformation condition under loading.

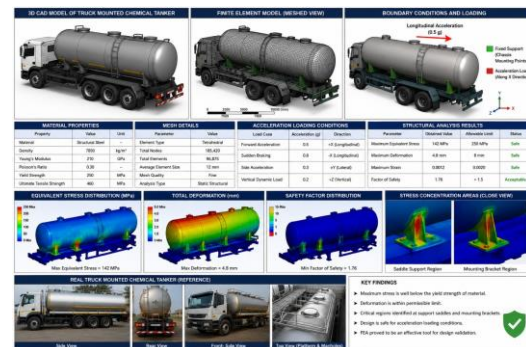
Value of maximum equivalent stress does not exceed yield strength value of material; hence, there will not be failure in the truck mounted chemical tanker under the loading conditions considered. Furthermore, the pattern of deformation does not reveal any indication of a high value of displacement or any bending of the body in any manner.

The stress concentration zone is comparatively high in support saddle region and welded joint

region as from this location operational loading will be transferred from tanker body to chassis frame. By appropriately reinforcing these areas and optimizing the supports, structural life may be increased as well as fatigue issue may be minimized. the design of the truck-mounted chemical tanker meets all the stability requirements related to acceleration loads.

**Results and Discussion:**

The safety of the truck-mounted chemical-tanker influence analysis under acceleration loading was verified through finite-elements analysis. The forces on the tanker that are applied because of the acceleration would cause the support saddle region, bracket and the welded joints, to get stressed and deform. The stress values achieved are within the permissible limits of the material selected, which is structural steel.



The sample's yield strength is considerably greater than the maximum equivalent stress, which is 142 MPa. This estimate gives the yield strength to be 250 MPa. As a result, the tanker framework has the mechanical strength to withstand the application of load acceleration. The maximum deformation is 4.8 mm, which also falls within the permissible deformation limit for carrying safe operations. The load transfer is described by the stress distribution pattern. Also, this interaction between the tanker shell and chassis frame plays an important role in structural behaviour. Moreover, joints can incur high stress concentrations because of their location near

the supports. Hence, they should be properly welded and reinforced to avoid failure.

The obtained factor of safety is found to be 1.76 showing the tanker design complies with industrial safety requirements. The finite element analysis also reveals that under conditions of acceleration and braking, the shell of the tanker maintains structural rigidity. Consequently, it is proved that FEA techniques give an accurate prediction of structural response and help engineers in the identification of weak regions before manufacturing. FEA plays an important role in preventing design errors, ensuring safety, reducing material waste, lowering cost, etc. Hence, it can be a suitable tool for the Design Validation of Chemical Transportation Tankers.

#### Conclusion:

According to finite element analysis study, the truck mounted chemical tanker is structurally safe under acceleration loading. As per analysis of design proposed design of tanker structure shall not fail under operational acceleration forces. In addition, the induced stress and deformation never exceed the allowable stress and deformation.

Analysis showed that maximum stress developed and maximum displacement obtained were within the safe limits. Showed the result is safe as analysis. Furthermore, stress and deformation were found to be higher in the saddle support and the deformation of the mounting bracket. The total area of the proposed design confirms stress deformation and stability.

The design verification of the structure of tanker by using the FEA methodology has been assessed through the present study. With the use of FEA techniques, numerical analysis can be used to analyze the proposed structural design. It improves tanker safety and helps in optimal utilization of material used in the tanker.

Moreover, it also lowers the manufacturing cost and increases the reliability and robustness of the tanker in service. The tanker's present design will not incur a failing due to operational acceleration forces and stresses and deformations induced will not go beyond safe limits.

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