Scholars Journal of Engineering and Technology (SJET) **ISSN 2321-435X (Online)**
Sch. J. Eng. Tech., 2017; 5(9):478-487 **ISSN 2347-9523 (Print)**

(An International Publisher for Academic and Scientific Resources)
www.saspublisher.com

Investigation and Parametric Analysis of Toppling Of Liquid Carrying Vehicles in Nigerian Roads

Asha Saturday[1], Agbadua Afokhainu Segun[2], Sumaila Sheidu[3], Marcus Anakuagbo Dickson[4], Ifowodo Henry Freedom[5], Agbadah Solomon Eze[6]
National Engineering Design and Development Institute (NEDDI), BOX 5082, Nnewi, Anambra State Nigeria

***Corresponding author**
Asha Saturday

Article History
Received: 17.08.2017
Accepted: 24.08.2017
Published: 30.09.2017

DOI:
10.21276/sjet.2017.5.9.5

Abstract: There has been incessant falling/toppling (a rollover) of fluid conveying tank cars especially petroleum products Conveying tank cars in Nigerian roads. This has led to loss of lives, petroleum products, vehicles and roads' environmental degradation surfaces damage that cannot be accounted for. This paper investigates critically the factors that are responsible for this menace and likely engineering suggestions and solutions are provided for future design adaptions and knowledge for the producers and users of petroleum Tank cars. Accidents, wastage of petroleum products, loss of these vehicles and spoilage of the road surfaces are grievous conditions that will incur debts or lost on the hands of marketers, petroleum companies – like NNPC etc. will be greatly minimized.
Keywords: Parametric Analysis, turning moment, Toppling/ rollover, Fluid conveying Tank car, dynamic stability

INTRODUCTION

Human survival provokes mobility which is essential human development. Human survival and relations depend on the will to move people, goods and services. Efficient mobility systems are essential promoters of economic development and industrialization. There could not be global and urban trade without systems that can move people and goods efficiently and at a moderate fair.

Over the past decades and even at present, Nigeria has recorded millions of accidents caused by toppling of tank cars, especially the petroleum products conveying vehicles in her roads. Most accidents that are devastating are caused by toppling of long vehicles besides the petroleum products carrying vehicles. No critical investigation has been done by any stake holders – Federal road safety corps or traffic department of Nigeria Police Force. But public views are speed of vehicles, reckless driving drunkenness and related drugs, over loading and break failures, fatigue, sneaky, steep slope and pot holes/failed part nature of the roads. These could be true or not but this work critically investigates these problems and other factors that could cause toppling. Rollover accidents are one of the most common types of accident that occur in commercial vehicles carrying fluid. Since most of the time, these tankers carry dangerous liquids such as ammonia, gasoline, and fuel oils, therefore stability of partially filled liquid cargo vehicles are of great importance [1]. Sloshing is a fluid oscillation phenomenon caused by the tank motion. Fluid oscillation depends on the tank geometry, filling conditions, and frequency range inside the tanker, Budiansky [2]. Besides, sloshing frequency and magnitude of sloshing forces are also dependent on these parameters, Hasheminejad and Aghabeig [3]. If the sloshing frequency is close enough to the structural natural frequency, resonance will occur, Ibrahim [4]. In addition, the stability is one of the most important points in design of vehicles used for carrying and storing objects and substances. Movement or sloshing of the liquid in the tank increases significantly when vehicle weights and dimensions increase. The liquid slosh coupled with heavy vehicle dynamics can lead to a significant reduction in longitudinal and lateral stability and controllability increased stresses on, as well as to the container structure, Bauer [5]. The handling and stability limits of tank trucks are thus dependent upon factors other than normal trucking practices. These factors include tank geometry; height of the Centre of gravity (cg); fill level; lateral and longitudinal bload shift during typical highway manoeuvres such as turning, braking and lane change; and liquid-structure dynamic interactions. Various accident analysis studies have reported that tank vehicles are more frequently involved in single vehicle highway accidents than rigid cargo vehicles. It has been reported that 40% of road accidents involving tank trucks were single vehicle accidents [6]. Nearly 50% of the single vehicle accidents and almost 80% of multiple vehicle accidents involved at least one fatality. The majority of single vehicle accidents occurred during cornering, 52% of which resulted in a rollover. Apart from heavy vehicle design factors, the dynamic stability limit of tank trucks are directly related to dynamic load shift. The dynamic load transfer encountered during a braking or turning manoeuvre is a complex function of fluid slosh, fill level, tank geometry, vehicle weight and dimension, suspension and tire properties. The motion of liquids in rigid containers has been the subject of many studies in the past few decades. It has frequent application in several engineering disciplines: sloshing in vehicles carrying liquid fuel cargo, in aircrafts and on suspension bridges; oil oscillation in large storage tanks; water oscillation in storage and water sloshing in nuclear fuel storage pools due to earthquakes. The problem is complex and strongly nonlinear. Directional stability limits of partially filled liquid cargo vehicles are known to be significantly lower than those of conventional rigid cargo vehicles due to the unique dynamic interactions between the vehicle and the sloshing liquid cargo. The forces and moments arising from a directional manoeuvre yield considerable dynamic load shifts in the roll and pitch planes due to the sloshing of the liquid cargo within the partially filled tank. The dynamic load shift affects the directional stability of the partially filled tank trucks in an adverse manner. When dangerous goods are transported unreasonable risk is imminent to Vehicles, users, highway surface safety and the environment.

They are basically three types of Tank cars –

- The bulkhead
- The baffles, and
- The smoothbores

The bulkhead tanker has it tank partitioned and each partition is loaded separately but care should be taken when loading or unloading such tanker because of weight or load balancing that may affect the vehicle during transition. The baffle tanker has baffles in the tank that helps to reduce liquid sloshing during transition while the smoothbore taker is all through whole compartment and no partitions no baffles ,liquid surge is common with this type.

Problem

Tank car conveying petroleum product pose threat to road users and owners who are worried till the product reach final destination. This is as a result of fear of accident that could arise from quite a spectrum of factors, to minimize this unforeseen incident that is inimical to the entire people, economic growth, and environment, a proactive analysis is needed to demystify these factors, and suggest engineering solutions to curb this menace.

Scope

This work focuses not only on the parametric factors of the liquid carrying vehicles – tank cars liquid structure dynamics(the product) and the roads but also the attitudes and experience of the users – drivers. Nigeria as the giant of Africa with vast land mass and populations, transporting petroleum products via pipelines is not cost effective but cannot be satisfactory since the populace in every nook and cranny need the products, hence, the indispensable use of petrol Tank cars – the liquid carrying vehicles for distribution of these products.

Aims and Objectives

Toppling of long petroleum products carrying vehicles –tankers in Nigerian roads that has led to loss of lives, products, vehicles and damage of road surface, is of great concern. It demands urgent Engineering intervention. Hence, this work is done to

- X- Rays the factors responsible for the toppling of liquid carrying vehicles.
- Suggest solution with engineering knowledge base and softwares.
- Minimize or eradicate toppling of these vehicles to reduce accidents from these conditions, loss of products and vehicles.
- Adapt these suggestions or solutions in further designs of liquid carrying vehicles.
- Save finance – (cost incurred) in the lost vehicles and products
- Minimize road damage by these accidents.

Significant

This paper proffer solutions to the problems that cause toppling of these long petroleum carrying vehicles while it is expected that design solutions are adapted in further designs of these vehicles.

ANALYSIS

Critical analytical assessment on the toppling (rollover) of long petroleum carrying vehicles – tankers is carried out under the following factors

A. Vehicles factors
   - Center of gravity and height
   - Width, and length
   - Shape orientation of the tank
   - Speed at curve/ bends land slope
   - Break system
     a. Ineffectiveness
     b. Capacity

c. type
- fluid structure dynamics at acceleration(liquid sloshing)
- Tires configuration and age of usage (traction)
- Vehicle suspension system

B. Road
- Bumps
- Pot holes
- Curves and bends
- Compactment of the road
- Surface roughness of the road

C. Driver
- Recklessness
- Age
- Experience
- Drunkenness/drugs
- Maneuver of vehicle
- Fatigue as a result of drivers tiredness

Height and C.G (Centre of Gravity)

The height of the vehicle affects its stability. This has to do its center of gravity. Hence, lowering the C.G of the vehicle will give more stability to the vehicle when accelerated (in motion). CG should be as low as possible to achieve stability. To achieve this design has to start from configuration of the chassis so as to accommodate sizeable wheels there by lowering the CG. From fig.1 .i. has high CG than than fig.1.ii

i. ii.

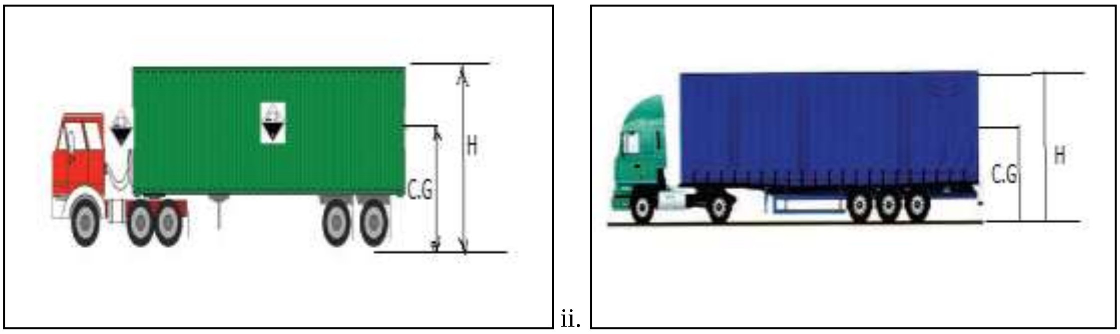


Fig-1: Pictorial view of Lorries showing reduction of tyre size to lower CGMost of the vehicles are built very high to a level of 15Ft to 16 Ft

Width or Track of Tank Car

Stability of the vehicles at bends or during maneuvering can also be guarantee if it is appreciably wide enough to counter the tilting. Hence the width to high ration should be high enough. This implies that the width of the vehicle should be more than the height. Most liquid conveying vehicles has their width lower than their height. It therefore means that Models of these vehicles at bends have stability that is guaranteed when

$$W \geq H$$

Where, W = Width of the vehicle .H = Height of the vehicle

Toppling is imminent when $W < H$ whether on straight plane, holling or bend road condition.

Hence in design, width to height ratio should be adapted as $W \geq H$. or better sill $W > H$

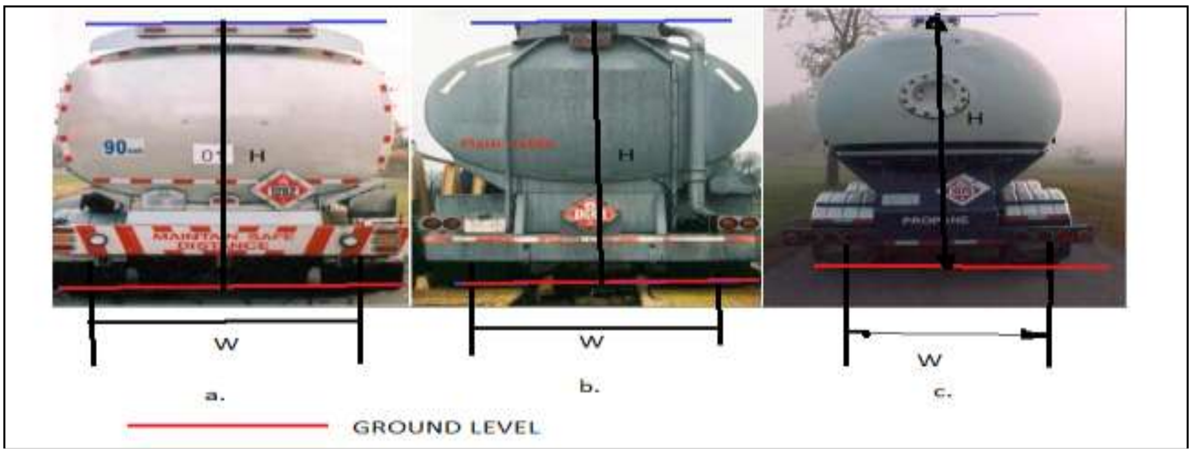


Fig -2a: A pictorial view of tankers showing width and height

From this pictorial view it shows these vehicles a pliable to toppling at bends or during maneuvering at certain accelerations since the $H > W$.The distance between the centres of each tyre on an axle is known as the track. The wider the track, W, the better the stability of the vehicle will be. In other words the wider the vehicle (within the maximum permitted vehicle dimensions), the more stable it will be. This results in better handling and improves the overall dynamics of the vehicle .The wheelbase of a rigid motor vehicle is the distance between the centre of the rear axle(s) and the centre of the front axle. In a twin-steer vehicle the wheelbase is measured between the centre of front (foremost) steering axle and the centre of the rear axle(s).

Fig-2b: pectoral view of a petro tanker with descriptive features.

Shape orientation of the tank.

The geometry of the tank places a big role in the stability during the liquid structure dynamics –liquid sloshing. Consider the following 2-D geometries of tankers.

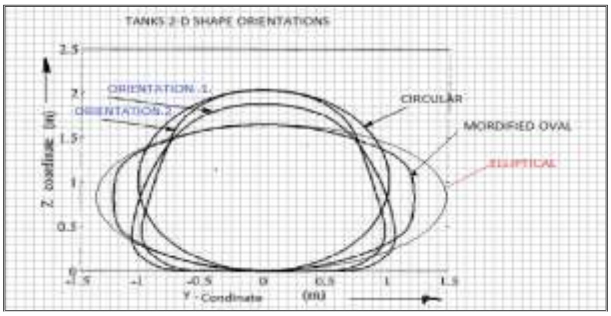
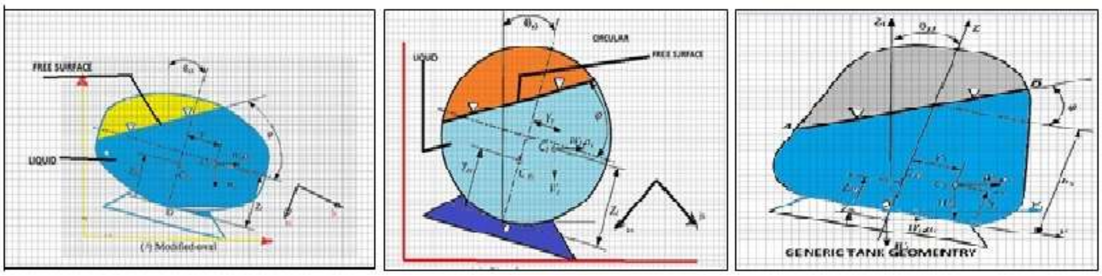


Fig-3a: different shape orientation of tankers

The shape orientation of a tanker defines the shape of the liquid in the tanker since liquid deforms to assume the shape of its containing vessels. As every geometrical shape has its center mass, centroid and other properties so their containing liquid.

Dynamics of the liquid structure and inertial force in Motion

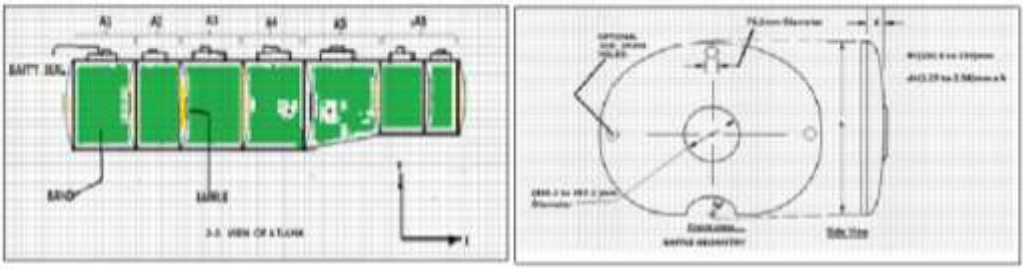
Consider a vehicle travelling on a straight road and accelerating. The passengers feel that they forced in a direction of the acceleration of the vehicle. In the petroleum product carrying vehicle, the product experience the same inertia effect which helps to initiate disability, but this effect is cancelled at some resident time of the oscillation and is governed by the shape orientation of the tank, whether is with or without baffles, position of the vehicle while accelerating, and the viscosity of the liquid, Viscosity plays a vital role to determine the level of response of a fluid to shear. Thus, viscous liquid respond slowly to flow or deformation. Therefore, viscosity as a factor is a major contributory factor governing the resonating response to the frequency of vibration as the vehicle travels. When the vehicle decelerates down the slope the weight tends to act towards the front, hence, more work for the breaks and the driver especially when the tank is not filled up. This could lead to toppling or rollover. For dynamic equilibrium whether a straight plane path, down a slope, the two forces acting on the liquid and the acceleration must be opposite to the direction of the acceleration of the vehicle. It weight tends to go to the rear when accelerating a slope when the tank is not filled. A filled tanker will not experience problems associated with fluid resonating dynamics.



A. Moerdified Oval Model **B. Circular Model** **C. Generic Geometry of a Tank**

Fig-3b: Different tank shape and liquid free surface

For the figures, the free surface created will affect the stability of the vehicle as it resonates with the vehicle movement. Petroleum products are volatile liquid whose structure is loose with individual molecules having created freedom of movement. Somebody may see the impossibility in filling the tank completely without allowing space for "breathing" or pressure reduction "vapour pressure" as the volatile liquid build up the pressure in the tank due to cavitation and emission (vapour pressure).Safety tanks seal sizeable enough be built on the top of the tank which indicate number of bands and their numbers is a function of the length of the tank. In line with the acceleration (movement) of the vehicle. To avoid this oscillation or tumbling which disturbs the stability of the vehicles while in motion? This free surface must be cancel/eradication by filling the tank completely.



a. b.

Fig-4: Baffle arrangement in a tank and baffle configuration

Motion at a bend (plane/slope)

Consider a vehicle travelling at a constant speed on a circular path. The force that keeps the vehicle and its content at the curve part is centripetal force which is directed towards the Centre of the path. At tolerable speed, vehicles survives toppling effect and at high speed, the force tend to throw them off the track, hence toppling will occur. The effect of speed on the cornering ability, braking distance and impact forces acting on a vehicle increase as the speed increases. Cornering forces don't just double when the vehicle speed doubles, they increase by four times. Centrifugal force is affected by the vehicle speed and the angle of turn/navigation. In other words, the higher the speed the vehicle is going and/or the tighter the turn, the more likely the driver is to lose control of the vehicle and for it to roll over. Changing direction causes the vehicle's weight to move to the outside of the turn which, unless the driver controls its speed, can lead to the vehicle rolling over or sliding out. Kinetic energy is the energy present in any moving object. The heavier and/or faster the object, the more energy it will contain, The effects of kinetic energy increase at the square of the speed – and have a major influence on all motor vehicles in braking, cornering and impact .

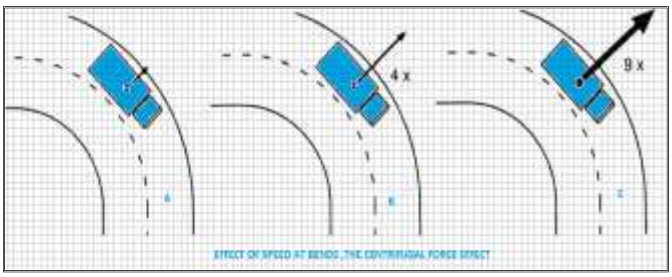


Fig-5: vehicle at bends

The liquid also in a relative equilibrium with the tank but is a continuous acceleration, the motion of the vehicle is transmitted to the fluid (liquid) and this affect the pressure distribution. The center of gravity of the liquid changes as the vehicles tilt either at bend, slopes or due to pot holes. These differences liquid carrying vehicles include the profile of the extrusion bands that join sections of the shell together, how the bulkheads/baffles have been welded to the extrusion bands, the presence and location of internal fillet welds and the extent of lack of fusion indications in the circumferential welds. Sloshing is a potential source of disturbance in liquid storage and transit Tanks.

Tire Factor

The tire factor can be categorized into

- Traction (Gripping)
- Surface area in contact
- Tractive force between the tire and the surface of the road is important especially down a slope and a bend. Tractive force can be lost if the tires have chop off or wear out, hence the ability to gripe the surface depends on how new or the tire are groove. Many practical have been done with types and soil and tar surfaces, these reveal that tractive forces are active and dependent on the amount of groove in the tires, nature of the soil whether wet, loamy, sandy or clay soil and the nature of the road. Hence, traction prevents toppling. Therefore tires should be new as possible.
- Surface area of the tire in contact with the surface of the road is also a factor. Hence to increase surface area of the type, design should be made to increase the width of the tire. This will help to increase stability. Besides, the height of the tires should be reducing by decreasing the nominal diameter as this will help in reducing the Chg. -center of gravity of the entire vehicle assembly.

Braking System

In any moving system in motion, it obeys the Newton's first law of motion – law of inertia. The only way to put a moving system like a vehicle to a stop is apply a force equal to the force causing the motion. Tire Hence, the Newton's third law of motion comes to play, the moving vehicle is in continued motion with the weight of the entire assembly and the weight of the petroleum product will require an equivalent braking force of the total load in motion. During this research, it was revealed that most of these vehicles were not factor design but fabricated, hence mismatch of brake system can cause failure leading to toppling of the entire vehicle. The type of brake fluid used in the system whether pneumatic or hydraulic can also constitute to failure of the brake. Leakages in the system are not left out. Active brake system is needed in big vehicles such as these tank cars. To build an effective braking system whose capacity must be matched with the driving force of the vehicle assembly and product, the total load comprising the vehicle weight, weight of the product and the maximum allowable of the vehicle must be considered. Hence braking force equal to the driving force will be used to determine the effective surface area of the pad and the pressure with equivalent heat dissipation should be designed to avoid heating up the entire assembly that can make it fail.

The Vehicle Suspension System

Vehicle suspension system add to its stability on a road characterized with bumps and pot holes like most Nigerian roads in the Eastern part of Nigeria and Benin-Ore Lagos road, need good suspension systems. The suspension system should be made of leaf springs and be damped to reduce the vibration that can be resulted during tank car transit on the road. Hyper sensitive suspension can lead to toppling of the vehicle. The suspension system should be made to reduce the frequency of vibration through increase of mass and stiffness of the suspension system. Most of these vehicles are with double arrangement of leave springs to reduce vibration due to transition.

Road

Most Nigerian roads are characterized with pot holes, bumps, dirts and refuses, bends, hills, oil and water spills besides the nature of the modern roads surfaces-smooth. These make toppling or rollover common in Nigerian roads. Bumps increase frequency of the resonating liquid as the tank car travels on bumps at any speed. The skid resistance is reduced with dirts or refuses on road surfaces especially under wet condition. The effect of hydrodynamic lubrications common with modern Nigerian ways as they built smooth thereby reducing friction and sliding and rollover is imminent under wet condition on such roads. Unavoidable bends, high slopes are found in most roads that pose danger to tank car and long vehicles if not treaded with caution.

Equilibrium and Vibration Analysis of Liquid in Elliptical Tank

The quasi-static fluid sloshing roll plane model of a elliptical tanker is established. Lateral acceleration and roll of the tank causes movement/displacement of the fluid mass center from point to point cl to the point xlIn this study, the rotation angle is assumed to be small and viscous fluid is Negligible. Eq. (1) shows the shape of an elliptical tanker.

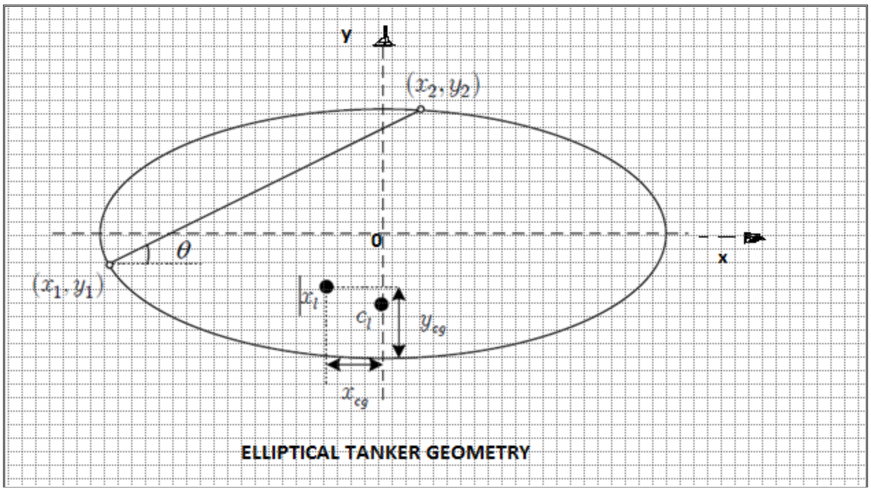


Fig-6: eliptical tank profile

The equation of eclipse reads

$$\frac{x^2}{a^2}+\frac{(y-b)^2}{b^2}=1 \qquad (1)$$

Where
x and y = the coordinates of elliptical geometry,
$2a$ and $2b$ are elliptical height and width respectively,

$$y = b\left(1 \pm \sqrt{1-\left(\frac{x}{a}\right)^2}\right) \qquad (2)$$

To obtain the mass and center of gravity, equations which represents the fluid motion, should be used repeatedly. The equation of fluid free surface without spring mass roll angle and lateral acceleration represented as:

$$y = -{h_0}^{(i)}, \quad i = 1,2,3,- - -,n \qquad (3)$$

While Equations (1-3) are solved simultaneously the intersecting points of the fluid free surface containing (x_1, $y1$) and (x_2, $y2$) are obtained (Figure 6). After comparing $h0$ (i) with the maximum and minimum values of the arcs limits, cross-sectional area are obtained. Since($x1$, $y1$) and (x_2, $y2$) are symmetrical points with respect to y axis in the absence of lateral acceleration and roll angle of sprung mass, therefore $x1$=-$x2$ and volume of fluid per unit of tank length is predicted as follows

$${A_0}^{(i)} = 2\int_0^{h_p}\int_{f_1(x)}^{h_{0(i)}} dxdy \qquad (4)$$

$f1(x)$ expresses the equation of tank geometry. The equation of free fluid surface under steady turning presented as:

$$y = -\left(\frac{\varphi_s-a_y}{1+\varphi_s a_y}\right)x+\alpha^{(i)}\ , i = 1,2,3,- - -,n \qquad (5)$$

ϕs is the roll angle of sprung mass, ay is the lateral acceleration in g (gravity acceleration) unit and α (i) is intersection of the y-axis with the free surface of the fluid. The total volume of fluid per unit length this compared with the initial volume in the case that ay = 0 and ϕs = 0. The error values corresponding to fluid volume are estimated as:

$$\varepsilon = \left|A^{(i)} - {A_0}^{(i)}\right| \qquad (6)$$

The process would be repeated again until the error function rate goes beyond the allowable error.

$$\begin{cases} {\overline{Y}_l}^{(i)} = \frac{1}{A^{(i)}}\int_{y_p}^{y_q}\int_{f_1(i)}^{f_2(i)} ydxdy; i = 1,2,3,- - -,n \\ {\overline{X}_l}^{(i)} = \frac{1}{A^{(i)}}\int_{y_p}^{y_q}\int_{f_1(i)}^{f_2(i)} xdydx; i = 1,2,3,- - -,n \end{cases} \qquad (7)$$

For one iteration if $b \le h \le 2b$, cross-sectional area (Ah) and fluid c.g. height (ycg) are represented as:

$$A_h = \pi a b^2 - \alpha \qquad (8)$$

$$\alpha = 2\left(x_h b - x_h \mathrm{h} + \frac{b}{2a}\left[x_h\sqrt{a^2-{x_h}^2} + x^2\sin^{-1}\left(\frac{x_h}{a}\right)\right]\right) \qquad (9)$$

$$y_{CG} = \frac{\pi a b^2 - \alpha\beta}{A_h} \qquad (10)$$

$$\beta = 2b - y_{CG} \qquad (11)$$

In order to optimize the tank cross-section, c.g. height and overturning moment are in challenge to each other. In low filling, circular cross-section presents more stability, as its overturning moment is less than elliptical tankers. The fluid c.g. height is dominated in high filling volumes. Therefore an elliptical tank car which has a lower center of gravity represents more stability. In addition lateral and vertical liquid load shifts affect vehicle roll stability.

In other hand liquid load shift reduces as vehicle roll stability increases. This happens by minimizing overturning moment due to lateral acceleration and fluid c.g. height. The overturning moment is calculated with the geometric variables such as elliptical height and width (that is employed for computing fluidweight (*W*), vertical and horizontal component of fluid c.g. (*Xcg, Ycg*).

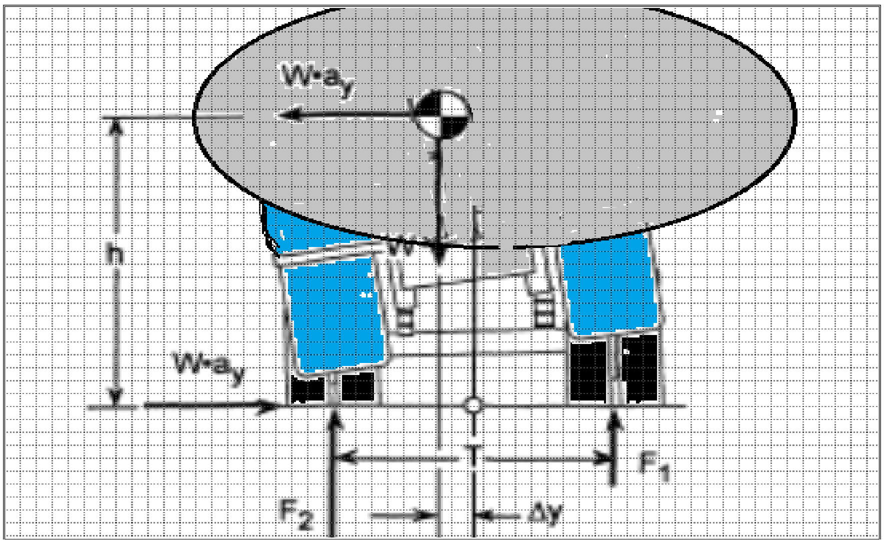


Fig-7: Stability analysis

Static Stability Factor ratio:

$$SSF = \frac{T}{2h} \quad (12)$$

Equilibrium equation for the stability

$$Wha_y = (F_2 - F_1)\frac{T}{2} - W\Delta y \quad (13)$$

ay = lateral acceleration,
Fi = the vertical tire loads, i=l, 2,
h = the height of the cg,
T = the track width,
W = the weight of the vehicle,
Δy = the lateral motion of the cg relative: to the track,
Q, is the roll angle of the vehicle

The Suspension System

A good suspension system can help to cushion the effect of unwanted vibration set in the entire tank car system. Apart from stability of the tank car, the problem of liquid sloshing will be minimized since the resonating effect of the vibration as a result of the transition on the road is absorbed by the suspension system. It is necessary that good suspension system and dampers are used in the tank cars.

Fluid Sloshing Dynamics

The oscillation of the liquid in resonance to the suspension system and road pavement surface dynamics is critical to consider when it comes to safety of the tank Car user, product and the road as well as other road users. The length of the tanker should be design as short as possible since the longer the length the higher the period of vibration (oscillation).This contributes immensely to the vibration or sloshing of the liquid .hence, the relation

$$T = 2\pi\sqrt{\frac{L}{g}} \quad (14)$$

Where,
T=period of the oscillation (sec);
L=length of the vibrating body (m)
g=acceleration due to gravity (ms^{-2})
The period only depend on length and acceleration due to gravity not on the mass. [7]. This implies the mass of the fluid in the tank does not contribute to the frequency of vibration but the length of the tank.

$$f = \frac{1}{T} \quad (15)$$

f=frequency of vibration

The dynamic load shift affects the directional stability of partially filled tank trucks in an adverse manner and can pose an unreasonable risk to highway safety and the environment when dangerous goods are transported. The wave velocity equation is obtained using some simplifications including infinite fluid depth, and fixed and variable flow. In an ideal incompressible liquid, fluid surface velocity $\overline{v}/ms$ in rotating mode is a function of wave length λ, tank depth

$$\overline{v} = \lambda f \quad (16)$$

$$v = \left(\frac{g}{k} tankh\right)^{\frac{1}{2}} \quad (17)$$

The resonance frequency in slow variation of speed is presented as:

$$f = \frac{\bar{v}}{2L} \quad (18)$$

$$\lambda = 2L \quad (19)$$

Where L is the wave length and c indicates the average wave speed and it is computed by the Eq. (20), as follows:

$$\bar{c} = \frac{\frac{L}{2}}{\int_0^{\frac{L}{2}} \frac{dx}{c(x)}} \quad (20)$$

The effect of wave length or in other word tank width especially for elliptical tank, in the case of fast wave speed variation should be mentioned in Eq. (21). The wave speed diminishes as a result of rapid depth difference, in both ends of elliptical surface. Therefore effective wave length (Lc) is actually shorter than the value measured in shape (L). Eq. (18) is used for determining sloshing frequency when the wave speed variation is in a limited band as Eq.21

$$\left|\frac{d\breve{c}(x)}{dx}\right| \geq a_{crit} \quad (21)$$

$$\left|\frac{d\breve{c}\left(\pm\frac{L_c}{2}\right)}{dx}\right| \geq a_{crit} \quad (22)$$

The equivalent fluid depth $\bar{h}$ is determined as a function of the liquid cross-sectional area and the fetch length L.

$$\bar{h} = \frac{A_{area}}{L} \quad (23)$$

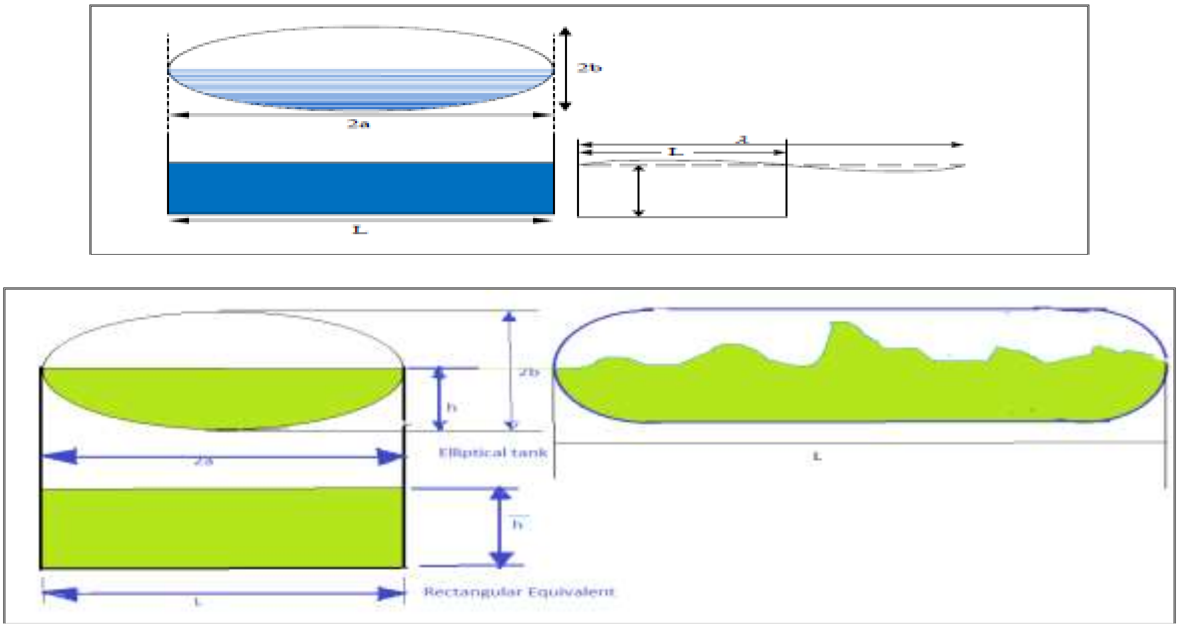


Fig-8: Equivalent fluid depth for a non-rectangular container

CONCLUSION

This work purely x-ray the factors that can cause tank car rolled over and the engineering suggestions are enormous among which the width – height ratio must be considered and decreasing the height as regards the CG –centre of gravity as well as the tire hieght should be duely considered. It is hoped that these suggestions will go a long way to save lives, petroleum products, vehicles of road users and the petroleum product vessels (tank carss) ,to save cost and the environment.

Future Work

The future work would be that researchers should do designs to prove these factors and make CAE (Computer Aided Engineering) of the works. Besides the design that will incorporate suggestions and solutions made so far.

ACKNOWLEDGMENT

This work is possible by the support of the management of National Engineering Design and Development Institute (NEDDI), Nnewi, Anambra State. Under the auspices of National Agency for Science and Engineering Infrastructure (NASENI). And the efforts of staff - Emmanuel Nnalue and Mike Amos for assisting in the investigation are appreciated.

REFFERENCE

1. Robinson T, Cuerden R. Transport Research Laboratory. Safer Lorries in London: Identifying The Casualties Associated With Side Guard Rails And Mirror Exemptions. 2014.
2. Budiansky B, Mangasarian OL. Plastic stress concentration at a circular hole in an infinite sheet subjected to equal biaxial tension. Journal of Applied Mechanics. 1960 Mar 1;27(1):59-64.

3. Shojaeefard MH, Talebitooti R, Satri SY, Amiryoon MH. Investigation on natural frequency of an optimized elliptical container using real-coded genetic algorithm. Latin American Journal of Solids and Structures. 2014 Jan;11(1):113-29.
4. Ibrahim RA, Pilipchuk VN, Ikeda T. Recent advances in liquid sloshing dynamics. Applied Mechanics Reviews. 2001 Mar 1;54(2):133-99.
5. Toumi M, Bouazara M, Richard MJ. Impact of liquid sloshing on the behaviour of vehicles carrying liquid cargo. European Journal of Mechanics-A/Solids. 2009 Oct 31;28(5):1026-34.
6. Toumi M, Bouazara M, Richard MJ. Impact of liquid sloshing on the behaviour of vehicles carrying liquid cargo. European Journal of Mechanics-A/Solids. 2009 Oct 31;28(5):1026-34.
7. Bird RB, Armstrong RC, Hassager O. Dynamics of polymeric liquids. Volume 1: fluid mechanics. A Wiley-Interscience Publication, John Wiley & Sons. 1987 Jun.