ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 2, August 2012

Design & Analysis of Tanker for Reduction of Sloshing Effects

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Abstract— ***Sloshing has widespread applications in many industries including automotive, aerospace, ship building and motorcycle manufacturing. The need for sloshing study is mainly to accept the challenge for transportation of partially filled tanker. The goal of sloshing simulation is first to study the sloshing pattern and then improve the tank design to reduce stresses on the tanker surfaces and optimize the baffle arrangements. In this work, simulation of the LPG in tank is studied and the design modification with baffle plate is considered to minimize the sloshing phenomena using ALE method. Also it is explained that there is strong need to analyze the sloshing phenomena in detail. Arbitrary Langrangian Eulerian finite element methods gain interest for the capability to control mesh geometry independently from material geometry, the ALE methods are used to create a new undistorted mesh for the fluid domain. In this work we used the ALE technique to solve fluid structure interaction problem. LPG slosh is an important design consideration not only for the transportation tanker, but also for the structure supporting the tanker. Sloshing can be generated by many ways: abrupt changes in acceleration (braking), as well as abrupt changes in direction (highway exit-ramp). Repetitive motion can also be involved if a sloshing resonance is generated. These sloshing events can in turn affect the overall performance of the parent structure. A finite element analysis method has been developed to analyze this complex event. A new ALE formulation for the fluid mesh can be used to keep the fluid mesh integrity during the motion of the tank. In this work, LPG sloshing analysis is done with various iterations in terms of enclosed baffle and suggested modified baffle. Then simulation is carried out to get affective parameters like pressure and velocity generation over period of time. These parameters are plotted in graphical nature to compare results of each iteration. Finally, selected modified baffle is analyzed for Sloshing pressure to get safe thickness and proper baffle shape is recommended for reducing sloshing effects.***

Index Terms— **Sloshing,ALE,FSI,Eulerian Mesh,Langrangian Mesh .**

I. INTRODUCTION

The tanker used for the transportation of liquid over the road-ways is an integral part of the Carrier/ Vehicle. The tanker is expected to withstand the unbalanced forces on account of the transit over uneven and irregular surfaces/ contours of the road as also due to sudden acceleration or deceleration (due to application of brakes). As a result, `sloshing’ of the liquid is experienced within the tanker. Different aspects of analyses are necessary to design the tanker but sloshing analysis is also one of the prominent aspects for reducing its detrimental effects over structure of tanker. Sloshing can be the result of external forces due to acceleration/deceleration of the containment body. Of particular concern is the pressure distribution on the wall of the container reservoir and its local temporal peaks that can reach as in road tankers twice the rigid load value. In road tankers, the free liquid surface may experience large excursions for even very small motions of the container leading to stability problems. Analysis of the sloshing motion of a contained liquid is of great practical importance. Motion of a fluid can persist beyond application of a direct load to the container; the inertial load exerted by the fluid is time-dependent and can be greater than the load exerted by a solid of the same mass. This makes analysis of sloshing especially important for transportation and storage tanks. Due to its dynamic nature, sloshing can strongly affect performance and behavior of transportation vehicles, especially tankers filled with oil. In fact, a significant amount of research has gone into developing numerical models for predicting fluid behavior under various loads. Hence liquid sloshing is a practical problem with regard to the safety of transportation systems, such as oil tankers on highways, liquid tank cars on railroads, oceangoing vessels with liquid cargo, propellant tank used in satellites and other spacecraft vehicles, and several others.

II. APPROACHES TO SOLVE FSI PROBLEM

This type of problem can be modeled in basic four approaches which are used for fluid structure interaction problem

a. Lagrangian approach
b. Euler approach
c. Euler and Langrangian approach
d. SPH

Lagrangian formulation is usually used for describing a solid mechanics problem. The problem is described with a high number of mass particles, where the motion of every single particle is being observed in space and time. The problem is exactly defined when the motion of all the particles is known. The Lagrangian formulation is very simple and easy to use for one or only a few mass particles. However, the method becomes very complicated and complex for description of high number of mass particles. (Fig.1) In the Eulerian formulation the problem is being observed at one point in space which does not follow the motion of the single particle. In one time step t several mass particles may pass the observed point. Their motion is exactly determined in the moment of passing through that point. In the observed point the field variables are time dependent. (Fig.2) . The basic difference between the Lagrangian and the Eulerian formulation is that at the Lagrangian formulation the magnitudes x , y and z are variable coordinates of a moving particle. At the Eulerian formulation those

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ISO 9001:2008 Certified
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coordinates represent steady coordinates of the defined field point.

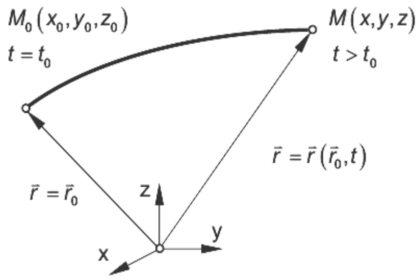

Fig. 1 Langrangian Formulation

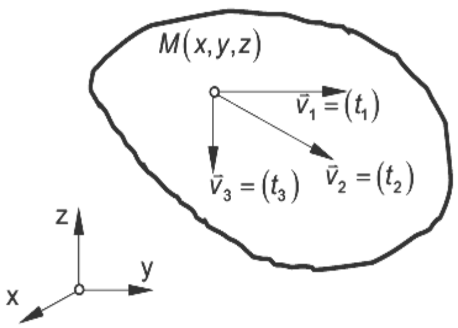

Fig. 2 Eulerian Formulation

There are many challenges in the numerical simulation of liquid sloshing in horizontal cylinders and spherical containers using the finite element method of `arbitrary Langrangian-Eulerian' (ALE) formulation: tracking the motion of the free surface with the contact points, defining the mesh velocity on the curved wall boundary and updating the computational mesh. In order to keep the contact points slipping along the curved side wall, the shape vector in each time advancement is defined to modify the kinematical boundary conditions on the free surface. A special function is introduced to automatically smooth the nodal velocities on the curved wall boundary based on the liquid nodal velocities. The elliptic partial differential equation with Dirichlet boundary conditions can directly rezone the inner nodal velocities in more than a single freedom. The incremental fractional step method is introduced to solve the finite element liquid equations. The numerical results that stemmed from the algorithm show good agreement with experimental phenomena, which demonstrates that the ALE method provides an efficient computing scheme in moving curved wall boundaries. This method can be extended to 3D cases by improving the technique to compute the shape vector. A computational procedure is developed to solve problems of viscous incompressible flows under large free surface motions. The arbitrary Lagrangian–Eulerian (ALE) method is used to move the free surface nodes as well as the internal nodes. The coupling of the mesh motion equations and the fluid equations is essentially done through the free surface boundary conditions.

III. ANALYSIS USING ALE CODE (MSC-DYTRAN)

A. Assumptions:

1. Tanker is perfectly cylindrical and leak proof
2. Thickness of tanker is maintained equal in all directions
3. Road surface is normal plain condition
4. Speed of vehicle is 40 kmph
5. LPG is in liquid state (under pressure)
6. Sloshing analysis is carried for sudden breaking condition

B. Preprocessing:

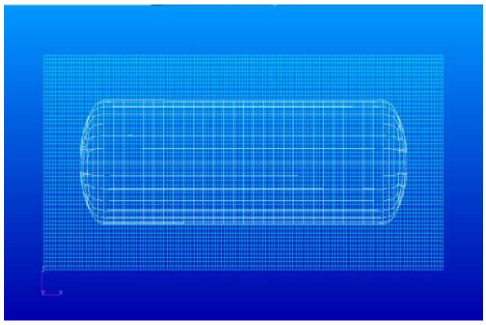

Fig 3 Aligning Euler and Langrangian

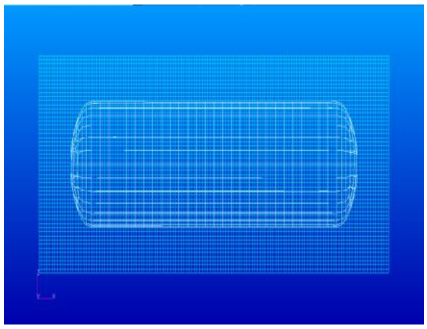

Fig.4 Meshing of LPG in Unbaffled Tank

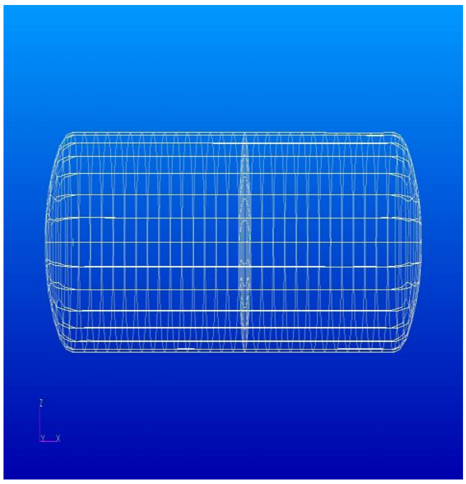

Fig.5 Meshing of LPG Tank with Full Enclosed Baffle at the Centre

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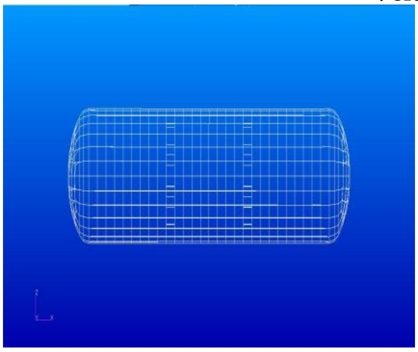

Fig. 6 Meshing of LPG Tank with Two Modified Baffles

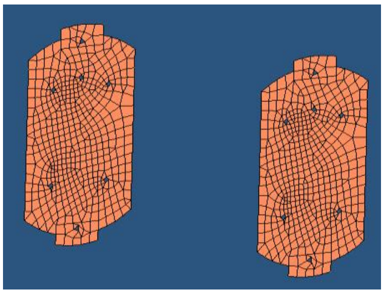

Fig. 7 Meshing of Modified Baffles

IV. RESULTS

After analysis of various iterations, results are plotted in this chapter in the form of simulation and graphs.

A. Simulation Results:

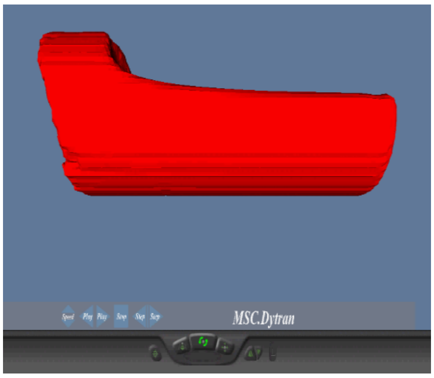

Fig. 8 Iteration 1 Sloshing of LPG without Baffle in Front View

Fig.9 Iteration 2: Sloshing of LPG in a Tank with Enclosed Full Baffle at Initial Stage

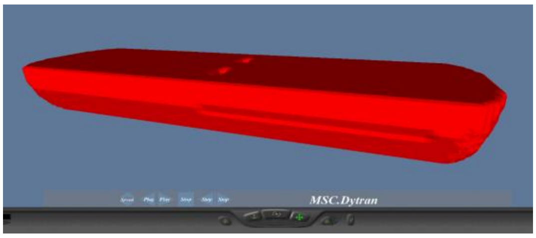

Fig.10 Iteration 3: Sloshing Of LPG in a Tank With One Modified Baffle

Fig.11 Iteration 4: Sloshing Of LPG in A Tank with Two Modified Baffle Showing Peak Amplitude of Fluid

B. Graphs

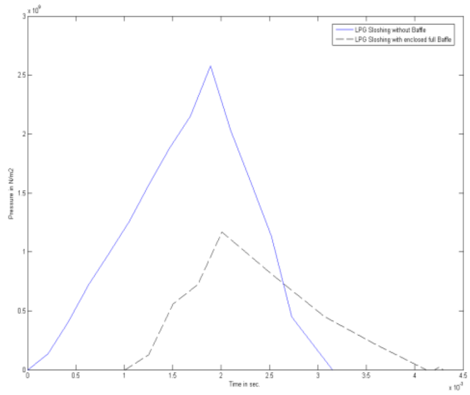

Fig.12 Comparison of LPG Sloshing Without Baffle and With Enclosed Full Baffle

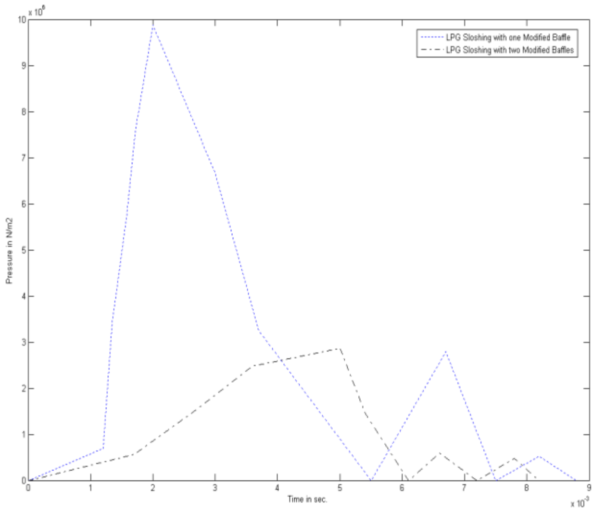

Fig.13 Comparison of LPG Sloshing With One Modified Baffle and Two Modified Baffles

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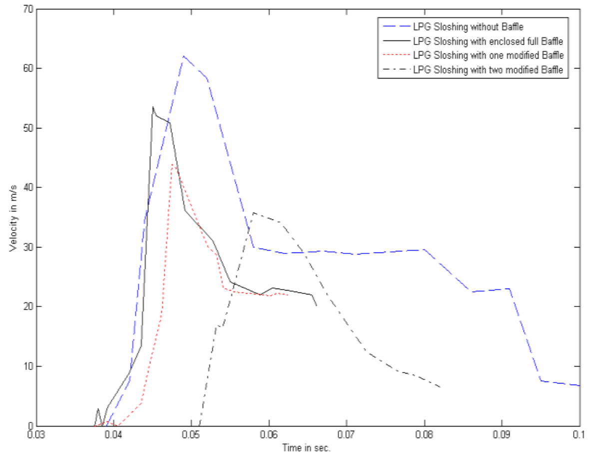

Fig.14 Comparison of Velocity Variations of Four Iterations

C. Findings:

From the simulation result of every iteration it can be found that, sloshing is reduced in considerable amount with the help of two modified baffles located at 2500 mm apart from each other. Also the maximum pressure generated in various iterations due to sloshing of fluid is as follows:

TABLE 1 MAXIMUM PRESSURE GENERATED IN VARIOUS CASES

Iteration No.	Case Name	Time in sec.	Pressure in N/m^2
1	LPG sloshing without baffle	0.00189	2.58×10^9
2	LPG sloshing with enclosed full baffle	0.00200	1.17×10^9
3	LPG sloshing with one modified baffle	0.0020	9.88×10^6
4	LPG sloshing with two modified baffles	0.0050	2.87×10^6

TABLE .2 MAXIMUM VELOCITIES DEVELOPED IN VARIOUS CASES

Iteration No.	Case Name	Time in sec.	Velocity in m/s
1	LPG sloshing without baffle	0.049	62.13
2	LPG sloshing with enclosed full baffle	0.045	53.48
3	LPG sloshing with one modified baffle	0.0475	43.85
4	LPG sloshing with two modified baffles	0.058	35.8

Therefore, from Table 1 and 2 we can say that, more time is required to generate maximum pressure and velocity in the case of two modified baffles compared to other cases.

V. CONCLUSION

The Analysis of cylindrical liquid carrier tanker is carried out using the finite element method. Studies of various methods in FEA are done and one particular method is selected to model fluid-structure interaction problem. These interaction problems are quite complex and they have been challenging as well. We can accept the challenge for transportation of liquid in partially filled tankers by using baffles in proper shape, numbers and location. In this problem sloshing of LPG is reduced in half filled cylindrical tanker at the speed of 40kmph by using two modified baffles. Also effect of sloshing over tanker and baffles are decreased with proper thickness. The pressure and velocity developed in two baffled condition is lower than unbaffled, one baffled and enclosed baffled condition. So it is recommended to use two modified baffles, 2500mm apart from each other with which can decrease the sloshing considerably.

ACKNOWLEDGMENT

I like to express my deep gratitude to our Principal Dr. Vikram S. Patil and Dean academic Prof. B. V. Birajdar, Head, Department of Mechanical Engineering Prof R.S.Kulkarni, Head, Department of Automobile Engineering Prof S.L.Ghodake for providing me continuous moral support to complete this paper in Sanjeevan Engineering & Technology Institute Panhala. Also I wish to thank my friends and everyone who have contributed during this work.

REFERENCES

[1] K.J. Craig, T.C. Kingsley "Design Optimization of Containers for Sloshing and Impact" Springer-Verlag 2006, Published online: 2 September 2006.

[2] Yonghwan Kim, "Numerical Analysis Of Sloshing Problem", American Bureau of Shipping, Research Department, Houston, TX, USA .

[3] M. Serdar Celebi, Hakan Akyildiz, "Nonlinear Modelling Of Liquid Sloshing In A Moving Rectangular Tank", Naval Architecture and Ocean Engineering Istanbul-TURKEY.

[4] P. Pal "Sloshing of Liquid in Partially Filled Container – An Experimental Study" International Journal of Recent Trends in Engineering, Vol. 1, No. 6, May 2009.

[5] Y.G. Chen , K. Djidjeli, W.G. Price, "Numerical simulation of liquid sloshing phenomena in partially filled containers" Journal of Computers & Fluids 38 (2009)830-842.

[6] R.H.M.Huijsmans, G.Tritschler, G.Gaillarde, R.P.D.Dallinga, "Sloshing of Partially Filled LNG carriers", Proceedings of The Fourteeth International Offshore and Polar Engineering Conference, Toulon, France, May 23-28 2004.

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[7] Donald Liu "Tanker Spills Prevention By Design" National academic Press, ISBN-10: 0-309-04377-8, pp.208-213, Publication Year1991.

[8] Jean Ma and Mohammad Usman Jean "Modeling of Fuel Sloshing Phenomenon Considering Solid-Fluid Interaction" 8TH International LS-DYNA Users Conference Fluid/Structure.

[9] Ranjit Babar and V.Katkar "Simulation of Fuel Tank Slosh Test-Coupled Eulerian-Langrangian Approach" Tata Technologies, TATA motors Ltd. Pimpri, Pune.

[10] Kim Hyun-Soo and Lee Young-Shin "Optimization design technique for reduction of sloshing by evolutionary methods" Journal of Mechanical Science and Technology, Vol. 22, Number1/January 2008.

[11] Jang-Ryong Shin and Kyungsik Choi and Sin-Young Kang "An Analytical Solution to Sloshing Natural Periods for a Prismatic Liquid Cargo Tank with Baffles" Proceeding of Sixteenth International Offshore and Polar Engineering Conference, California, USA, May 28-June 2, 2006.

[12] N. Aquelet and M. Souli, J. Gabrys, L. Olovson "A new ALE formulation for sloshing analysis" Structural Engineering and Mechanics, Vol.16,No. 4 (2003).

[13] K.J. Craig, T.C. Kingsley, R. Dieterich, L.J. Haarhoff and N. Stander " Design Optimization of the Fluid-Structure Interaction in a Fuel Tank" 16th AIAA Computational Fluid Dynamics Conference, Orlando, Florida, 23-26, June2003.

[14] Lyes Khezzar, Abdennour Seibi, Afshin Goharzadeh"Water Sloshing in Rectangular Tanks – An Experimental Investigation & Numerical Simulation" International Journal of Engineering (IJE), Volume (3): Issue (2).

[15] Samuel Seyoum "Dynamic Analysis of Liquid Containing in Cylindrical Tanks" Thesis submitted to Addis Ababa University School Of Graduate Studies, October 2005.

[16] J A Romero1, O Ramirez, J M Fortanell, M Martinez, and A Lozano, "Analysis of Lateral Sloshing Forces within Road Containers with High Fill Levels", Proc. IMechE Vol. 220 Part D: J. Automobile Engineering,2006

[17] J. Donea, A. Huerta, J.-Ph. Ponthot and A. Rodrguez-Ferran, "Arbitrary Lagrangian-Eulerian methods", John Wiley & Sons, Ltd, Encyclopedia of Computational Mechanics,2004

[18] Odd M. Faltinsen ,Olav F. Rognebakke, "Sloshing", Department of Marine Hydrodynamics, Norwegian University of Science and Technology, N-7491 Trondheim, Norway

[19] Prasanna S. Gandhi, Jatinder Mohan, Keyur B. Joshi, N. Ananthkrishnan, "Developrnent of 2DOF Actuation Slosh Rig: A Novel Mechatronic Systern", IEEE 1-4244-0726-5/06/2006.

[20] Takashi Okamoto, Mutsuto Kawahara, "Two dimensional Sloshing analysis by the Arbitrary Langrangian-Eulerian Finite Element Method", Structural Eng./Earthquake Eng. Vol.8,No.4,207s,216s,Japan Society of Civil Engineers (Proc.of JSCE No.441/I-18),January 1992.

[21] Y.G. Chen , K. Djidjeli, W.G. Price, "Numerical simulation of liquid sloshing phenomena in partially filled containers", Elsevier, Computers & Fluids 38 (2009) 830–842.

[22] MSC-Dytran software datasheet available online at: www.mscsoftware.com.