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Modelling and Analysis of Liquid Container Baffler to Reduce Sloshing Effect

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Abstract:Sloshing means any motion of the free liquid surface inside its container. It is caused by any disturbance liquidcontainers. Depending on the type of disturbance and container shape, the free liquid surface can experience different types of motion including simple planar, nonplanar, rotational, irregular beating, symmetric, asymmetric, quasi-periodic and chaotic. When interacting with its elastic container, or its support structure, the free liquid surface can exhibit fascinating types of motion in the form of energy exchange between interacting modes. Modulated free surface occurs when the free-liquid-surface motion interacts with the elastic support structural dynamics in the neighborhood of internal resonance conditions. Under low gravity field, the surface tension is dominant and the liquid may be oriented randomly within the tank depending essentially upon the wetting characteristics of the tank wall. The basic problem of liquid sloshing involves the estimation of hydrodynamic pressure distribution, forces, moments and natural frequencies of the free-liquid surface. These parameters have a direct effect on the dynamic stability and performance of moving containers .

Sloshing can be generated by two Reasons are abrupt changes in acceleration and abrupt changes in direction.The aim of sloshing simulation is to first study the sloshing pattern & then improve the tank design to reduces stresses on tanker surface. & also optimize the baffle arrangement. In this work used LPG tank also modified baffle design. In this work used the ALE technique to solve the fluid structure interaction problems.. It has been modified to analyze sloshing effects & also minimized them by designing the modified baffles. Analzysed for sloshing pressure as well as velocity which used to finding of proper selection of baffle thickness, shape .quantity & location .

Keywords: Sloshing, ALE, FSI, Eulerian mesh, Langrangian mesh, Baffle,Sloshing effect etc.

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. Any attempt to reduce this `sloshing' would further help optimizing the design in terms of economy and reducing bare weight of the tanker.As such, any improvement made to the design of the tanker (or structure) would directly enhance the experience of transport of fluid filled tankers w.r.t benefits to the industry in the form of:

The reduced time taken for transport because of more acceleration of vehicle while sloshing is reduced

Reduced cost of tanker

A. Problem Definition

The problem under consideration includes the analyses of liquid carrying tanker considering sloshing phenomenon and modifying the existing tanker for reducing its effects.

B. Theory Description

1) Approaches to solve FSI (fluid structure interaction) 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 (Smoothed Particle Hydrodynamics)

2) ArbitraryLangrangian-Eulerian formulation (ALE)

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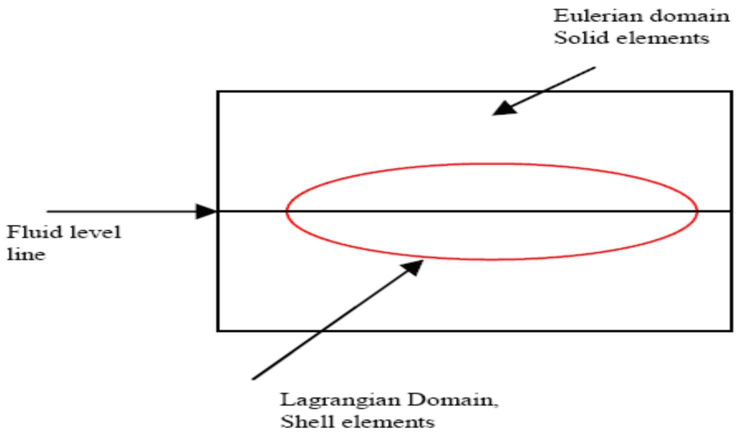

Fig. 1.1 Coupling

C. General Coupling

1) Fluid-Structure Interaction
2) Lagrangian and Eulerian meshes can be used in the same analysis and coupled together allowing the solution of Fluid-Structure Interaction problems.
3) Arbitrary Motion
4) The coupling surfaces can be of any shape and can undergo arbitrary motions
5) The Lagrange mesh acts as a boundary to the flow of materials in the Euler mesh.
6) The Euler mesh loads the structure

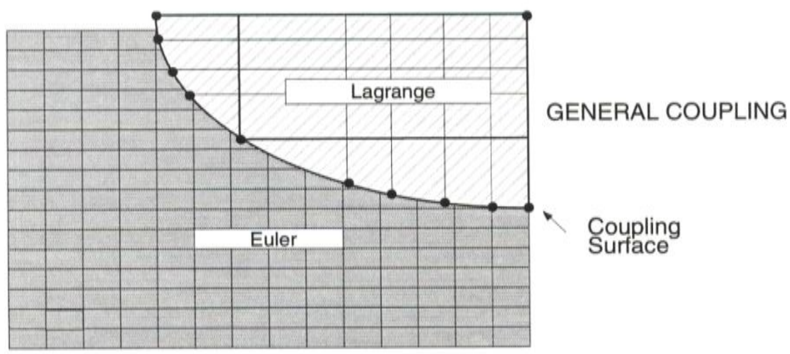

Fig.1.2 ALE Formulation

In this formulation the mesh partly moves and deforms because it follows the material (Lagrangianformulation), while at the same time the material can also flow through the mesh (Eulerianformulation).

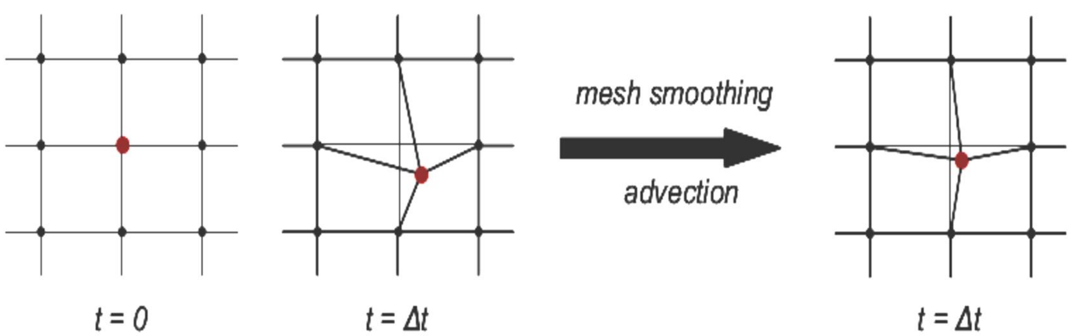

Fig.1.3Mesh Deformation In ALE Formulation

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The ALE solving procedure is similar to Eulerian procedure. The only difference is the meshsmoothing. In the Eulerian formulation the nodes are moved back to their original positions, while inthe ALE formulation the positions of the moved nodes are calculated according to the averagedistance to the neighboring nodes (Fig.3.7).A similar calculation scheme is also used in other comparable codes.

7) *In LS-DYNA there are two types of ALE elements:*

a) *Single material and Multi material:*Single materialelement type can contain only one phase (fluid) at one moment, while the multi material element typeis able to contain several materials.The advantage of the ALE formulation is evident when a stress front needs to be followed and themesh is automatically refined. Another example is analysis of fluid tanks, where fluid movement insidethe tank is of interest and the boundary surface is continuously changing due to interaction betweenfluid and tank surfaces (Fig.3.8).

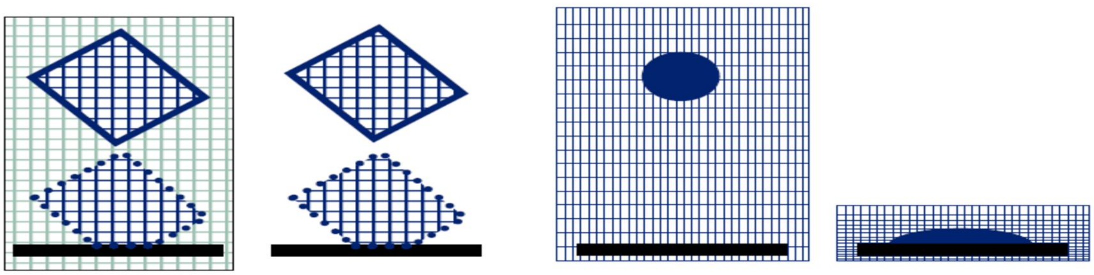

Fig. 1.4 Boundary Surface Change In Fluid And Tank Interaction

D. *Smoothed Particle Hydrodynamics (SPH)*

The SPH method is an integration scheme which was developed by Lucy, Gingold and Monaghan(1977). It is based on the Lagrangian formulation with the purpose to avoid the mesh restrictions whenlarge deformations appear within the finite element method. The main difference between the standardmethods and the SPH is the absence of the mesh, since the SPH formulation is essentially amesh less method (Fig. 3.9)

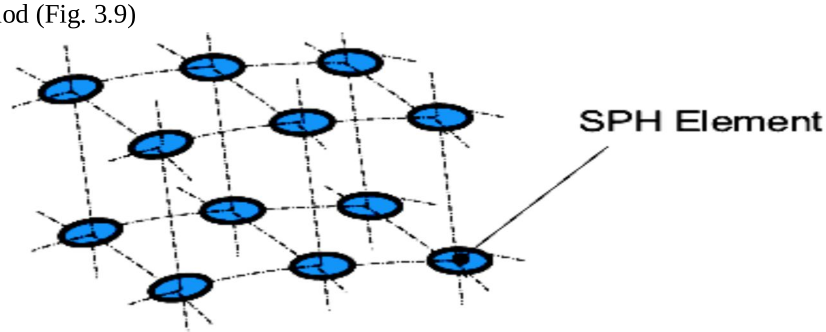

Fig.1.5 SPH Formulation

Four approaches to fluid flow modeling in LS-DYNA have been presented in the paper. Differentformulations (Lagrangian, Eulerian, ALE and SPH) can be used to analyze a fluid motion in tank. Computational simulations have shown that the fluid motion and fluid-structureinteraction can be accurately described by applying different alternative formulations in the LS-DYNA. The applied models provide a basis for economical computational models that can be used foranalyzing more complex problems (e.g. automotive fuel tanks).

Fig.1.6Meshing of Modified baffle

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II. METHODOLOGY

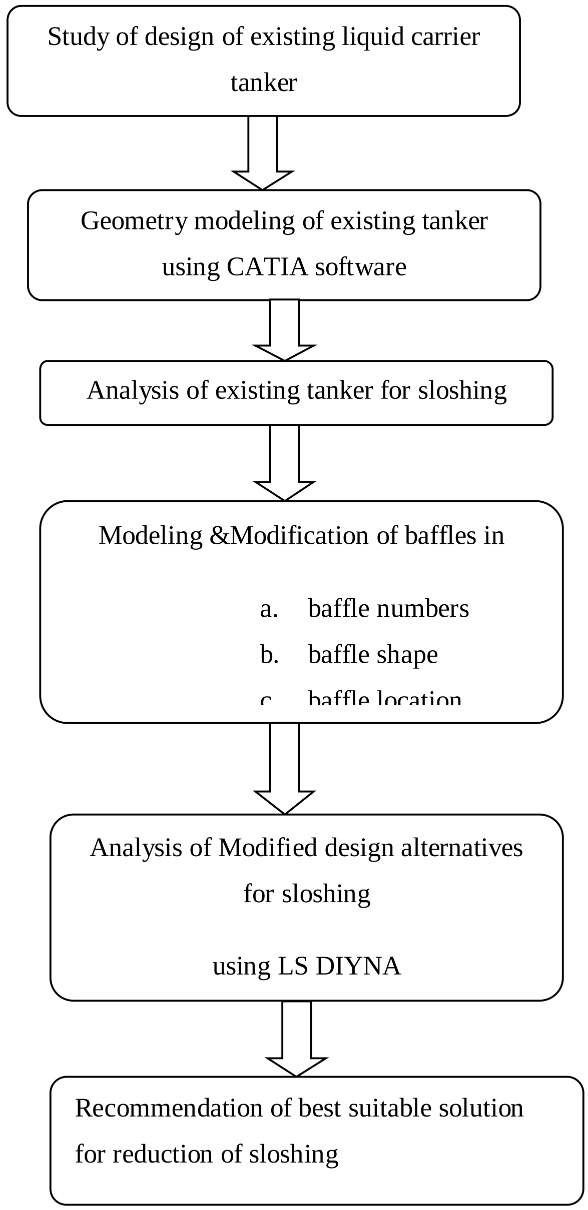

Fig. 1.7Methodology

A. *Scope of Work*

Liquid Carrier Tanker is having different shapes i.e. rectangular, circular, cylindrical, oval etc. Here analysis is carried for cylindrical tanker with half filled condition for LPG (Liquefied Petroleum Gas) with number of iterations to study the sloshing phenomena and it is decreased with the help of baffles having variation in quantity and shape. Analysis is carried for 40kmph vehicle speed and proper baffle quantity and shape with proper thickness is suggested to reduce sloshing effects

III. ANALYSIS IN “LS-DYNA”

A. *Rigid tankproperties*

Use MATRIGwith Steel properties as follow:
Density = 7830 Kg/m3
E = 2.068e11 Kg/m/s2
Poisson ratio = 0.3

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Thickness = 0.005 m
Water Properties:
Rho=1000Kg/m3
Bulk Modulus=K=a1=2.2e9 Pa
Gravity = 9.8 m/s2 in -Y direction
LPG Properties:
Rho=553Kg/m3
Bulk Modulus=K=a1=0.6e9 Pa
Vapors pressure=10.7 bar
Gravity = 9.8 m/s2 in -Y direction
Filling level
Define the 50% filled condition of tank
Braking Velocity
Define the braking velocity at 40 Km/hr (11.11 m/sec) as a time function
Runtime Parameters
Simulation time = 0.02 sec
Initial Timestep = 1.0E-6
Save output for 25 steps (0 thru end by 0.0008)

IV. RESULT IN TABULAR FORM

A. *Pressure Table*

Iteration No.	Case name	Time in sec.	Pressure in N/m2
1.	LPG sloshing without baffle	0.00189	2.58 x 109
2.	LPG sloshing with enclosed full baffle	0.00200	1.17 x 109
3.	LPG sloshing with one modified baffle	0.0020	9.88 x 106
4.	LPG sloshing with two modified baffles	0.0050	2.87 x 106

Table-1: TABLE - Maximum pressure generated in various cases.

B. *Velocity Table*

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	43.12
4.	LPG sloshing with two modified baffles	0.058	35.15

Table-2: - Maximum velocity generated in various cases.

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C. Comparison Between Without & Enclosed Baffle

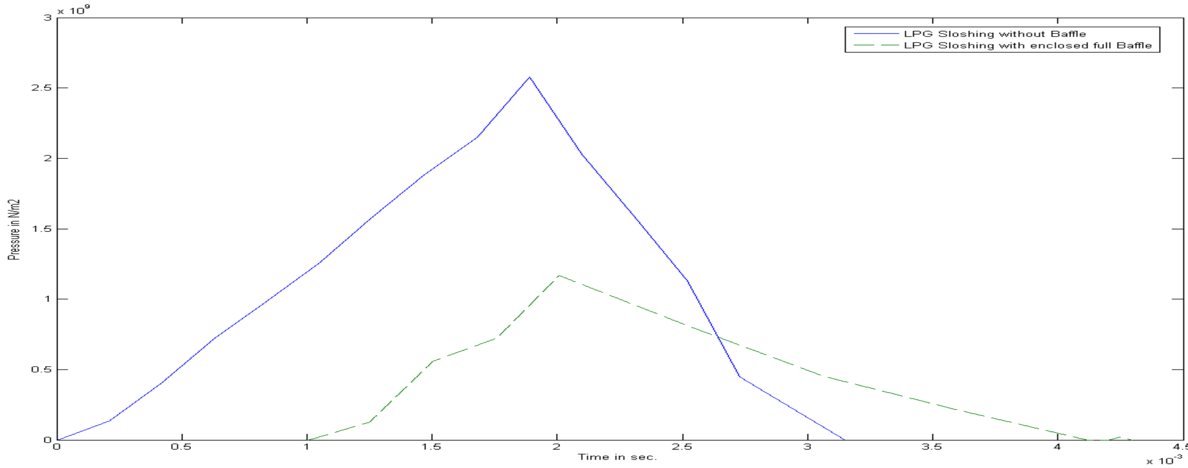

Fig.1.8 Combine Pressure VS Time Graph 1

D. Comparison Between One & Two Modified Baffle

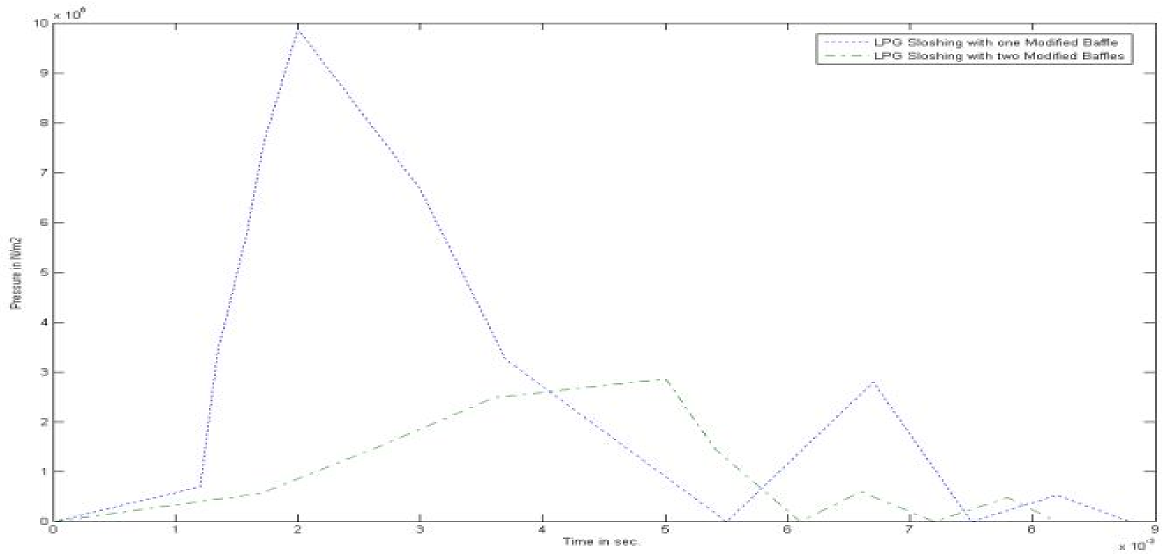

Fig.1.9 Combine Pressure VS Time Graph 2

E. Comparison Between Different Condition Of The Baffle

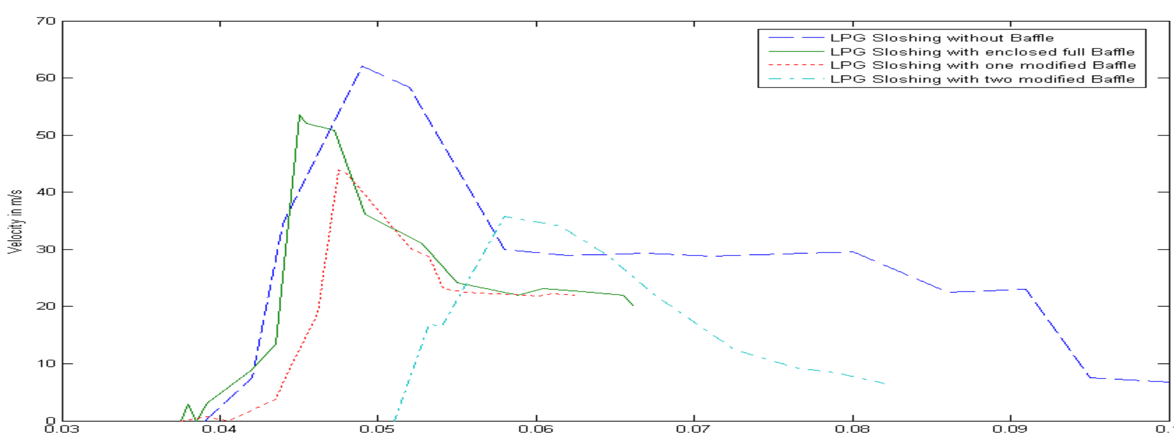

Fig.1.10Combine Velocity VS Time Graph

IV. DISCUSSIONS

From all the above results, Analysis of cylindrical liquid carrier tanker is carried out using the finite element method. Using**"LS-**DYNA" software defined problem has been modeled which uses Arbitrary LangrangianEulerian method (ALE). Elements depicting the properties of the tanker and the liquid are selected and coupled.At first iteration using full baffle the max. Pressure developed is 15.44E+01N/mm2 & max. Velocity of fluid is 7.72E+01m/s is occurred.At second iteration using three full baffles the max. Pressure developed is 5.08E+02N/mm2 & max. Velocity of fluid is 1.27E-02m/s is occurred.At third iteration using one half baffles the max. Pressure developed is 19.00E+01N/mm2 & max. Velocity of fluid is 1.06E-02m/s is occurred.At fourth iteration using three half baffle the max. Pressure developed is 5.68E+02N/mm2 & max. Velocity of fluid is 1.28E-02m/s is occurred.At fifth iteration using three modified baffle the max.pressure developed is 0.99E+02N/mm2 & max. Velocity of fluid is 9.02E-03m/s is occurred.

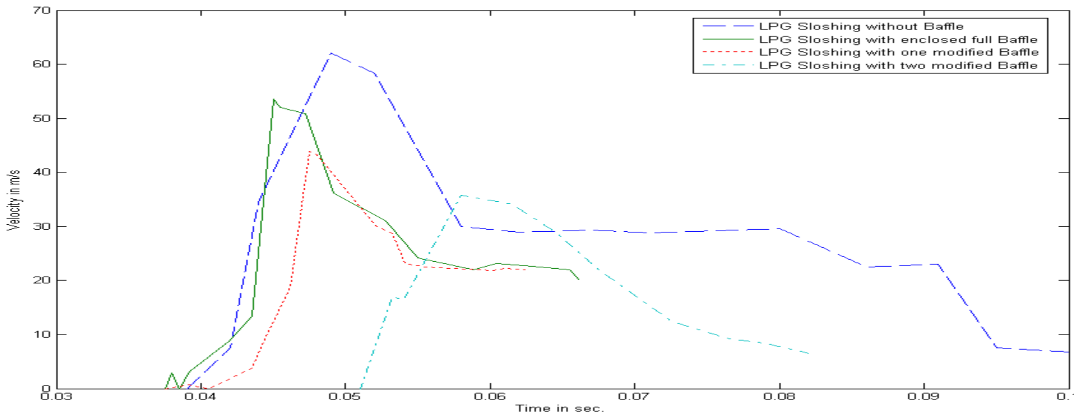

Fig.1.11Combine Velocity VS Time Graph

A. *Future Scope*

1) We will use in shipping area .Where import-export of crude oil and other liquids take place.
2) Transportation of oil by using railway tankers.
3) Aviation transportation.
4) Marine transport

V. CONCLUSION

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.Using LS-DYNA software defined problem has been modeled which uses Arbitrary LangrangianEulerian method (ALE). Elements depicting the properties of the tanker and the liquid are selected and coupled. Water is selected first to see the nature of sloshing and to get the maximum pressure. Then iterations are taken for real liquid in the problem i.e. Liquefied Petroleum Gas (LPG). Analysis is done to obtain sloshing patterns, pressure and velocity parameters in different cases. From the results that obtained in analysis following conclusions can be drawn: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 three modified baffles. Also effect of sloshing over tanker and baffles are decreased with proper thickness. The pressure and velocity developed in three modified baffled condition is lower thanonefullbaffled ,threefull baffled, one half baffled condition and three half baffled condition. So it is recommended to use three modified baffleswith thickness 20 mm in existing tanker design, which can decrease the sloshing considerably and sustain the sloshing pressure.

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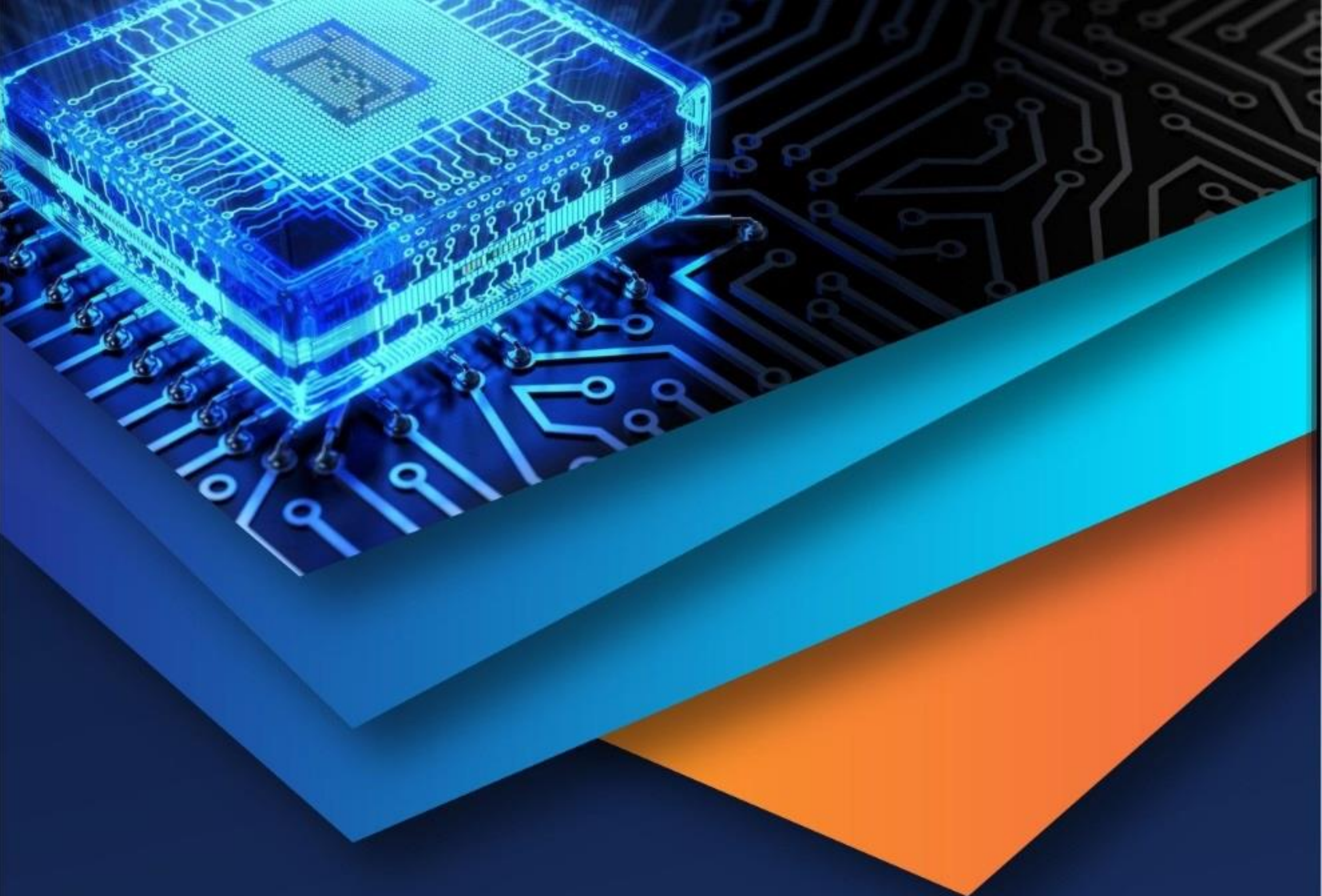

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