Impact of Baffle on Liquid Structure Connection in Fuel Tank Sloshing

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Abstract.

The current age has a desire to do explore in sloshing because of its intriguing applications with regards to different fields, for example, estimation of surface profile, DIC [Digital Image Correlation] and so on. The specialists have accomplished effective statures in sloshing strategy, yet answer for sloshing is a major test. This is a direct result of its exceptionally nonlinear component. This undertaking is managed the examination of sloshing elements in airplane fuel tank and the impact presenting confounds. This undertaking is managed the examination of sloshing elements in airplane fuel tank and the impact presenting confounds. This additionally provides data for assurance in the powerful area of confounds through the extent of the tank to refine execution also limit disposition of the vehicle. This correlation is finished using outcomes from computational examination of both 2D and 3D.

Keywords: Effect of sloshing, Baffle, CFD Analysis 2D & 3D

1. Introduction

Sloshing is the liquid movement within the tank. Slosh dynamic direct on the top of liquid will be based on the liquid properties, condition of the compartment [3]. The limits can impact the quality of the tank which moves and decrease its effect [4]. Hydrodynamic load calculation in compartments which moves contains two extraordinary portions which is achieved by the fluid moving with the speed and increases the tank speed. The resulting one is surface and liquid association which is required weight [5].

There are numerous kinds of capacity tanks relying upon the structure, development material, substance, volume, and capacity condition [5]. Fluid stockpiling tanks can be worked by steel or cement. Because of extraordinary harms on steel tank, the solid stockpiling tanks are commonly utilized these days. Fortified Concrete (RC) has been utilized in natural designing structures, for example, water repositories and sewage treatment tanks. Water tanks are these days utilized massively for different applications, for example, stockpiling of drinking water, horticultural cultivating and animals, fire concealment, and numerous different applications.
Fluid structure affiliation happens on account of the coupling of helper curving and tricky fluid stream [4]. It is a two-way coupling of weight and redirection. Its application consolidates airbag showing, fuel tank sloshing, heart valve illustrating, helicopter crash appearances, etc. Motivation behind inspecting FSI is that fluid mechanics may impact and be affected by the fundamental mechanics, and the opposite way around [6]. From now on for this circumstance the coupling of the fluids pressure and the development of the structure is essential.

1.1. Surface representation
Various methods exist are available for following immiscible interfaces, which can be grouped under the principle of classifications as per physical and numerical methodology:

- Lagrangian approach or Moving Grid approach (Capturing).
- Eulerian Approach or Fixed grid method (Tracking).
- Combined Approach - Lagrangian and Eulerian.

1.2. Suppression devices
As the size of fluid compartments builds the hydrodynamic powers and minutes become huge especially in the area of reverberation. While trying to keep away from auxiliary disappointment or bothersome powerful conduct, one must acquaint a few methods with smoother or to slice the dynamic burdens [4]. We can lessen dynamic burden by utilizing bewilders [6]. Puzzles change the liquid normal recurrence relying upon the shape, size and position. Against slosh perplexes are relied upon to keep the all-out fluid power from surpassing a specific recommended most extreme incentive under all conceivable filling conditions, tank direction and outside excitation[6].

The factor impacting the plan of slosh-concealment are as per the following
- The vehicle's main goal profile and direction.
- The damping prerequisites for a given holder
- The physical qualities of the tank, for example, its calculation, flexible distortion and protection.
- The fluid filling and depleting necessities.
- Properties of the fluid.
- The taking care of, slosh and sway stacks that must be continued by the gadgets.

2. Physical Model

2.1. Effective parameters
The main important parameter used in the simulation that plays viral role has been listed below:
- Tank geometry
- Propellant properties
- Acceleration field
- Effective damping
- Level of propellant in the tank
- Perturbing motion of tank

2.2. Physical model description
The description of the physical model shown in figure 1, 3D rectangular tank is given in the table 1. Tank is set up with vertical astound with thickness 0.005m of distinction in stature to decrease the effect of sloshing on tank divider, it depends on the water level inside the tank. Physical model with different measurements are given in figure 1. Variety of tank shape is available like cubic, spherical, rectangular, prismatic and circular, in this project rectangular tank is preferred because a rectangular tank with baffles mounted at the bottom is the common engineering remedy applied to loaded liquid containers.
2.3. Motion of tank
The simulation has been done for uniform acceleration of 1.3 m/s². In the negativity x direction and negativity g in y direction for 1 seconds initially and then undisturbed. Simulation works are carried for a minimum of 2 seconds.

2.4. Fuel tank with baffle
Sloshing happens because of movement of liquid inside mostly filled tank [1]. Thus, to decrease the impact of sloshing puzzles are presented in the tank at fitting areas. In the current examination, re-enactment is finished with and without perplex and contemplated the adequacy of various tallness of confound on sloshing powers and weights applied on tank divider. The confound thickness of .005m is remembered for the centre of tank divider vertically corresponding to YZ plane is shown in figure 2. The math for the current examination is demonstrated as follows.

2.5. Geometry modelling
2-Dimensional rectangular tank of dimension 0.5mx0.5m without baffle and with both horizontal and vertical baffle is drawn. Thickness and height of the vertical baffle is 0.005 m and 0.25 m. Thickness and position of the horizontal baffle is 0.005m and 1) 0.25m, 2) 0.125m from the bottom of the tank. Rectangular tank model created for 2-D Geometry without baffle, 2-D Geometry with single baffle, 2-D Geometry with double baffle, 2-D Geometry with holed baffle, 2-D Geometry with baffle at 50%, 2-D Geometry with baffle at 25%. A 3-Dimensional rectangular tank with dimension 0.5mx0.5mx0.5m without baffle and with baffle are drawn. Thickness and height of the baffle is 0.005m and 0.25m. Model created for 3-D Geometry without baffle, 3-D Geometry with single baffle, 3-D Geometry with double baffle. (Reference diagram is shown in figure 2)
3. Computational Analysis

Computational liquid elements is mostly used to foreseeing liquid stream, compound response, heat move, and related wonders. Numerically solved by the set of governing mathematical equation.

- Mass conservation
- Momentum conservation
- Energy conservation
- Body force effect

Liquid stream and warmth move are administered by essential thing conditions. Thus, expectation of liquid stream should be possible in the accompanying methodologies

- Experimental Approach
- Analytical Approach
- Numerical Approach

The advantages of CFD are it can handle LPDE, jumbled physical marvels can be managed, time appraisal of stream can be procured and we can recreate in the ideal condition. There are no such disadvantages in CFD approach aside from there is a couple of botches in this cycle, for instance, truncation botch, alter, and machine botch, etc.

3.1. Mesh generation

After creation of model, meshing is done in the ANSYS pre-processor. In present cases uniform quadrilateral mesh is generated. Mesh is generated for 2-D Mesh without baffle, 2-D Mesh with single baffle, 2-D Mesh with double baffle, 2-D Mesh with holed baffle, 2-D Mesh with baffle at 50%, 2-D Mesh with baffle at 25%, 3-D Mesh without baffle, 3-D Mesh with single baffle, 3-D Mesh with double baffle.

(A reference mesh diagram is shown in figure 3).

![Figure 3](image)

**Figure 3.** a) 2-D Mesh with double baffle, b) 3-D Model without baffle

3.2. Boundary condition – Fluent analysis

When cross section is being done, work document is next sent out to FLUENT. In present examination 2-D and 3-D two fold exactness familiar solver with equal handling is utilized. The operating conditions are mentioned in the table 2.

- Total time for simulation 2sec and time step size is 0.1 and number of time step is 20.

| Boundary conditions                      | Values          |
|-----------------------------------------|-----------------|
| Pressure                                | 1 bar           |
| Acceleration for first one second       | X= -6 m/s²      |
| Acceleration for next second            | Y= -9.81 m/s²   |
| Density                                 | 1.225Kg/m³      |

4. Results and Discussion

In this part addresses a point by point discussion about the eventual outcomes of the current examination. In this examination a computational multiplication is finished for a fuel tank when is presented to uniform speeding up field. In view of this animating development, sloshing powers is made in the tank. Amusement is finished as tank without baffle and with befuddle at three particular circumstances along the tank.
Results of the analysis is discussed from Case 1 – Case 12, and for each and every cases effect of sloshing, impact of sloshing, sloshing height is showed for different time seconds like 0.2,0.4,0.6,0.8 and 1. All the effects are shown for 2-D and 3-D with and without baffle. Case 1 represent slosh dynamics in the fuel tank without baffles, case2 represent slosh elements of fuel tank when the baffles are embedded at half of the length of the tank, case 3 represent slosh dynamics of the tank if the baffles are introduced at 30% & 70% with respect to the length of the fuel tank, case 4 represent slosh dynamics of fuel tank if the hole baffle is introduced at 50% with respect to the length of the tank, case 5 represent slosh dynamics of the tank when the horizontal baffle is introduced at 50% of the height of the tank, case 6 represent slosh dynamics of the tank when the horizontal baffle is inserted at 25% of the height of the tank, case 7 represent slosh dynamic of the tank when the comparison of horizontal baffle at 25% and 50% at 1,case 8 represent slosh dynamic of the tank when the comparison of horizontal baffle at 25% and 50% at 1,case 9 represent 3-D slosh dynamics of fuel tank without baffles, case 10 represent 3-D slosh dynamics of the tank when the baffles are inserted at 50% of the length of the tank, case 11 represent 3-D slosh dynamics of fuel tank if the baffles are introduced at 30% & 70% with respect to the length, case 12 represent slosh dynamic of the tank when the comparison of the theoretical, 2-D and 3-D value of sloshing height.

4.1 CASE 1: At the point when the tank without baffle is exposed to speeding up for 1 second at 2-D: 
Figure 4 represents the slosh dynamics in the fuel tank without baffles.

![Figure 4](image1)

Figure 4. a) At 0.2 seconds, b) At 0.6 seconds, c) At 1.0 second

4.2 CASE 2: At the point when the tank with baffle at half is exposed to speeding up for 1 second at 2-D: 
The following figure 5 shows the slosh elements of fuel tank when the baffles are embedded at half of the length of the tank

![Figure 5](image2)

Figure 5. a) At 0.2 seconds, b) At 0.6 seconds, c) At 1.0 second

4.3 CASE 3: If the tank with 2 baffles at 30% & 70% is subjected to acceleration for 1 second at 2-D: 
The following figure 6 shows the slosh dynamics of the tank if the baffles are introduced at 30% & 70% with respect to the length of the fuel tank.

![Figure 6](image3)

Figure 6. a) At 0.2 seconds, b) At 0.6 seconds, c) At 1.0 second
4.4 CASE 4: If the tank with hole baffles at 50% is subjected to acceleration for 1 second at 2-D:
The following figure 7 shows the slosh dynamics of fuel tank if the hole baffle is introduced at 50% with respect to the length of the tank.

![Figure 7](image)

**Figure 7.** a) At 0.2 seconds, b) At 0.6 seconds, c) At 1.0 second

4.5 CASE 5: If the tank with horizontal baffle at 50% is subjected to acceleration for 1 second at 2-D:
The following figure 8 shows the slosh dynamics of the tank when the horizontal baffle is introduced at 50% of the height of the tank.

![Figure 8](image)

**Figure 8.** a) At 0.2 seconds, b) At 0.6 Seconds, c) At 1.0 Second

4.6 CASE 6: At the point when the tank with even baffle at 25% is exposed to quickening for 1 second at 2-D:
The following figure 9 shows the slosh dynamics of the tank when the horizontal baffle is inserted at 25% of the height of the tank.

![Figure 9](image)

**Figure 9.** a) At 0.2 seconds, b) At 0.6 Seconds, c) At 1.0 second

4.7 CASE 7: Comparison of tank's sloshing for baffle with hole and without hole for 1 second at 2-D:
The following figure 10 shows the slosh dynamic of the tank when the comparison of baffle with hole and without hole at 1 second.

![Figure 10](image)

**Figure 10.** a) Without hole at 1 Second, b) with hole at 1 second
4.8 CASE 8: Comparison of tank's sloshing horizontal baffle at 25% and 50% for 1 second at 2-D:
The following figure 11 shows the slosh dynamic of the tank when the comparison of horizontal baffle at 25% and 50% at 1

![Figure 11](image1)

**Figure 11.** Horizontal baffle at 25% at second 1, b) Horizontal baffle at 50% At 1 Second

4.9 CASE 9: Fuel tank without baffle subjected to acceleration for one second at 3-D:
The following figure 12 diagram shows the slosh dynamics of fuel tank without baffles.

![Figure 12](image2)

**Figure 12.** a) At 0.2 seconds, b) At 0.6 seconds, c) At 1.0 second

4.10 CASE 10: Fuel tank with baffle at 50% is subjected to acceleration for 1 second at 3-D:
The following figure 13 shows the slosh dynamics of the tank when the baffles are inserted at 50% of the length of the tank.

![Figure 13](image3)

**Figure 13.** a) At 0.2 seconds, b) At 0.6 seconds, c) At 1.0 second

4.11 CASE 11: Fuel tank with 2 baffles at 30% & 70% is subjected to acceleration for 1 seconds at 3-D:
The following figure 14 shows the slosh dynamics of fuel tank if the baffles are introduced at 30% & 70% with respect to the length.

![Figure 14](image4)

**Figure 14.** a) At 0.2 seconds b) At 0.6 seconds, c) At 1.0 second
4.12 CASE 12: Comparison of theoretical, 2-D and 3-D value of sloshing height:
The following figure 15 shows the slosh dynamic of the tank when the comparison of the theoretical, 2-D and 3-D value of sloshing height.

Figure 15. a) Theoretical sloshing height- 0.4021 m, b) Sloshing height- 0.431 m, c) Sloshing height- 0.41229 m

5. Conclusion
Unsteady flow simulation is carried out, the results are validated for different time seconds and compared the theoretical results with the numerical results. From the outcome, it is noted that, the inclusion of puzzles diminishes the impact of sloshing. The vertical confuse hoses the sloshing impact. As the quantity of astounds builds the slosh tallness can be diminished yet the heaviness of tank increments. The slosh tallness can be successfully diminished by putting even confounds precisely on the interface of fluid and air. The indented capacity of the flat confounds lessens when it set inside the interface of fluid and air. When contrasting perplexes and gap and without opening, the weight lessens and fuel limit increments in the latter case. Moreover the variety in slosh tallness is unimportant when looking at those two cases. From the liquid and structure perspective, the permeable perplex kept at level position precisely on the interface is proclaimed as the best model. The investigative 2D and 3D arrangement is corresponded with the hypothetical arrangement and is discovered that the rate mistake is 6.7 %.

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