RESEARCH ARTICLE OPEN ACCESS

Analysis of the Effect of Variation of Baffle Height on the Liquid Sloshing In the Tank with CFD Approach

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Abstract
Sloshing is a common physical phenomenon which occurs in moving tanks with contained liquid masses, such as liquid cargo carriers, rockets, aircrafts, and the seismically excited storage tanks, dams, reactors, and nuclear vessels. The sloshing frequencies of contained liquid are essential in the analysis and design of the liquid tanks and the associated structures. In this paper an attempt made with the VOF model and considered with immiscible fluids by solving a single set of momentum equations and tracking the volume fraction of each of the fluids throughout the domain. Further investigated the effect of the vertical baffle heights on the liquid sloshing in a three-dimensional (3D) rectangular tank. studied dynamic analysis of sloshing in rectangular tanks with multiple vertical baffles. ANSYS-CFX software was used to study this dynamic analysis subjected to random excitations including earthquake induced motions. analytically estimated hydrodynamic damping ratio for liquid sloshing phenomenon in a partially filled rectangular tank for baffles. They used the velocity potential formulation and linear wave theory for analytic calculations.

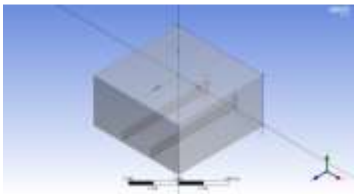
Key words: sloshing, CFD, VOF model

I. INTRODUCTION

The present work is to examine computationally the effect of variation of baffle height on the liquid sloshing in the tank, The vertical height of the baffle was varied relative to the initial liquid fill level.. The analysis shows that if the tank is subjected to excitation Frequency, liquid sloshing will become extreme and wall forces will be intensified. Result shows that after a certain height (critical height) of baffle, the liquid does not reach at roof top and when baffle height is equal to liquid fill level, almost linear behavior of the free surface is observed in each section.

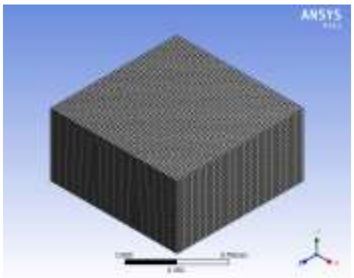
II. METHODOLOGY

In this case two sub cases with vertical baffle height of 0.12m and 0.38m is considered. 0.12 m vertical baffle height is below the optimum level of liquid in the tank of 60% volume fraction and 0.38m height is at the surface level of the liquid in the tank with 60% volume fraction.**CASE I**: **Vertical baffle height of 0.12m :**The below figure shows the cad layout of the tank with two baffles of same 0.12 m vertical height, the height of the baffles was well below the level of liquid in the tank of 60% volume fraction.



2.1CAD model of the tank with two baffles of 0.12m vertical height

Wall boundary conditions were assumed for baffles while doing the analysis and fluid domain was chosen for the interior of the tank.

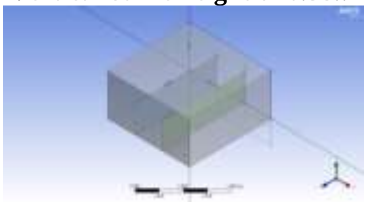


2.2 Meshed model of the tank with baffles

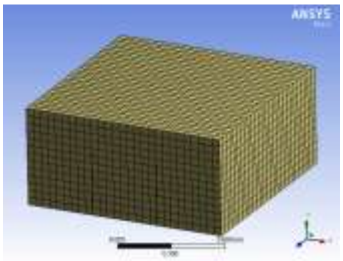
Mesh report - Table 2.1

Domain	Nodes	Elements
solid	54144	49266

CASE II: Vertical baffle height of 0.38.:-



2.3 CAD model of the tank with two baffles of 0.38m vertical height



2.4 Meshed model of the tank with baffles of vertical height 0.38m

Mesh report –Table 2.2

Domain	**Nodes**	**Elements**
solid	12096	9963

III. RESULTS AND DISCUSSIONS

Figures 3.1- 3.21 show the liquid sloshing in tank with two baffles with vertical height of 0.12m which is below the height of the liquid level in the tank. Liquid level of 60% volume fraction was considered in this case which was found to be optimum from the previous case**.**Figure below shows the sloshing of the liquid at 0.01sec for lateral effect with two baffles, with baffle height of 0.12m there was no much sloshing was observed.

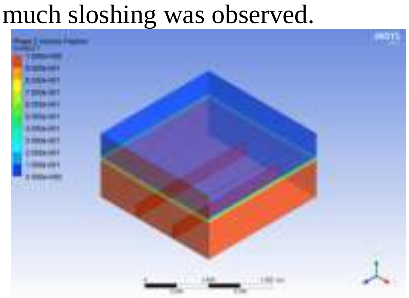


Fig 3.1: Tank sloshing with vertical baffle height of 0.12m at 0.01 sec

From the figure, the sloshing at 0.2 sec was almost the same as that was observed in case 1 without baffle, the vertical height of 0.12m baffle does not shows much effect on sloshing.

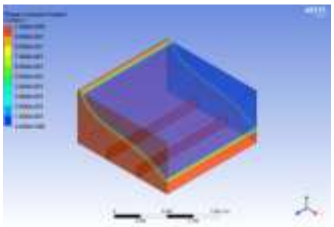


Fig 3.2: Tank sloshing with vertical baffle height of 0.12m at 0.2 sec

From the figure it can be observed that the liquid reaches the top of the tank at much less time as in case of the sloshing in tank without baffles, this was observed for 0.4sec also.

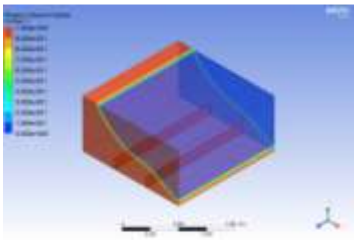


Fig 3.3: Tank sloshing with vertical baffle height of 0.12m at 0.3 sec

The sloshing in the tank became more predominant at 0.4 sec and baffles does not show much effect on the sloshing, Since the baffles vertical height was very less the liquid reached the top of the tank early , as the baffle does not have much stopping impact on the liquid.

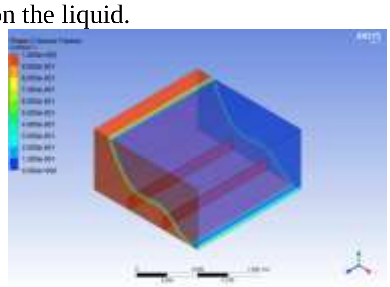


Fig 3.4: Tank sloshing with vertical baffle height of 0.12m at 0.4 sec

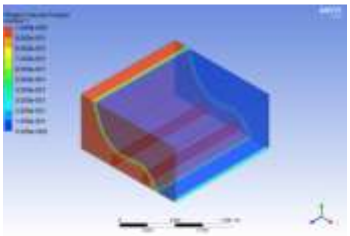


Fig 3.5: Tank sloshing with vertical baffle height of 0.12m at 0.6 sec

As there is increase in time the sloshing became more predominant in the tank and vertical heigt of baffle does not have any impact on the liquid causing the liquid to reach the top surface of the tank which was commonly observed for tank with no baffles.

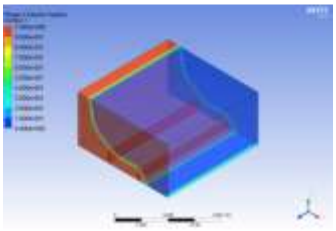


Fig 3.6: Tank sloshing with vertical baffle height of 0.12m at 0.8 sec

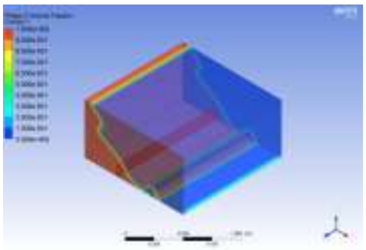


Fig 3.7: Tank sloshing with vertical baffle height of 0.12m at 1 sec

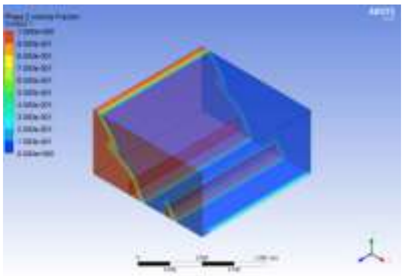


Fig 3.8: Tank sloshing with vertical baffle height of 0.12m at 1.2 sec

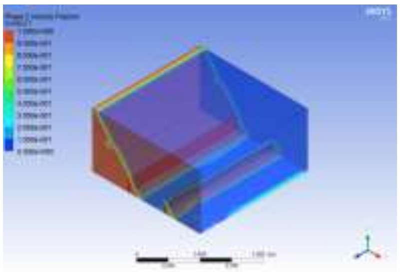


Fig 3.9: Tank sloshing with vertical baffle height of 0.12m at 1.4 sec

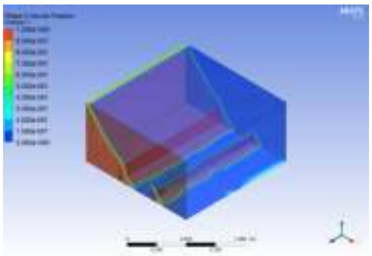


Fig 3.10: Tank sloshing with vertical baffle height of 0.12m at 1.6 sec

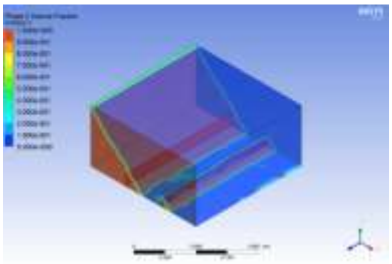


Fig 4.11: Tank sloshing with vertical baffle height of 0.12m at 1.8 sec

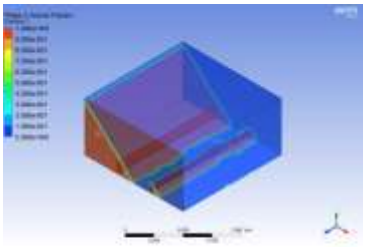


Fig 3.12: Tank sloshing with vertical baffle height of 0.12m at 2 sec

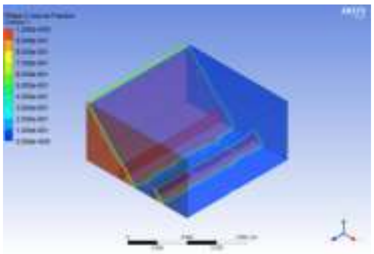


Fig 3.13: Tank sloshing with vertical baffle height of 0.12m at 2.4 sec

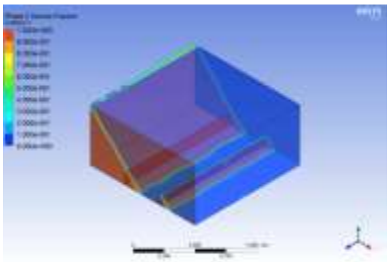


Fig 3.14: Tank sloshing with vertical baffle height of 0.12m at 2.6 sec

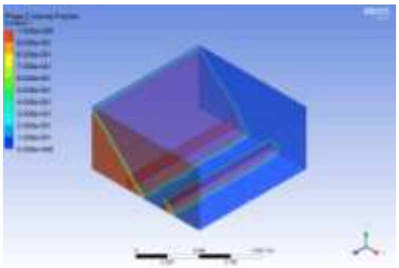


Fig 3.15: Tank sloshing with vertical baffle height of 0.12m at 2.8 sec

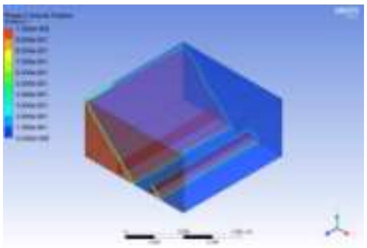


Fig 3.16: Tank sloshing with vertical baffle height of 0.12m at 3 sec

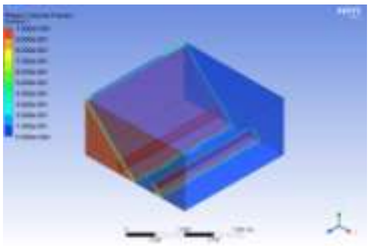


Fig 3.17: Tank sloshing with vertical baffle height of 0.12m at 3.2 sec

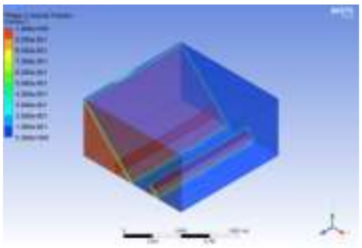


Fig 3.18: Tank sloshing with vertical baffle height of 0.12m at 3.4 sec

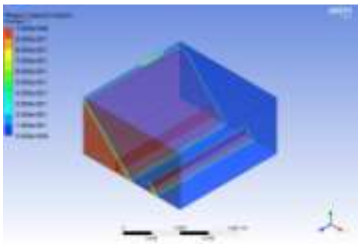


Fig 3.19: Tank sloshing with vertical baffle height of 0.12m at 3.6 sec

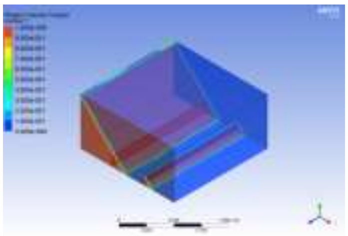


Fig 3.20: Tank sloshing with vertical baffle height of 0.12m at 3.8 sec

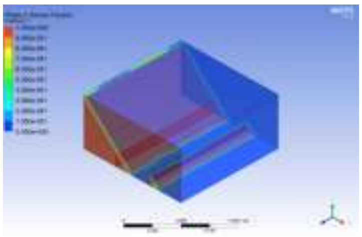


Fig 3.21: Tank sloshing with vertical baffle height of 0.12m at 4 sec

The pressure distribution caused by liquid sloshing at different probes is shown in figure. It was observed that the compression zone is located in the down right corner of the tank and in the baffle down. The maximum pressure in the tank was observed to be approximately 400Pa at 0.04sec and was found to be gradually decreased with increase in time to minimum pressure or no pressure at 2 sec and 75pa at 4sec.

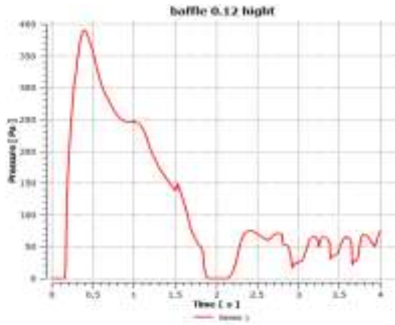


Fig 3.22: Variation of pressure with respect to time

The figure below shows the variation of amplitude with frequency maximum amplitude of the liquid sloshing wave was found to be 40db and was decreasing with increase in frequency.

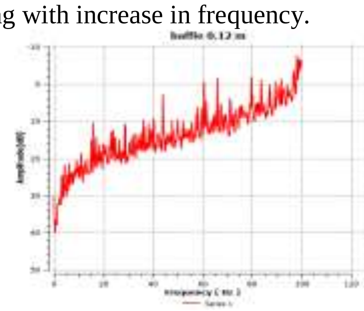
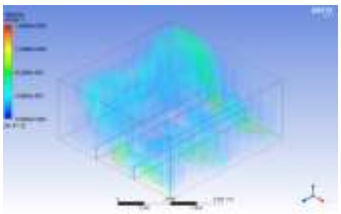


Fig 3.23: Variation of Amplitude with respect to Frequency

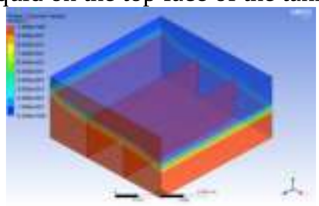


3.24 Velocity vectors of liquid sloshing inside tank for 1.2m vertical height of the baffles

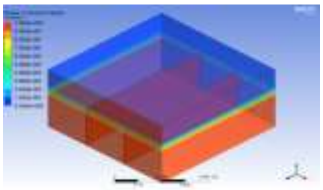
3.25 Velocity streamlines of liquid sloshing inside tank for 1.2m vertical height of the baffles

CASE II: Vertical baffle height of 0.38m

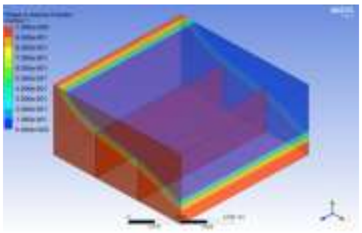
Vertical baffle height of 0.38m was considered in this case fr 60% volume fraction of liquid and two baffles, The critical baffle height of the baffle was obtained from this analysis,The vertical height of the baffle was found to be a critical case in case of liquid sloshing in tanks, It was found that as the height of the baffle increases the blocking effect on the liquid in reaching the top of the tank and avoiding the impact of liquid on the top face of the tank.



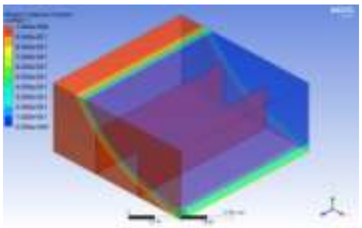
3.26 Tank sloshing with vertical baffle height of 0.38m at 0.01 sec



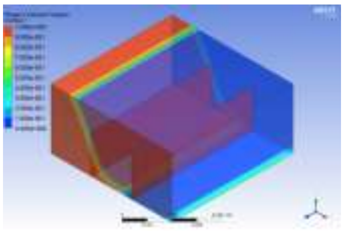
3.27 Tank sloshing with vertical baffle height of 0.38m at 0.1sec



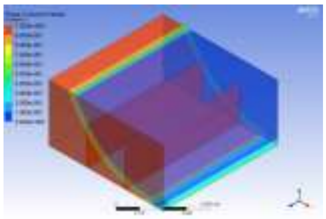
3.28 Tank sloshing with vertical baffle height of 0.38m at 0.2sec



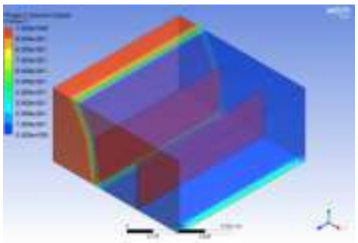
3.29 Tank sloshing with vertical baffle height of 0.38m at 0.35sec



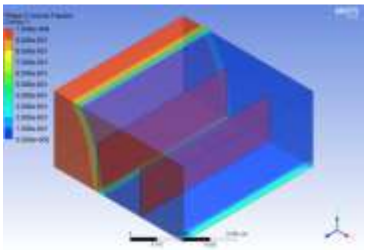
3.30 Tank sloshing with vertical baffle height of 0.38m at 0.4sec



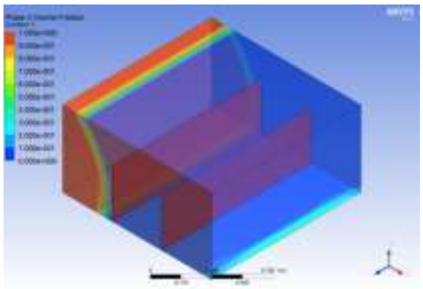
3.31 Tank sloshing with vertical baffle height of 0.38m at 0.5sec



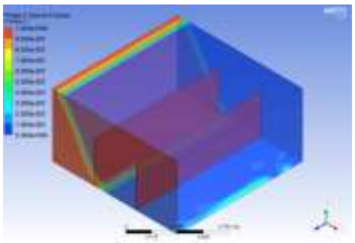
3.32 Tank sloshing with vertical baffle height of 0.38m at 0.6sec



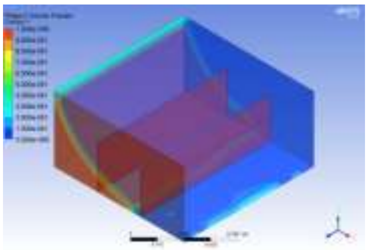
3.33 Tank sloshing with vertical baffle height of 0.38m at 0.7sec



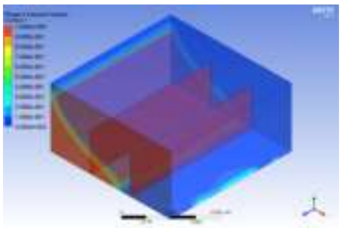
3.34 Tank sloshing with vertical baffle height of 0.38m at 0.8sec



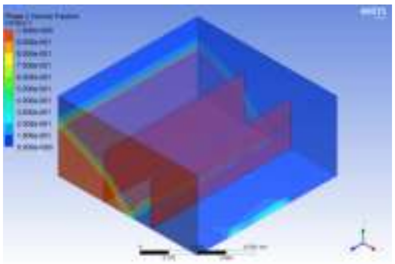
3.35 Tank sloshing with vertical baffle height of 0.38m at 0.9sec



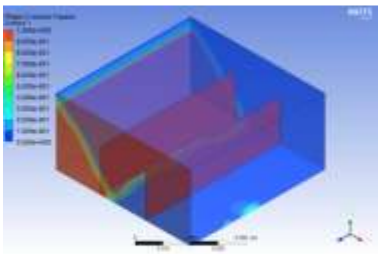
3.36 Tank sloshing with vertical baffle height of 0.38m at 1.2sec



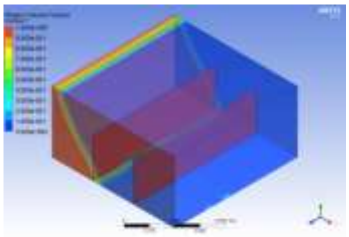
3.37 Tank sloshing with vertical baffle height of 0.38m at 1.3sec



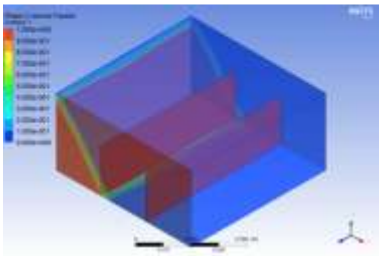
3.38 Tank sloshing with vertical baffle height of 0.38m at 1.4sec



3.39 Tank sloshing with vertical baffle height of 0.38m at 1.6sec

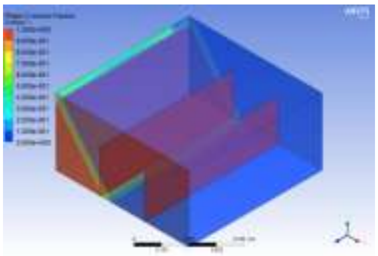


3.40 Tank sloshing with vertical baffle height of 0.38m at 1.8sec



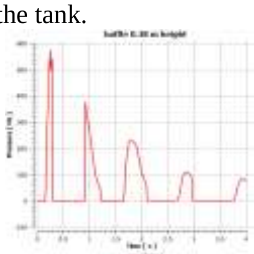
3.41 Tank sloshing with vertical baffle height of 0.38m at 3sec.

The critical baffle height is hB/h=0.3 beyond which liquid does not reach the roof of the tank at any instant and consequently does not lead to roof impact. Effect of the vertical baffle height on the liquid sloshing in a three-dimensional rectangular tank.

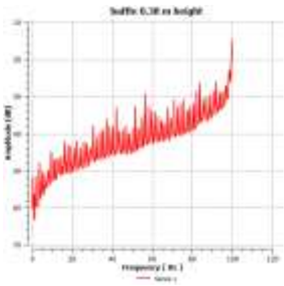


3.42 Tank sloshing with vertical baffle height of 0.38m at 4sec

Figure shows the variation of pressure with time for 0.38m of baffle height. The variation of pressure with time was converse as in case of vertical baffle height of 0.12m , It was observed to be maximum at 0.2 sec with magnitude of 600Pa approx and then showed irregular variation due to the blocking effect of the baffle as the height of the baffle is more then the liquid level, which restricted the liquid to reach the top surface of the tank.

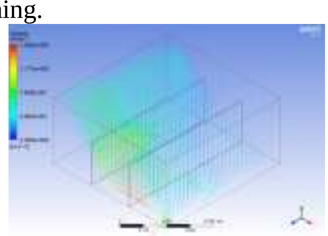


3.43 Variation of pressure with respect to time for 0.38m vertical baffle height



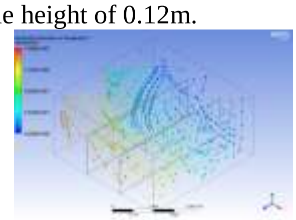
3.44 Variation of Amplitude with frequency

The liquid no longer goes over the baffle and the liquid sloshing is restricted to within half of the tank and an almost linear behavior of the free surface is observed in each section. The vortex generated by the flow separation from the baffle tip becomes weaker and smaller with increasing baffle height, leading to a diminished damping effect of the tip vortex on the liquid sloshing.



3.55 Velocity vectors of the liquid for 0.38m vertical baffle height

The figure below shows the streamline of the liquid in the tank, the vortex shedding was found at the tip of the baffle, which was more as in case of the vertical baffle height of 0.12m.



3.56 Flow streamlines across the tank with baffles.

IV. CONCLUSIONS AND FUTURE SCOPE

Pressure comparisons in both cases it is found that the vertical baffle height of 0.38m was optimum. As vertical height increases the free surface behavior of liquid is found to be stable without reaching top surface of the tank. As the vertical baffle height increases, the blockage effect of the vertical baffle on the liquid convection is predominant to the tip vortex. Free surface elevation was found to be decrease as height of the baffle increases. It was observed that the vertical baffle is a more effective tool in reducing the sloshing amplitude. As the impact pressure of the liquid increase on the baffles with increase in vertical height, because of this impact the thickness variation can be considered as an extension for the research. Impact pressures can vary by changing tank design by keeping the volume constant.

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