IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

A Project On Design And Experimental Validation On Sloshing In A Rectangular Tank With Vertical Baffles

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2022-23

ABSTRACT –

The quest of publishing this paper in this journal is to bring in the latest developments and experiments conducted to present the free surface behaviour of fluid in a partially filled rectangular tank in uniformly accelerated motion. The fluid/liquid in the tank is subject to abrupt sloshing during sudden acceleration or stopping of the vehicle which will produce structural vibration and hydrodynamic pressure induced in the tank. To reduce this sloshing, baffles are used inside the tank. The objective of this work is to study the influence of baffles which are mounted vertically and fill levels on the free surface liquid in the partially filled tank.

I. INTRODUCTION

Sloshing phenomena in moving rectangular tanks can usually be described by considering only two-dimensional fluid flow if the tank width is much smaller than its breadth. The problem of liquid sloshing in moving or stationary containers remains of great concern to aerospace, civil, and nuclear engineers, physicists, designers of road tankers and ship tankers, and mathematicians. Civil engineers and seismologists have been studying liquid sloshing effects on large dams, oil tanks, and elevated water towers underground motion. They also mounted liquid tanks on the roofs of multi-story buildings as a means to control building oscillations due to earthquakes. The dynamic stability of liquefied natural gas tankers and ship cargo tankers, and liquid hydrodynamic impact loading are problems of current interest to the designers of such systems. In populated cities, gasoline and other flammable liquid tankers are prone to rollover accidents while entering and exiting highways. The slosh loads depend upon the two major important factors they are
1) Type of disturbance and
2) Tanker shape

Based upon these two factors earlier many experiments were conducted to find the effect of tanker geometry. The disturbances can be occurred due to seismic excitations or when the vehicle hits a brake and even when we hit any obstacle. Even at a steady-state, the fluid will have motion inside the tanker due to the nature of the fluid. Liquid sloshing strongly influences the directional dynamics and safety performance of highway tank vehicles in a highly adverse manner. Hydrodynamic forces and moments arising from liquid cargo oscillations in the tank understeering and/ or braking manoeuvres reduce the stability limit and controllability of partially filled tank vehicles. Anti-slosh devices such as baffles are widely used to limit the adverse liquid slosh effect on directional performance and stability of tank vehicles. This is mainly due to the displacement of the free surface motion of the liquid. The free surface is the top surface layer of the fluid or liquid.

II. OBJECTIVE

a) To perform a test involving sloshing of fluid / liquid to determine the elevation of free liquid surface & the positions of the baffles.
b) To minimise the pressure induced by the hydrodynamic forces inside the tank due to sloshing, with the help of ANSYS software.
c) To find the difference in behaviour of the liquid in the tank by using baffles **and** without using baffles with Modal Analysis Perform in ANSYS.

III. PROBLEM STATEMENT

In industrial applications for both factory & household consumptions, there is huge need to transport the liquids from one place to another. During this transportation the sloshing phenomena is a big problem. There is constant need to design & develop the inner structure of the containers which ensure minimum or no sloshing of these liquids for proper manoeuvre.

IV. SCOPE

The current project work is concentrated on design of a vertical baffle for a rectangular tank for a fire brigade truck. This can be accomplished by the following steps:

- Performing a sloshing test on a scale down model of the actual tank to determine the position of baffles, free liquid surface elevation, as well as a number of baffles, require to dampen the sloshing can be obtained.
- By performing VOF modeling hydrodynamic pressure induced on tank’s walls and free liquid surface elevation can be compared with experimental data.
- After evaluating results required hydrodynamic pressure induced in the tank for optimum design can be obtained.
- By performing modal analysis on the tank with baffles the natural frequency of the tank can be increased, the other methods like increasing thickness, changing shape of the tank, changing material, etc, are not viable in this scope of experiment.

V. METHODOLOGY

The following are the aspects to be taken into consideration for accomplishing the project

A. Study of Sloshing & Suppression devices-

• Study of sloshing & its causes, different suppression devices used for damping.
• Study of different factors affecting sloshing, suppression devices working, and selection.

B. Experimental Approach

- Performing Sloshing Test to simulate vehicle braking conditions at different fill levels at constant acceleration for finite displacement.
- Determination of free liquid surface elevation and No. of baffles require damping.

C. Computational Analysis

- Performing VOF (Volume Of Fluid) modeling for determination of free liquid surface motion and induced hydrodynamic pressure.
- Modal analysis for comparing natural frequencies modes of the tank without baffles and with baffles.

VI. SLOSHING

In fluid dynamics, sloshing refers to the movement of two or more immiscible fluids (generally liquid and gas) inside another object (which is, typically, also undergoing motion).

Dependent Factors of Sloshing

As per the early work that was conducted on the sloshing effect a few factors were responsible for the effect of sloshing. They are listed below

1) Amplitude and frequency of the tank motion
2) Liquid fill depth
3) Liquid properties
4) Tank geometry

Suppression Devices

As the size of liquid containers increases the hydrodynamic forces and moments become very large particularly in the neighborhood of resonance.

The summarized primary parameters influencing the design of slosh-suppression devices are as follows:

1) The vehicle's mission profile and trajectory
2) The damping requirements for a given container or liquid-slosh-motion amplitudes at various liquid levels.
3) The physical characteristics of the tank such as its geometry, elastic deformation, and insulation.
4) The liquid filling and draining requirements.
5) The physical properties of the liquid.
6) The handling, slosh, and impact loads that must be sustained by the devices.

VII. EXPERIMENTAL APPROACH

The Baffle selection mainly lies on the liquid flow path, As mentioned earlier baffles are passive slosh damping devices in liquid storage containers to obstruct vertical velocity of sloshing. The horizontal baffles are most effective in this condition, however in our condition, the vertical velocity of the liquid is not of major concern, hence horizontal baffles are rejected. The baffles like conical, radial, and Z ring conic baffles are majorly used in a cylindrical tank. Floating cans and floating lid devices are not practical in the case of large volume tanks. The basic concept of a passive sloshing damper is to dissipate sloshing motion energy by breaking a main sloshing flow into several weaker sub-streams this can be achieved by using vertical baffle plate.

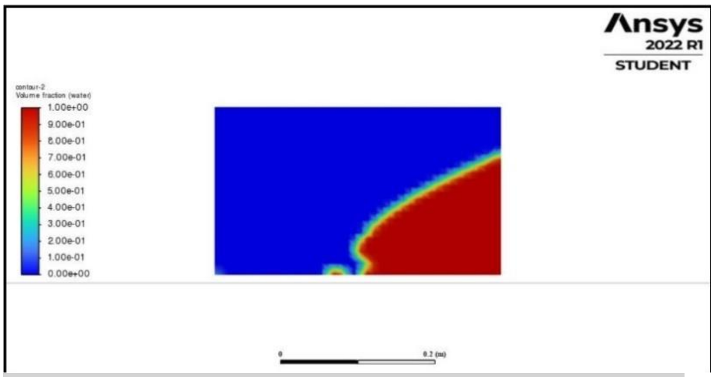
Types of Baffles

1. Horizontal baffle rings, which can be movable, or fixed, or rings with radial clearance
2. Conical baffles, which are placed upright or inverted
3. Radial or sectored baffles in the form of complete sectored baffles
4. Vertical Baffles with orifice, perforation, plate
5. Z-ring conic section baffles, Floating cans & Floating lid devices.

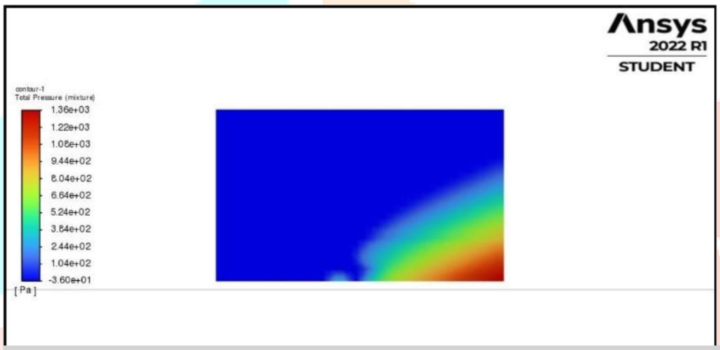
VIII. COMPUTATIONAL ANALYSIS

Result at 25% Fill Level

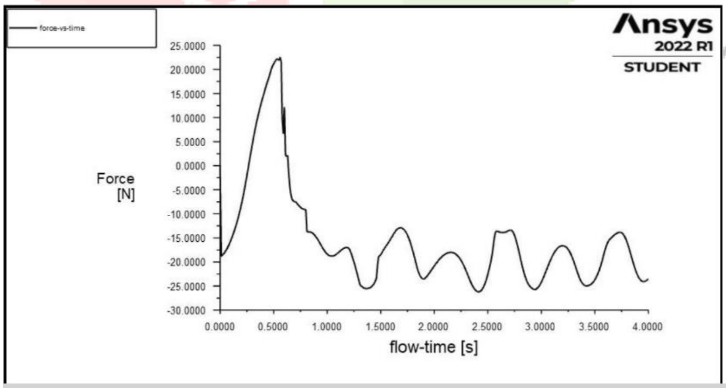
Tank Without Baffle



Volume Fraction of 25% fill level tank without baffle

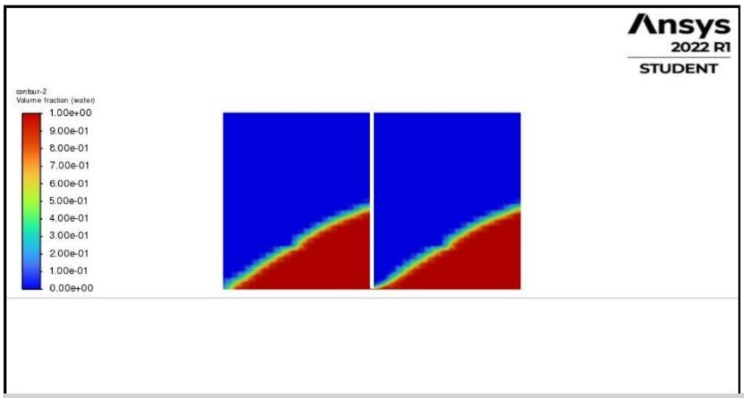


Total Pressure contours of 25% fill level tank without baffle

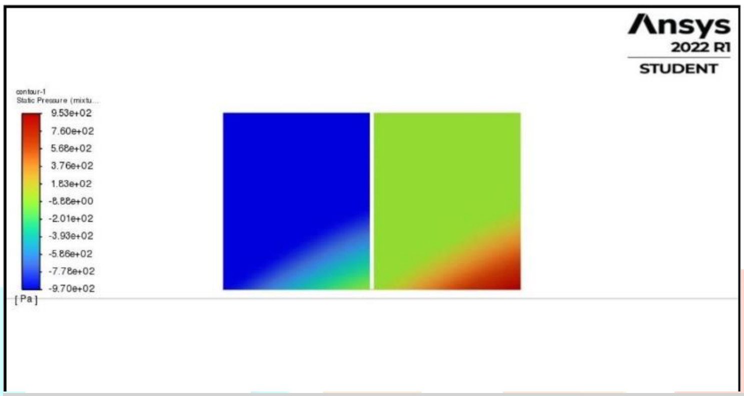


Force vs time graph of 25% fill level tank without baffle

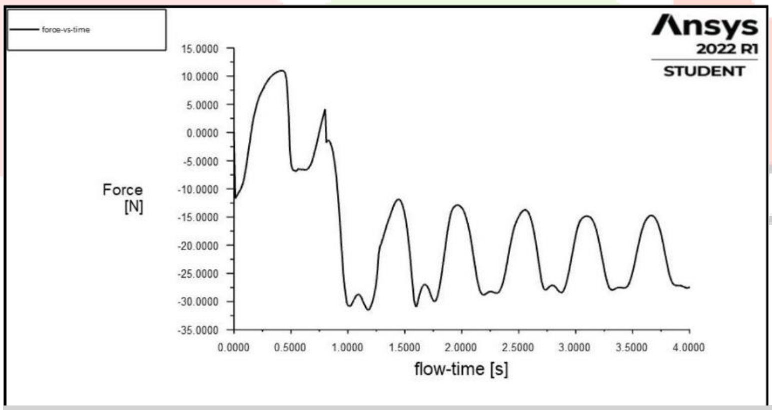
Tank With One Vertical Baffle



Volume Fraction of 25% fill level tank with one vertical baffle

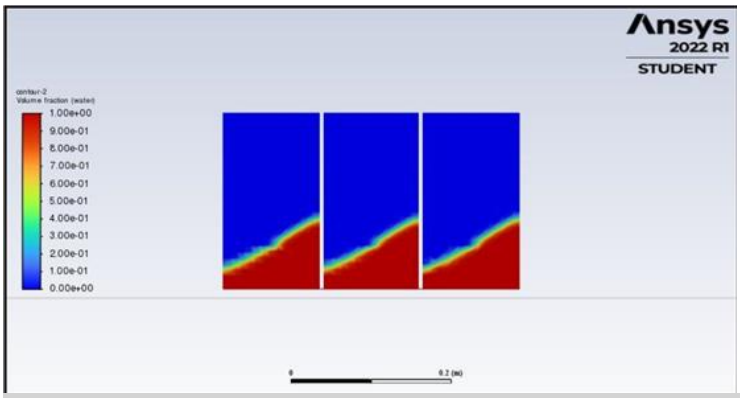


Total Pressure contours of 25% fill level tank with one vertical baffle

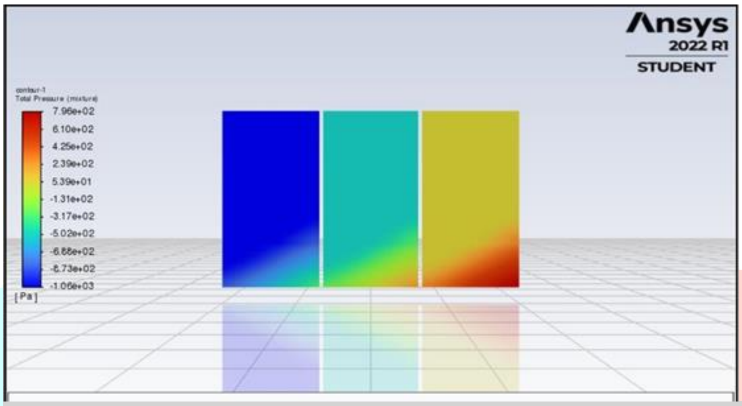


Force vs Time graph of 25% fill level tank with one vertical baffle

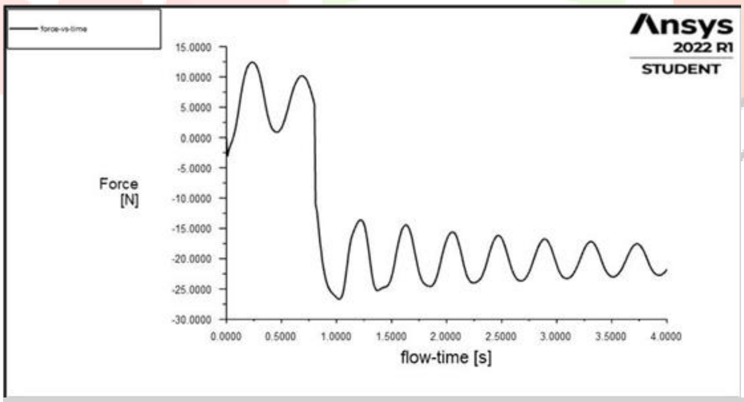
Tank With Two Vertical Baffles



Volume Fraction of 25% fill level tank with two vertical baffles



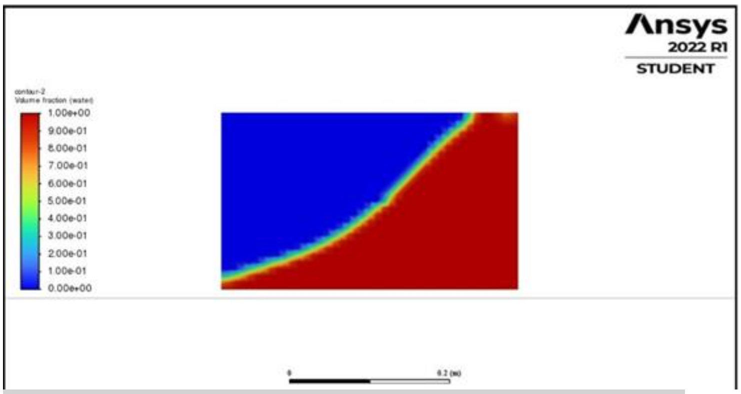
Total Pressure contours of 25% fill level tank with two vertical baffles



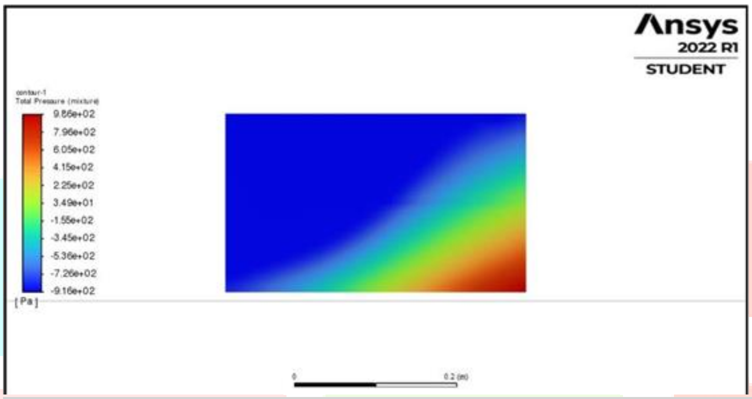
Force vs Time graph of 25% fill level tank with two vertical baffles

Result at 50% fill level

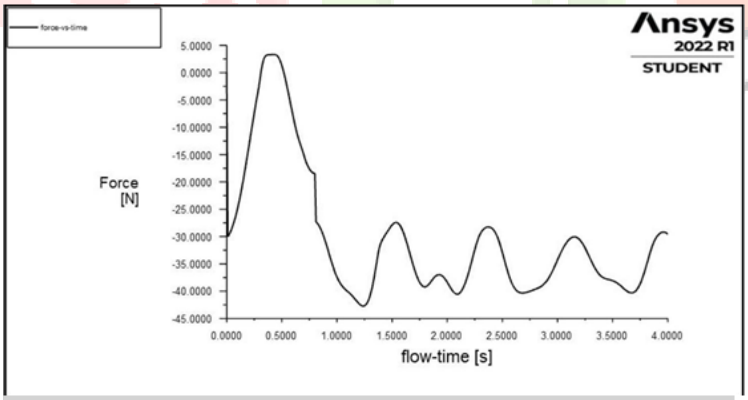
Tank Without Baffle



Volume Fraction of 50% fill level tank without baffle

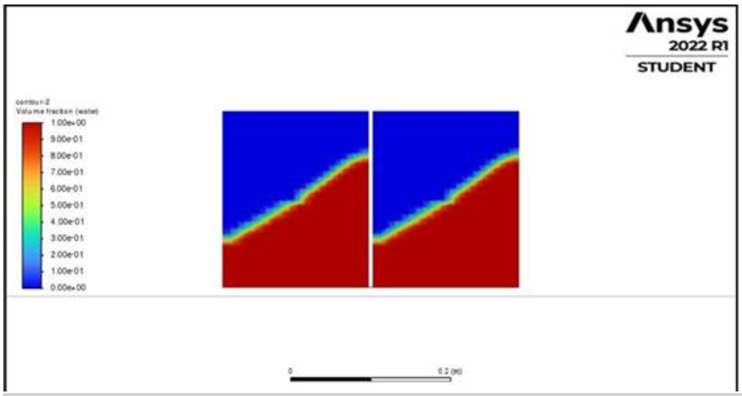


Total Pressure contour of 50% fill level tank without baffle

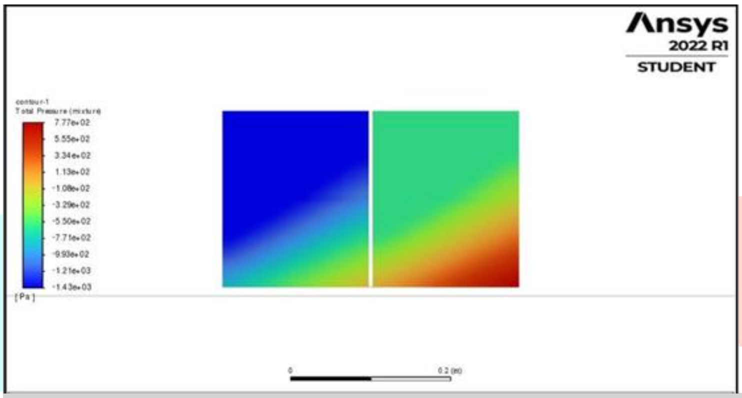


Force vs Time graph of 50% fill level tank without baffle

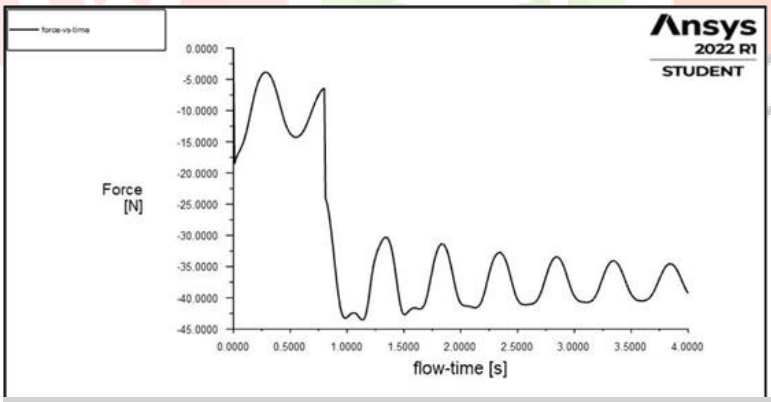
Tank With One Vertical Baffle



Volume Fraction of 50% fill level tank with one vertical baffle

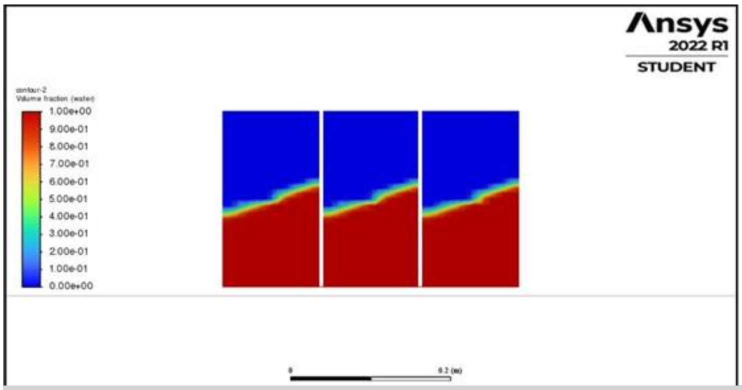


Total Pressure contour of 50% fill level tank with one vertical baffle

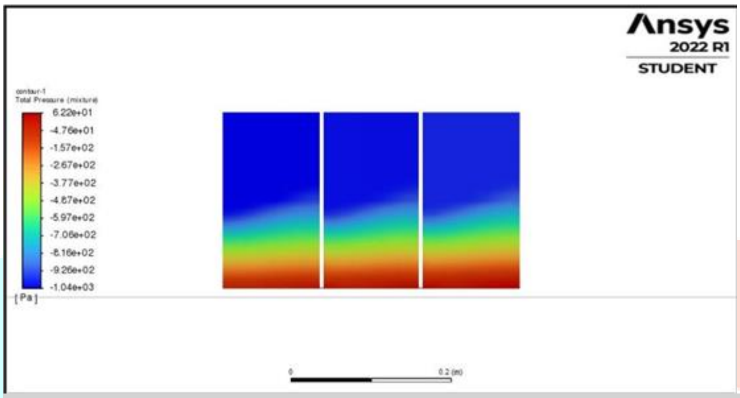


Force vs Time graph of 50% fill level tank with one vertical baffle

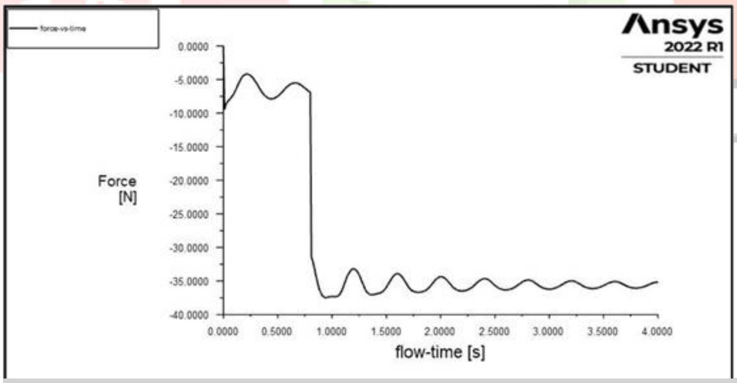
Tank With Two Vertical Baffles



Volume Fraction of 50% fill level tank with two vertical baffles



Total Pressure contours of 50% fill level tank with two vertical baffles



Force vs Time graph of 50% fill level tank with two vertical baffles

IX. CONCLUSION

From above-given figures of volume fraction of different fill level. We can see that as number of baffles increases the free liquid surface elevation decreases irrespective of the fill level. As the number of baffles increases the maximum total pressure in the tank decreases as given the table. The total pressure decreases around 30% using one baffles and 42% with two vertical baffles in case of 25% fill level. In case of 50% fill level the total pressure decreases about 21% with one vertical baffle and 37% with two vertical baffles. The graph of force vs time shows the force acting on the front wall with time. We can also used it as to determine the damping of liquid with time in tank. From the graph we can see that two vertical baffles are most effective than one vertical baffles.

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