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Design And Experimental Validation of Vertical Baffles On Sloshing Noise In A Rectangular Tank.

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***Abstract*— Liquid sloshing in fuel tanks has become a major source of noise or vibration in hybrid vehicles under various driving conditions. Flow dampening devices like baffles proved to be a good solution to control sloshing induced loads on the tank walls. But their effect on sloshing noise or resonance yet to be understood clearly. This study provides insights into generation mechanisms of sloshing vibration in a rectangular tank, in the presence of vertical baffles, in different sloshing regimes. Three types of vertical baffle configurations, placed at the center of the tank are considered for this study, which are immersed bottom-mounted, flush mounted and surface-piercing bottom mounted baffle configurations. Different sloshing regimes are created by applying longitudinal periodic excitation at various frequencies to the tank. design modeling of experimental liquid sloshing rectangular tank setup will be done using Catia V5R20 software . Modal analysis of rectangular tank will be perform using ANSYS 19 workbench. In this experimental setup understand effect of vertical baffles on sloshing induced loads on the tank walls. To obtain natural frequency of rectangular tank wall under loading conditions using ANSYS software.**

***Keywords*— Design, Model Analysis, Harmonic Analysis, Effects On Tank (With Baffles), Effects On Tank (Without Baffles)**

I. Introduction

Sloshing is associated with an uncontrollable violent motion of free surface inside the liquid tank subjected to external excitations. The sloshing-induced loads may damage the tank; thus, the liquid sloshing should be reduced to avoid the liquid carrier instability and structural failure. Among anti-slosh devices, the vertical and horizontal baffles have been known as an effective tool for suppressing liquid sloshing. Abramson [1] first experimentally and theoretically studied the baffles to suppress liquid sloshing in the tank. Since then, many researchers have been greatly interested in various baffle configurations, including horizontal, vertical, ring, bottom-mounted, and surface-piercing baffles as well as porous (slotted, perforated) baffles. Their researches showed that appropriate baffle's dimensions, shapes, numbers, and arrangements can effectively reduce the liquid sloshing. Although such baffles effectively damp the sloshing energy, they impose a substantial weight on the liquid carrier. Recently, the flexible structure has also gained much interest in many engineering fields. Especially, the introduction of the flexible elastic material to the baffle is of some merits, such as light, inexpensive, and rapidly deployable.

Sloshing is a phenomenon commonly found in partially- filled liquid storage vessels, such as liquid cargo tanks and fuel tanks, in motion. Violent sloshing may result in serious structural damages to the liquid-tank or even overturn the liquid cargo ship. Thus,a reliable prediction of the sloshing is crucial for the design and deployment of such structures. For this purpose, theoretical analyses, physical experiments, and numerical simulations are commonly utilized. As a pioneer, Moiseev [1] developed a nonlinear analytical solution for the sloshing problem by using the approximations and model methods combined with the potential flow theory. Based on Moiseev theory, Faltinsen [2] developed a third-order steady-state solution for the liquid sloshing in a 2D rectangular tank under the swaying and rolling excitations. Faltinsen [3,4] also established nonlinear analytical solutions for liquid sloshing in a rectangular tank by using the multimodel approach. Ikeda and Nakagawa [5] studied liquid sloshing in a rectangular tank under a horizontal excitation using the potential flow theory and analyzed the influence of fluid sloshing on the nonlinear vibration of the structure. However, the theoretical analysis approach may lead to unreliable predictions when complex physical phenomena such as wave breaking and slamming occur due to their fundamental assumption of the potential flow.

Resonance also plays a role when the external forcing frequency is close to a natural frequency of the liquid volume. Existing analytical models for predicting the effects of sloshing sometimes offer a reasonable approximation, but their basic assumptions make them invalid for a wide range of applications. Liquid sloshing in two-dimensional (2-D) and three-dimensional (3-D) rectangular tanks is simulated by using a level set method based on the finite volume method. In order to examine the effect of natural frequency modes on liquid sloshing, we considered a wide range of frequency ratios ($0.5 \le fr \le 3.2$). The frequency ratio is defined by the ratio of the excitation frequency to the natural frequency of the fluid, and covers natural frequency modes from 1 to 5. When fr = 1, which corresponds to the first mode of the natural frequency, strong liquid sloshing reveals roof impact, and significant forces are generated by the liquid in the tank. The liquid flows are mainly unidirectional. Thus, the strong bulk motion of the fluid contributes to a higher elevation of the free surface. However, at fr = 2, the sloshing is considerably suppressed, resulting in a calm wave with relatively lower elevation of the free surface, since the waves undergo destructive interference.

II. LITERATURE REVIEW

1. **“Effects of Sloshing on Analysis and Design of Elevated Service Reservoirs (ESR)”** Abhijeet. B. Babar and H. S. Jadhav Journal of Civil Engineering and Environmental Technology ISSN: 2349-879X;Volume 3, Issue 9; October- December, 2016.

The research paper study is focused on the effect of sloshing on Analysis and design of elevated servicereservoirs.
All over the world, most of the failures of large water tanks after/during earthquakes are suspected to haveresulted from dynamic buckling caused by overturning moments of seismically induced liquid inertia and surface slosh waves and also because of unsuitable design of supporting system or wrong selection of supporting system and underestimated demand or overestimated strength.
The results obtained from the comparison made between the Static (considering SDOFS) and Dynamic analysis (Considering 2DOFS), They concluded that the results obtained from the dynamic analysis for base shear and base moment (for the same problems considered for static analysis keeping the conditions identical) are less as compared to those obtained from static analysis, which is the point of consideration forany engineer.

2. **“A variational domain decomposition scheme for the natural sloshing modesin the baffledtanks.”** Ruiyang Shen, Jing Lyu , Shimin Wang.

In this research paper A variational domain-decomposition scheme is presented to obtain the analytically approximate natural sloshing modes inthe rigid baffled tanks. There were three steps in the following scheme:

Dividing the unperturbed complicated liquid domain into several simple sub-domains by introducing artificial interfaces, and auxiliary artificial non- dimensional densities of fluids in these sub-domains arealso introduced.
Obtaining spectral matrix problem by combing the approximate variational formulation of the approximate natural sloshing problem with the Trefftz method, eigenvalues of the spectral matrix problem are computedand Plotted.
Extracting the pursued analytically approximate natural sloshing modes fromthe eigen functions given by the spectral matrix problem with artificial non- dimensional densities sufficiently close to 1.

3. **“Influence of the vibroimpact interaction on sloshing dynamics in a rectangular tank.”**
Jian Zhang , Oleg Gaidai , Bin Gui , Daniil Yurchenko.

The paper studies a sloshing phenomenon occurring as a result of a vibroimpact motion of a rectangular tank subjected to an external harmonic excitation. This presented model is a result of an idealization of realistic scenario in which an impact interaction between a ship and floating ice can occur.
The behavior of a liquid inside the tank is modeled by the five mass-spring- damper subsystems mimicking a response of the liquid at different sloshing response modes. Two-sided motionless barriers are introduced to model the vibro-impact motion of the tank. The paper studies the influence of the vibro- impact motion onto the sloshing intensity and proposes a sloshing mitigation strategy, which employs a flexible verticallyoriented baffle.
The results of the numerical simulations indicate that the sloshing intensity is higher in the case of a classical rigid baffle and can be significantly reduced by the flexible baffle. The proposed model without impacts was validated against existing experimental and numerical results, presented in and demonstrated a good agreement in the far-from-resonance region.
The results of the numerical simulations have indicated high sloshing intensity due to the vibro-impact motion of the tank when compared to the nonimpact harmonic response. The sloshing mitigation strategy representedby a flexible baffle has been proposed and studied numerically. The flexible baffle was modeled as an extra

set of linear springs whose stiffness were selected appropriately to tune to a selected number of sloshingmode.

4. **“Liquid sloshing in a swaying/rolling rectangular tank with a flexible porouselastic baffle”**
I.H. Cho

In this research paper the flexible porous elastic baffle was proposed as an anti-slosh device to reduce the liquid sloshing in a swaying/rolling rectangulartank. The analytical model was developed to assess the effectiveness of the porous elastic baffle on liquid sloshing.
A one-dimensional beam model, along with Darcy’s model, was taken to implement the characteristics of porous elastic baffle. The matched eigenfunction expansion method (MEEM) with the Green functionfor the liquid sloshing interaction with the porous elastic baffle was employed.Numerical results were presented that illustrate the effects of thebaffle’s geometry (porosity, height), and structural parameters (flexural rigidity, stiffness of mooring line) on the liquid sloshing.

Through parametric studies, the flexural rigidity, porosity, and mooring line’s stiffness have to be adjusted properly to enhance the sloshing-reduction effect.The flexible porous elastic baffle showed the potential as a useful anti-slosh device within a limited application range compared with a rigid baffle.

5. “Effect of sloshing in elevated water tank on levelled and sloping ground”
Megha Rachel Philip and Minu Antony

In this research an elevated water tank is a large water storage container constructed for the purpose of holding water at a certain height to pressurize the water distribution system. Elevated tanks are supported on staging which consist of R.C.C. columns braced together, and walls subjected to water pressure from inside the tank.
In water supply scheme, water tanks mainly account for 10% to 20% of the overall cost. The base is exposed to weight of water, weight of walls and weight of roof. The Main failures occurred in water tanks are shear failure in beam, bending-shear failure in beam, axial failure in columns and rupture in tank walls.
The main damage of water tank is occurred due to sloshing effect. Sloshing is any motion of the free liquid surface inside its container caused due to any disturbance to partially filled container.
A circular elevated water tank of same capacity and same staging heights are considered for this study. The modelling and analysis are carried out using ETABS software.

6. “Sloshing effects in tanks containing liquid”
Martin Sivý, Miloš Musil, OndrejChlebo and René Havelka.

The paper is primary focused on the behavior of the free liquid surface (the convective portion of liquid) subjected to the dynamic loading which may result in liquid spilling or tank wall damage. Therefore, the sufficient freeboard must be required to design.
The paper deals with the seismic design of the open cylindrical liquid storage tank with the aim to determine convective dynamic properties (natural frequencies and modes of oscillation), maximum vertical displacements over tank radius and overall response of the liquid to an earthquake.
The analysis is performed analytically by applying procedures for the determination of convective effects based on simplified equivalent spring mass model, numerically response spectrum, and method of motion integrating equations utilizing ANSYS Multi-physics.

III. PROBLEM STATEMENT

- As a effect of sloshing on water tank, water tank surfaces get damaged due to the resonance took place while braking or random crust and pots on the road or due to natural phenomena like earth quake.
- To avoid the deformation of tank surfaces baffles are being provided to maximize the stiffness or improvise the natural frequency modes of the storage tank.

IV. OBJECTIVES

- To design and manufacturing of pneumatic base experimental setup of liquid sloshing rectangulartank setup.
- Understand effect of vertical baffles on liquid sloshing induced loads on the tank walls.
- To obtain natural frequency of rectangular tank wall under loading conditions using ANSYSsoftware .
- Experimental validation of natural frequency will be done using FFT analyzer andimpact hammer test.

V. METHODOLOGY

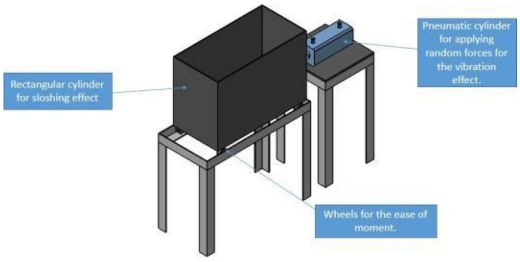
STEP 1 : Identification of Need:
In this semester we started the work of this project with literature survey. Gathered many research papers which are relevant to this topic. After going through these papers, we learnt about the Sloshing effect and cause of the phenomena.

STEP 2 : Creating the concept design Through literature survey:
After gathered research paper we describe literature gap on, and identify need of project. Then started work on concept design with the help of literature survey market survey.

STEP 3 : Synthesis (Material selection, design calculation, fabrication):
After finalizing concept 3D model of project, we started work on material selection design calculation and also discuss about component selection.

STEP 4 : Analysis and Experimental testing:
After deciding the components, the 3D Model and drafting will be done with the help of CATIA software. FEA model simulations of rectangular tank with baffles and without baffles will be done with the help of ANSYS.

VI. EXPERIMENTAL SETUP



VII. COMPONENTS

Pneumatic Cylinder2*1
Pnumatic Valve
Rectangular Tank (Without Baffles)
Rectangular Tank (With Baffles) Compressor

VIII. CONCLUSION REMARK AND SCOPE FOR FUTURE WORK

We are going to find out the natural frequency modes for the rectangular tank to observe the effect random vibration caused due to sudden braking or natural phenomena like earthquake, bumps and pots on the road. Due to such random shocks the sloshing effect take place and cause the tank to resonate, which can adversely affect the surface of the tank.To improve the vibration stability or to increase the stiffness of the tank to avoid such damage due to resonance, we are going to install vertical baffles which will increase the natural frequencymode values, hence increase the resonance handling capacity of the tank.

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4. "Liquid sloshing in a swaying/rolling rectangular tank with a flexible porous elastic baffle" I.H. Cho.
5. "Effect of sloshing in elevated water tank on levelled and sloping ground"Megha Rachel Philip and Minu Antony.
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