Introduction

Free surface of liquid in a partially filled container undergoes oscillation when subjected to external disturbances. The above phenomenon is termed as sloshing of liquid. Excessive amount of sloshing of liquid may result into undesirable dynamic behavior and structural instability of the container and its supporting structures. This problem due to sloshing has been observed in many engineering applications. Fuel sloshing of rocket propellant, sloshing of coolant in reactor vessel, sloshing of LNG in marine tankers and fuel sloshing in passenger cars are few of the problems caused by some sort of external excitations and may result into structural instability.

It is, therefore, necessary to reduce or eliminate the adverse effects of sloshing. This can be achieved by preventing the liquid from sloshing freely when subjected to various types of excitations such as a) changing the physical features of the container, including its geometry, elastic deformation, and insulation, or b) by installing slosh suppression devices within the container. The effectiveness of these features may be measured by monitoring liquid-slosh-motion amplitudes at various liquid levels depending on physical and chemical properties of the liquid.

Considerable research effort has gone into the study of sloshing of liquids in containers and the sloshing phenomenon is well understood by now. Sloshing characteristics in cylindrical containers, annular tanks, sectored tanks, rectangular tanks, conical containers, toroidal containers and elliptical containers have been studied and the results have been reported by different researchers.

The most commonly employed means of providing damping to the sloshing liquid is to provide baffles inside the containers. NASA monograph SP-8031(1969) suggested several techniques such as use of rigid and flexible annular baffles, cruciform baffles, deflectors, floating cans etc. to dampen the liquid sloshing caused by tank motions. Researchers have suggested the use of a floating structural element within the liquid container. Some researchers proposed to stiffen cylindrical containers with ring stiffeners connected to the outer periphery of the cylinder (Amabili, Paidoussis & Lakis,1998, Bauer & Werner, 1997,1999). In recent times analysis of slosh suppression by using annular rigid and flexible baffles has been done by Amabili, Paidoussis & Lakis.(1998), Pal, Bhattacharyya & Sinha(2003), Biswal, Bhattacharyya & Sinha(2002) and Cho & Lee (2004). The annular baffles are connected to the inner surface of the cylindrical shell at different levels and interact with the liquid inside. However, it is observed that, as sloshing is a near-free surface phenomenon, only the baffle closest to the free surface of liquid, is effective to reduce the sloshing height. The influence of other baffles which are either above the free surface or deep inside the liquid is much less. This phenomenon makes the baffles ineffective in a container with varying liquid level, as with the change in liquid level there may not be any baffle at the free surface of the liquid. Therefore, it is felt that a baffle system which will always be in contact with the liquid, near its free surface, irrespective of the liquid level will be more effective. Based on this conjecture, it was felt that a helical baffle provided inside the container may fulfill this requirement since irrespective of liquid depth some volume of liquid near the free surface will always be in contact with the helical baffle.

Analytical solutions of sloshing phenomenon have been reported for relatively simple geometric configurations. However, analytical solution of slosh suppression by various means and devices is difficult to obtain, particularly when the containers and suppressing devices have irregular and complex geometries. Linear and non-linear sloshing dynamics for different container configurations have been compiled by R.A. Ibrahim (2005) in his book. The author has also presented an analytical solution for sloshing in containers fitted with annular baffles.

Numerical methods such as finite element, finite volume and finite difference methods have been used by many researchers to simulate the linear and non-linear liquid waves due to sloshing. But three dimensional analysis of sloshing phenomenon is a time consuming process, as it requires large numbers of elements. Therefore, many researchers resorted to two-dimensional analysis. In the recent past a Mesh-less Local Petrov-Gakerkin method (MLPG), has been employed by Pal and Bhattachryya (2008) for slosh dynamics of liquid filled rigid containers subjected to forced excitations in a two-dimensional domain. With the advent of such sophisticated numerical techniques, flow behaviour may be predicted using numerical simulations, but the numerical results need to be validated through experimental investigations as well.

Experimental investigation plays a significant role in complex liquid-structure interaction problems to understand the flow behaviour not only due to external disturbances in the liquid, but also due to the effect of structural deformations. Understanding of sloshing phenomenon thus needs detailed experimental investigation to confirm the efficacy of analytical or numerical solutions. Most researchers have therefore resorted to experimental investigations to validate the numerical models developed by them. However, the availability of literature exclusively on exhaustive experimental investigation of the sloshing phenomenon is relatively sparse.

In the present investigation, it is therefore, proposed to study the sloshing behaviour of partially filled rigid cylindrical container with helical baffle, primarily through experiments. Numerical solution has also been attempted for comparing, with the experimental results.

The objective of the present investigation, therefore, is:

To study the efficacy of helical baffle in suppressing sloshing of liquid in partially filled Cylindrical Containers.

The work is presented through six chapters. Problems related to the sloshing of liquid and various slosh suppressing devices along with the objective of the work are introduced in Chapter 1.

In Chapter 2, the pertinent literatures are reviewed. Earlier works on slosh suppression devices are studied in order to identify unresolved and open issues where the present work can contribute and hence to define the scope of the present work.

Experimental procedures adopted to study the sloshing in partially filled rigid cylinders are presented in Chapter 3. The major results related to the sloshing phenomenon as observed in the work are presented in this chapter. Elevation of the free surface of liquid in cylinders with and without baffles is presented. Video graphic images of the free surface are also included in this chapter.

The model used for the numerical study is presented in Chapter 4. The chapter also includes the results and features observed from the numerical study.

Chapter 5 contains an analysis and discussions of some of the main results presented in Chapters 3 and 4. Results obtained from the experimental and numerical studies are compared.

Based on the results and discussions, major conclusions emanating from the present study are summarized in Chapter 6. This is followed by a brief outline of the scope of further investigation in this research area.

A list of important references cited in the present thesis is added at the end.