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Design and Development of a Cheap Slosh Testing Rig as Laboratory Equipment

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Abstract

Liquid sloshing in container is a classic problem in fluid mechanics and many other engineering fields. Due to the complexity of fluid dynamics, sloshing is studied using analogical model. Different equivalent mechanical model of sloshing phenomena have been developed in the last century [4,6,7,9]. Each of these models can predict the sloshing behavior of fluid with a fairly good accuracy, but within some practical limit. As a result, sloshing is still a burning research topic in more modern fields like aerospace. The apparatus used for studying sloshing through experimentation, is called a "Slosh Testing Rig". Building a full-fledged Slosh testing rig is very expensive due to the costly 6DOF load sensors, precise data acquisition boards and actuators. Recently, a very cheap slosh testing rig has been built using local technology for the hydrodynamics lab of Department of NAME, BUET as a part of the academic thesis. The rig has 1Degree of freedom. Cheap microcontroller based data acquisition boards and several single axis load cells were used to lessen the cost. This paper contains the overall description of this rig.

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Keywords: Sloshing; Free surface effect; Slosh testing rig; Load cell; accelerometer

1. Introduction

The present trend of dealing with the sloshing phenomena is apparently the usage of computational fluid dynamics (CFD). Usage of CFD minimizes various costs regarding the experimentations. However experimental results are more preferredby the scientific community because of the limitations of CFD. Experimentations regarding sloshing needmultidimensional equipment, consisting of mechanical, electrical and software part. A good setup requires expensive mechatronic system too for creating the excitation. In recent days, many researchers have created their own test beds for studying sloshing, [1–5]. Specially, the one in IIT Bombay is very impressing, [1,6,8]. This rig is very expensive as it uses a 6DOF load cell along with powerful data acquisition and mechatronic system.

In our research project, we focused to build a simple, easy to use, low cost apparatus for conducting experiments regarding sloshing phenomena. This was done by a novel approach. A combination of accelerometer and single axis load cell provided the way to determining the sloshing phenomena in a rectangular box. As the accelerometer is capable of measuring external force of any magnitude, there is no need for controlled excitation. Thus the necessity of any mechatronic system mitigates, which makes the testing rig as simple as only a combination a single axis load cell and a triple axis accelerometer.

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2. Concept

As the liquid in a container sloshes, the center of gravity of the liquid shifts along the axis of the exerted force. If we know the volume, i.e. the total mass of the liquid and the exact geometry of the container, a single axis load cell installed at one end of the container is enough to find out the overall displacement of the liquid in the tank. In order to study the relationship between the displacement and the force, an accelerometer is attached on one side of the container. As the effective influence of the force on the container is the acceleration it creates, measuring the acceleration is enough.

3. Design

The main part of the testing rig is a rectangular container, which has a length of 19cm. The breadth and height of the container is 9 cm and 15 cm respectively. The container is attached on an aluminum frame which is also rectangular in shape. One side of the container is directly bolted on the frame and the other side is bolted through a 5 KG load cell. As we pour water into the container, the load cell indicates the increment of force, i.e. weight on it. When the container is oscillated, that means the C.G. of the water changes, the distance of the C.G. from the load cell changes too. As a result, the component of weight acting on the load cell changes. This is detected by reading the output of the load cell. The output of the load cell is very tiny analog voltage. To make it sensible to the microcontroller, a voltage amplifier was needed. For this purpose, we have used HX711 24 bit analog to digital converter IC. It is used extensively with load cells.

To measure the acceleration caused by the force, a triple axis accelerometer was installed. The accelerometer gives analog output in a range which is directly readable using microcontroller. The main CPU was built using an Arduino UNO, which is a popular open source hardware prototyping board based on ATMEL's ATmega 328 microcontroller.

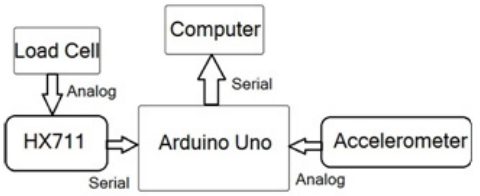

Fig. 1: Block diagram of the system

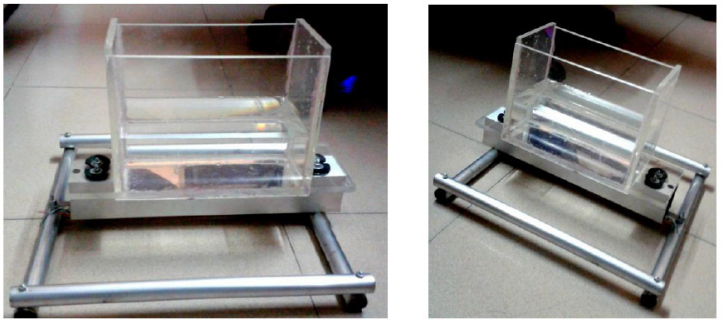

Fig. 2: Slosh Testing Rig: The structure

4. Calculations and mathematical model

The force or component of weight on the load cell at a certain moment can be derived from the output value of the HX711 chip using the following expression:

$$W_s = m \times ADC + C$$