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Development of a Sloshing Test Rig

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Abstract

After more than 30 years of intensive research the sloshing motion of liquids in partially filled containers is not fully understood, yet. Recent advances in the numerical fluid dynamics and the great achievements of the computer industry improved the applicability of computational fluid dynamics to such complex flow phenomena. Despite the dramatic increase in computer power reliable numerical simulations of sloshing flows require high computational efforts and long computation times. And still physical model tests are required to provide data for the validation of improved physical, mathematical, and numerical models employed for the analysis of sloshing flows. Also the model tests facilitate the insight into complex phenomena like liquid sloshing. Once installed and operating the data sampling on physical model tests is accomplished much faster than with numerical simulations.

Therefore there still is a demand for sloshing model tests in the scientific community engaged in sloshing research. Especially so against the background of the recent development of new LNG Carriers that double the size of the vessels currently in service within 5 years, and which are envisaged to sail with the cargo tanks not fully loaded.

The aim of this study is to improve the physical understanding of the sloshing phenomena in partially filled containers. For this purpose a small and simple sloshing test rig with a rectangular tank excited in one translational degree of freedom is constructed and is successfully brought into service. The complete test rig is created in a do-it-yourself approach. The test fluids for the model tests are water and air. The drive train for the excitation of the test tank consisting of a crank gear based on an old motor of a car window wiper is designed to generate a close-to-harmonic exciting motion. The sensors employed at the small test rig are commercial pressure sensors selected according to the information found in the literature. The selection of the measurement range and further properties of the pressure sensors is proven in service. The test rig is also equipped with a load cell for the recording of the total force acting on the tank in the direction of the excitation. The information on the total force is a valuable input for the development of the large test rig in the second part of this study. For the detection and recording of the tank motion a position sensor is created from a standard linear translational potentiometer.

The position sensor is also a key component of the controller developed for the numerical control of the drive train. One chief prerequisite for the first test series carried out with the small test rig is a constant excitation period of the oscillating tank motion. Therefore the core task of the controller is to ensure this constant rotational speed of the drive train motor. For the physical implementation of the drive train controller the wiring of the numerical control for the power supply of the drive train motor is adapted. Eventually the drive train controller is upgraded to take the control over full test runs conducted with the small test rig.

In a set of preliminary model test runs two determining parameters for the later test runs are established. These to parameters are the initial crank angle and thus the starting position of the tank at the beginning of a test run, and secondly the number of oscillations during the start and end ramps. The aim of the following detailed systematic test series is to investigate on the influence of the combination of the filling height of the liquid in the tank and the excitation period. For this purpose more than 120 individual test runs are carried out for 6 different filling levels and 7 excitation frequencies. With any given combination of these two parameters 3 test runs are conducted over a period of 1 000 oscillations with constant excitation period.

In this study the recorded model test data are assessed with the focus being on the quality of the drive train and the drive train control. The assessment of the data confirms that the small sloshing test rig is fit for service and can be employed to obtain scientifically relevant model test data.

In the second part of this study a large sloshing test rig is developed around a test tank double the size of the small test tank. This large test rig is designed with 2 degrees of freedom, one translational and one rotational degree. The kinematics of the drive trains for these motions are a major concern of this part of the study. Eventually the assessment of the tank motions and of the design facilitates the selection of the electric driving motors. The detailed design and the construction of the large test rig are carried out by a professional company. The test rig is installed in the laboratory and currently first trial measurements are carried out.