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Title

CFD Analysis of the Lateral Sloshing Phenomenon inside an Aerospace LCH4 Cryogenic Tank

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Abstract

This work aims at investigating the flow dynamics of the sloshing phenomenon inside a reservoir, which is still of a great interest for space launchers and aerospace vehicles. The motion of the fluid can generate forces and moments that can affect the control and stability of the vehicle, and can also cause damage to the tank structure. In order to design and operate aerospace tanks that are safe and efficient, it is important to understand the dynamics of sloshing and to develop methods for predicting and controlling it.

The problem of sloshing inside tanks has received considerable attention in the last decades and it has been studied by several numerical [1-2] and experimental campaigns [3-4]. One of the key challenges in predicting and controlling sloshing is the complexity of the fluid dynamics. To overcome this, reduced order models (ROMs) have been studied and proposed in the literature as a useful tool for simulating and predicting the sloshing dynamics [5]. These methods can provide a simplified but accurate representation of the fluid dynamics, and can be used to predict the response of the system to various disturbances.

In this work, we propose to perform unsteady 3D numerical simulations by means of the VOF methodology to understand the behavior of the lateral sloshing inside an aerospace LCH4 cryogenic tank. The first geometry that will be analyzed is a simple laboratory-scale cylindrical tank model, designed to investigate the sloshing phenomenon with the presence of a single baffle ring [6], which will be used to assess the capability of this method to predict the correct sloshing damping. The second geometry that will be investigated is inspired to a typical common bulkhead cryogenic tank used in space launchers. The performed simulations will be used to investigate sloshing inside the tank under normal gravity conditions. The unsteady lateral force on the tank wall, as well as the center of gravity position and the moment will be used to obtain a validate ROM model that takes into account the non-linear nature of the damping and will also be analyzed through the Fourier-based spectral analysis performed in time and by the wavelet transform analysis by decomposing the time series of data into time-frequency space, which is used to determine the time evolution of the energy associated to the excited mode.

References

[1] H. Yang et al., "Prediction of Liquid Slosh Damping Using a High Resolution CFD Tool," in 48th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, Atlanta, Georgia, 2012.
[2] S. Green, "A Comparison of Methods for Estimating Slosh Model Parameters from CFD Simulations," in AIAA Propulsion and Energy Forum, Cincinnati, Ohio, 2018.
[3] D. Stephens et al., "Investigation of the Damping of Liquids in Right-Circular Cylindrical Tanks, Including the Effects of a Time-Variant Liquid Depth," NASA TN D-1367, Washington, 1962.
[4] J. Pérez et al., "Validation of Slosh Model Parameters and Anti-Slosh Baffle Designs of Propellant Tanks by Using Lateral Slosh Testing," in 27th Aerospace Testing Seminar, 2012.
[5] A. Abramson, "The Dynamic Behavior of Liquids in Moving Containers," NASA SP-106, 1966.
[6] J. Miles, "On the Sloshing of Liquid in a Cylindrical Tank," The RAMO-WOOLDRIDGE CORPORATION, 1956.