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CFD DESIGN METHOD FOR CAPACITIVE POGO SUPPRESSOR DEVICES

Abstract

As the space launcher market is becoming increasingly competitive, a reduction of development cost and time for space propulsion systems is essential. Hardware testing is one of the main sources of expense, especially for cryogenic engines which involve complex facilities. Capacitive POGO suppressor devices (PSD) are intended to avoid coupling between launcher structure modes and propellant feed system hydraulic modes. To this purpose, they feature a trapped gas bubble in communication with the propellant feed line through calibrated orifices. The unsteady behavior of such system can be modeled via electrical analogy with RLC circuit. PSD development formerly relied extensively on experimental characterization with real propellants to assess its hydraulic performance. Generation of sine pressure fluctuations with a dedicated modulator, along with measurement of the unsteady gas bubble pressure, allows identification of the RLC values. Design exploration is limited by test time and available hardware.

Advance in computing power now makes possible the identification of PSD hydraulic characteristics via numerical simulation, with a feedback time compatible with design loop requirements. An unsteady Reynolds-Averaged-Navier-Stokes (URANS) methodology was developed under commercial CFD code Ansys Fluent. To achieve a quicker response time than for a full multiphase model, only the liquid phase is computed in 3D. The gaseous phase is modeled through user-defined-function (UDF) assuming an adiabatic behavior of the bubble. By applying a sine pressure fluctuation at various frequencies in the feed line and computing the unsteady gas pressure, the transfer function of the PSD can be derived the same way as during experimental tests.

Validation of the model was first performed on experimental data from a subscale test bench using water and air at ambient temperature. This configuration is easier to simulate since there is no phase change. The code was validated for different water mass flows and pressure fluctuation amplitudes. The application to full size PSD with real fluids (LOX/He) was also performed, and led to good consistency with test data despite the simplified physics. The current modeling is therefore appropriate for computing PSD hydraulic performance from its geometry, so that the code is now useable in a design loop. Continuous improvements will nonetheless be performed to integrate more physics such as propellant vaporization and surface tension effects, following the progress of multiphase models and computing power.