MULTI-PHASE FLUID HAMMER: MODELING, EXPERIMENTS AND SIMULATIOS

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The operation of spacecraft propulsion systems is regularly faced with adverse fluid hammering effects during the priming phase. This maneuver is done by fast opening of an isolation valve and the classical water hammer taking place also involves multiphase phenomena, such as cavitation and absorption/desorption of a non-condensable gas. Due to the lack of experimental studies modeling the spacecraft's hardware, the physical models implemented in the numerical codes cannot be validated properly and they fail when computing the corresponding overpressures during priming.

The aim of this thesis is to study the fluid hammer in a confined environment with experimental and numerical approaches. The experimental results come to complete the data already available in the literature, but using an experimental facility that can reproduce all the physical phenomena taking place in the propellant lines during priming. The numerical investigation is done with 1D and 3D CFD codes and their results are compared against the experimental data. The final objective is to improve and validate the physical models implemented in the numerical tools.

This study uses a new VKI facility that basically consists of a pressurized vessel, a fast opening valve, a given length of a propellant line and a vacuum system to set the test initial conditions. At the dead end of the line there is a measurement module equipped with unsteady piezoelectric pressure transducers and an unsteady coaxial thermocouple to record both the pressure (figure 1) and temperature at the impact location. The facility can also mount a transparent module made out of quartz to visualize the liquid front evolution with high speed imaging, as figure 2 shows. In the snap shots of this figure the vapor formation appears as a dark zone in the flow, and it is produced due to the low pressure left after the liquid front impact. The vapor bubbles collapse with the next arrival of the liquid column. All this data will allow the creation of an experimental database for validation purposes, and will also help on the understanding of the water hammer phenomenon and related multiphase behavior of the flow.

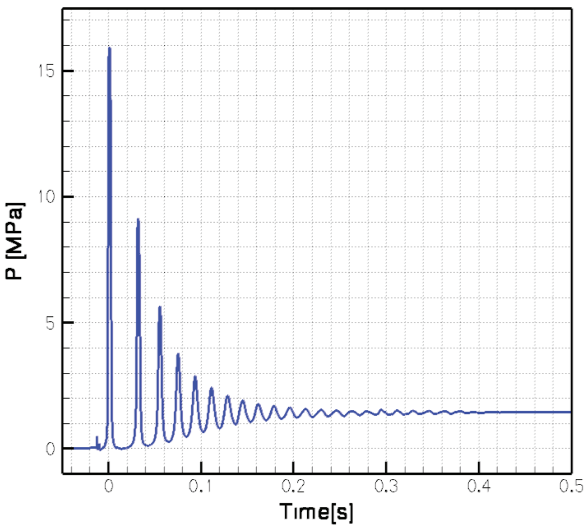

Figure 1 : Pressure evolution recorded at the dead end after fast opening the valve with test conditions Ptank=20 bar and Pline = 1 kPa

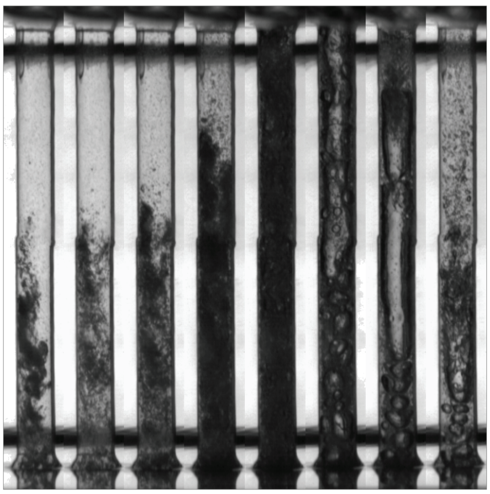

Figure 2 : Instantaneous snap shots recorded with high speed imaging during the first impact of the liquid front at the propellant line dead end