VOF COMPUTATION OF THE DEFORMATION OF A LIQUID SURFACE

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In solid rocket motors with submerged nozzle a cavity is formed during the combustion. An inhibitor, which divides the solid propellant compartments, protrudes inside the flow field causing vortex shedding. As a by-product of the combustion, droplets of liquid alumina (Al_2O_3) are created and some of them are accumulated inside the cavity forming a puddle of liquid alumina (slag). The oscillations of the liquid surface and its interaction with the flow can result in vibrations and reduced performance of the rocket motor.

The objective of the project is to perform 2D computations of the liquid surface inside the cavity in order to investigate its interaction with the flow field. The main goal is to investigate if a link exists between the frequency of the vortex shedding after the inhibitor and the frequency of the liquid surface oscillations.

The liquid interface was detected by unsteady 2D simulations of the flow in a simplified geometry of the rocket motor (Figure 1) using CFD-ACE+ commercial code and VOF model, and the results were validated against experimental data. The liquid droplets were not simulated in the flow, but a constant volume of liquid was placed in the cavity. Since the VOF model is not compatible with turbulence modelling in the commercial solver, MILES approach was used without explicit turbulence modelling. A comparison of MILES and LES in 2D without the liquid indicated that similar results are obtained in terms of mean and fluctuating flow field, as well as for the frequency content. So the miles approach simulates correctly the vortex shedding phenomenon and can be combined with VOF to investigate the effect of varying inlet velocity and volume of liquid in the cavity.

The frequencies of vortex shedding and liquid oscillations were obtained by FFT analysis on the time evolution of different parameters for several positions inside the domain. A set of post processing programs were developed to extract the interface position for each instantaneous result and compute the statistics. The frequencies of the vortex shedding for different velocities indicate a constant Strouhal number, whereas the frequencies of the liquid oscillations have much lower values and were not found to be directly linked to the vortex shedding, but mostly influenced from the phenomena inside the cavity (Figure 2). The results were validated against experimental data obtained by the LeDaR technique. Differences are indicated for the average interface due to the 3D effects in the experimental data. Lower deformation and amplitude of oscillations are predicted by the 2D simulations. The frequencies of liquid oscillations are in good agreement for nominal conditions. Finally, an attempt to model the surface waves by a simple theoretical description was made. However the complexity of the phenomena inside the cavity indicated that various theories should be combined.

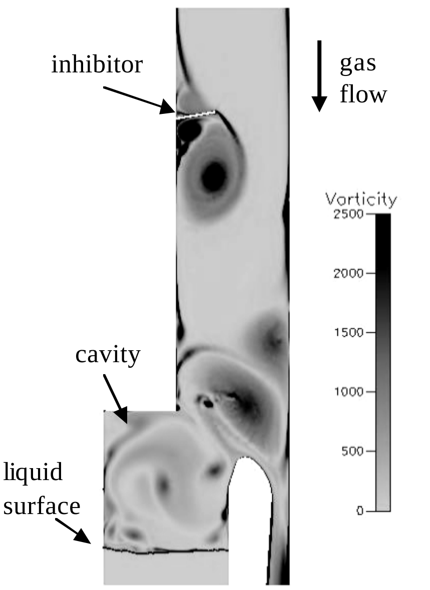

Figure 1: Instantaneous contours of vorticity and liquid surface oscillations

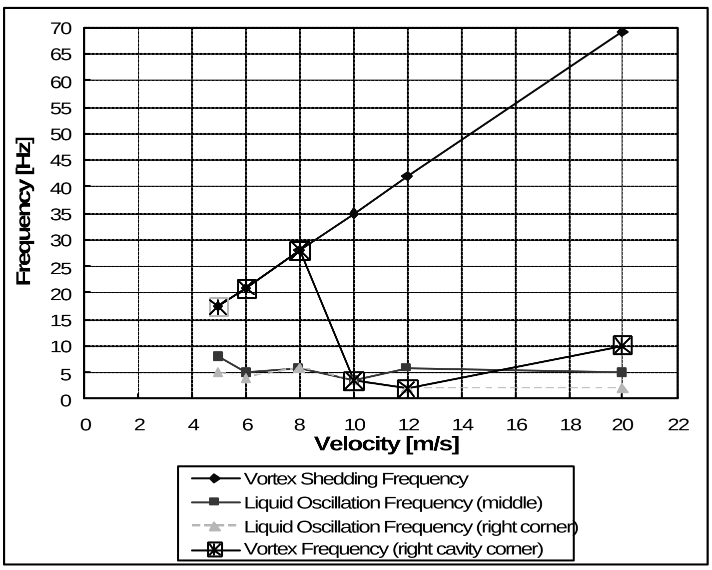

Figure 2: Main frequencies of vortex shedding and liquid oscillations for different inlet velocities