ENTRAPMENT AND ACCUMULATION OF DROPLETS IN STAGNANT AREAS

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Large Solid Rocket Motors, such as the Ariane 5 boosters, are composed of a submerged nozzle and segmented propellant grains separated by inhibitors. During propellant combustion, a cavity appears around the submerged nozzle and liquefied alumina droplets are generated from chemical reaction of the aluminium composing the solid propellant. The alumina droplets being carried away by the hot burnt gas are flowing towards the nozzle. Meanwhile the droplets interact with the vortices formed by the internal flow and thus may modify their properties. On the other hand, some of these droplets are entrapped in the cavity - instead of being exhausted through the throat -, which generate an alumina puddle, also called slag. This slag, which accounts for about five tons for the two Ariane 5 boosters, reduces the performance of the solid propellant motor.

The goal of the present study is to characterise experimentally the driving parameters of the slag accumulation in a stagnant area modelling the nozzle cavity. To achieve this goal, the interaction of the droplets with the vortices of the flow and the droplets entrapment process need to be investigated.

The experimental approach is mainly based on scaled 2D cold-gas, two-phase (the gas-phase is modelled by air and the models of the alumina droplets are water droplets) measurements with Particle Image Velocimetry (PIV), Particle Tracking Velocimetry (PTV) and free surface detection (LeDaR) techniques. The PIV and the PTV techniques are used to study the interaction between the vortices of the flow and the droplets. The LeDaR technique is applied to detect the free surface of the accumulated water in the cavity (simulating the slag) and study its mean shape and the rate of increase of its volume.

The PIV and the PTV techniques are based on image processing. The images are acquired from a seeded flow. However, performing two-phase measurements, the seeding particles and the water droplets can not be distinguished from each-other due to fundamental optical and image formation problems. Therefore, a method is developed (see also *Figure 1*) that helps separating the instantaneous images of the tracers and the droplets based on a laser emitting light simultaneously at 266 nm (UV) and 532 nm (green), two different fluorescent paints in the two phases and two PIV cameras equipped with proper optical filters. Once the two kinds of images are separated, both the gas-phase and the droplet-phase properties can be extracted using the conventional tools.

The LeDaR technique originally applies a laser sheet and an ordinary video camera to detect liquid free surfaces in a plane. After the validation of the technique, it is optimised to the current conditions. The processing algorithm is converted in order to accommodate series of images of any kind of still camera. Furthermore, additional filters are implemented to improve the quality of the surface detection.

Based on a literature survey a symmetric 2D-like test-section is built simulating the main features of the internal booster geometry (e.g. inhibitor and nozzle cavity). After its characterisation, single-phase PIV measurement is performed to determine the internal flow-field in the mid-span plane in a fixed configuration. These data are used for numerical code validation. Furthermore, two-phase PIV experiments show that as the droplets are not able to follow the air-phase motion, they act on it and therefore slightly a modified mean flow-field can be obtained. The largest mean velocity deviation is observed in the shear layer downstream the inhibitor.

Using the LeDaR technique an in-depth investigation is carried out in the nozzle cavity to determine the most relevant parameters related to the liquid accumulation. Based on the obtained results the importance of the relative transversal distance between the inhibitor tip and the nozzle tip is pointed out.

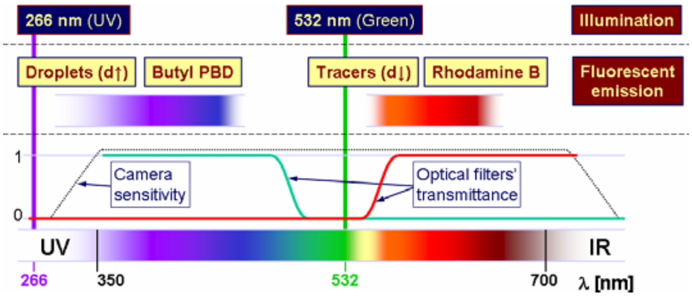

Figure 1: Principle of the two-phase PIV technique