TRACKING OF ALUMINUM PARTICLES BURNING IN SOLID PROPELLANT COMBUSTION GASES BY FOCUSING SCHLIEREN TECHNIQUE

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ABSTRACT: It concerns the analysis of the behavior of aluminum (Al) particles burning in the solid propellant combustion gases. Aluminum particles are added in solid propellants aiming at increasing the gas temperature and, finally, the specific impulse of the propellant. It allows a higher thrust level for the booster or missile. The behavior of aluminum particles depends on parameters: the Al mass fraction (15-20 %), the aluminum particle size (5 to 40 µm), the flame temperature and a specific process which occurs at the regression combustion surface: the aggregation process which generates particle networks of higher volume and various features called aggregates and evolving toward spherical agglomerates once the fusion temperature reached. Particles burn in the volume of the combustion chamber of the motor and are able to trigger on instability regime of the flow. Knowing particle sizes close to the burning surface (a few millimeters) is of major interest for numerical simulations of a solid rocket motor. The particle temperature stands above 3000 K raising up to 3600 K for alumina, the combustion gas temperature is 2400 K, the surface temperature is much lower (1000 K). The radiative emission level does not allow using “classical” visualization techniques. The Al mass fraction is quite high; this means that there are lots of particles burning at the same time in the gas volume above the surface. These are the two main reasons why we decided to implement the focusing schlieren technique (FST). This FST creates, as a laser does, an optical thin sheet normal to the regression surface (at a few mm/s). Its depth of focus is very limited depending upon the optical arrangement (from 0.25 to 0.5 mm). The deviation of the external light by the optical indexes allows obtaining oriented optical gradients and particle shadows. This also acts as a high pass filter because a part of the radiation emitted by particles is received by the high speed camera (10,000 fps and more). Results are excellent in term of image quality and clues for a better understanding of the particle burning process. The fitting of the image acquisition is not simple; it is related to pressure changing the local equivalent optical indexes. Once we get “good” images, the challenge is particle tracking. We are seeking velocity profiles particle diameters or features, and particle state evolution (inert, melted, burning, or burnt). This is not obvious and a specific tracking code has been developed named “Emotion” (estimation of the object movement by Onera image analysis). The work is far to be ended in this image analysis domain. Examples in terms of particle behavior and tracking are presented in the paper. The FST applied to combustion phenomena is very promising due to the drastic reduction of the combustion own radiation and all the details and pieces of information which are able to be sought as the ones that validate the Al particle behavior models.