Title: High amplitude/high frequency acoustic field acting on atomization of coaxial air-assisted liquid jets: Application to rocket engines

Profile of applicant: Master 2 in Fluid Mechanics/Energetics. Knowledge in acoustics, optical diagnostics, image analysis or signal processing will be well-appreciated.

Summary:

This work is related to the phenomenon of combustion instabilities that can occur in the combustion chamber of rocket engines. Reactant can last in the form of liquid jets and liquid droplets during transient periods. Dynamics of the liquid system can thus be modified by azimuthal acoustic modes that can lead to nonlinear acoustic effects in case of high-amplitude perturbations. The objective of the present study is to quantify changes occurring in one or several coaxial (air/water) jets in membrane or fiber atomization regimes under the action of a transverse acoustics field of high amplitude (~170dB). Analyses of acoustic perturbations going up in the feeding lines of the injectors are also of interest.

To reach the objectives of the program, several acoustic and optical diagnostics will be used. A model for the interaction between an acoustic field and a cylindrical liquid column or a plane liquid sheet will be developed.

Subject description:

It is by no means rare that combustion instabilities occur in the combustion chamber of rocket engines. When nominal working conditions of the engine are not reached, i.e. during transient periods, a liquid phase of reactants can last in the chamber, under the form of either liquid jets or of liquid droplets resulting from atomization of the liquid jets. The dynamics of liquid jets and droplets can thus be controlled by azimuthal acoustic modes in the chamber. When high amplitude acoustic perturbations occur, these acoustic modes can lead to nonlinear effects on the liquid phases. Several studies were started in the combustion community to reveal and explore such effects, and to develop strategies to prevent them. In that context, a research team from CORIA showed that an air-assisted liquid jet can present unusual phenomenological responses to the action of a high amplitude standing acoustic wave (SPL between 160 and 167 dB). The responses were explained by physical mechanisms involving acoustic quantities including nonlinear effects of the acoustic field. Additional instabilities induced by morphological changes of the liquid jet, but not related to nonlinear acoustics, were also observed. The high acoustic level is a key parameter to induce and then explain and quantify the physics responsible of the perturbations on the liquid systems that are,
even so, subject to high amplitude hydrodynamic driving-forces. Thus, one of the main courses of action to study such particular phenomena is to constantly increase the SPL reachable in the experiments.

The objective of the PhD is to quantify modifications occurring in an air-assisted liquid jet as well as perturbations going up in the feeding lines, upstream from injection nozzles, when submitted to a transverse acoustic field of a very high amplitude (~170 dB and frequency = 1 kHz). Focus will be put on membrane and fiber atomization regimes [1]. The phenomena will be characterized by several optical diagnostics such as high speed imaging, drop size and drop shape analysis [2-4]. The experimental study will be performed on a working testing bench and will take advantage of a numerical model simulating the acoustic field in the experiment. Determination of local acoustic quantities is aimed in order to quantify some threshold effects in the acoustic field responsible of changes in the morphology or in the drop size distribution of the liquid system.

Flattening and deviation of the liquid jet observed experimentally by CORIA team were related to the action of the radiation pressure and of the resulting force calculated over the liquid-gas interface [5-9]. Both of them are elemental quantities in nonlinear acoustics [10]. The analytical expression of the resultant was established for spherical (droplets) objects [11-12]. We aim at developing a similar model for the case of cylindrical (jet) or planar (sheet) systems in order to elaborate a sharp analysis of these phenomena. Interaction between longitudinal acoustic modes and fluid flows in the injector will be investigated also to understand coupling effects that are supposed to produce resonances between the combustion chamber and the feeding system.

The previous investigations at CORIA were able to explain some observations made in combustion conditions on tests conducted on the Mascotte bench at ONERA [13]. These works will take part in French-German group REST (Rocket Engine Stability research Initiative) and results will be presented in the annual REST workshop. Interaction with other research groups acting in the REST group will be possible during this study, especially with groups working on two-phase combustion under transverse acoustic perturbations.

Bibliography:


