PhD Thesis proposal at Pprime Institute

Research Area: Flame Structure and Turbulent Combustion

« Computational investigation of elementary processes involved in CVC conditions»

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The conception and optimization of a future aeronautical combustion chamber designed to perform thermodynamic cycles based on constant volume transformations require understanding, analyzing and modeling the involved elementary physical processes taking place in these conditions as well as their intimate couplings. The flow-field induced in such a CVC (Constant Volume Combustion) device will be subject to a strong competition between residence time scale, mixing (between fresh reactants and burned gases) time scale, as well as chemical time scale themselves (ignition and propagation) and the objective of the present computational study is to assess the respective influence of each of these processes. Such an analysis is indeed difficult to conduct in a prototypal CVC chamber. Therefore it is appropriate to elucidate such physical processes in well-defined and controlled conditions that gather the influence of the same key phenomena. Direct Numerical Simulation (DNS) and Large Eddy Simulation (LES) appear as reference tools to conduct such analyses.

The aim of this PHD work is twofold:

1) Analyze the influence of the turbulent flowfield on the ignition processes in the presence of heterogeneities of equivalence ratio and temperature.
2) Perform numerical simulations of the combustion chamber based on CVC regime to investigate the elementary processes involved.

To carry out **the first step**, different numerical activities may be envisioned:

- Partially Stirred Reactor (PaSR) simulations. Such calculations will be conducted to analyze the sensitivity of the ignition process to turbulent fluctuations. Such numerical simulations can incorporate the most detailed chemical descriptions and display the remarkable advantage of being compatible with parametric investigations.
- PaSR calculations, such as the ones mentioned above, ignore the dynamics of the “flame kernel” development. However, DNS conducted in HIT (Homogeneous Isotropic Turbulence) can avoid this limitation but at the price of using skeletal chemical kinetics schemes. Such DNS will be performed to assess the kernel birth and its development for different (initial) level of turbulent kinetic energy.
- Finally, the influence of the mean velocity field, and associated shearing effects, require to extend the above analysis to shear layer flow configurations, including at least one inhomogeneous direction, that can be addressed using either DNS or LES computations.

For each sub-step mentioned above, it would be interesting to analyze the effects of (i) the initial temperature level and its distribution (PDF and characteristic length scales), (ii) the presence of partially reacted gases in the fresh mixture, as well as (iii) the possible equivalence ratio heterogeneity and its distribution. The effect of the compression induced by the growth of the volume of burned gases can be readily included.

For **the second step**, both non-reactive and reactive RANS (Reynolds Averaged Numerical Simulations) and LES of the CVC combustion chamber will be performed. The RANS calculations will offer the opportunity to optimize the retained operative conditions at a reduced computational cost and the corresponding results will clearly provide very valuable guidelines to determine the primary choices. These preliminary results will be subsequently used to determine the relevant characteristic time and length scales of the turbulent flow field, which will provide some useful insights to delineate the nature of the turbulent combustion regime. This set of information will be used to settle a DNS considering both stagnating and sheared flow conditions relevant to the flow field conditions developed in the CVC experimental device. The corresponding DNS will be conducted with a detailed description of both transport and chemistry. The molecular transport will be represented within the formalism of the EGLIB Library (Ern and Giovangigli, 1995). A detailed investigation of the local conditions for various levels of dilution with burned gases will allow to find out conclusions about the prevalence of one given combustion regime within the combustion chamber. The influence of an additional injection of burned gases will also be thoroughly investigated. The corresponding numerical investigation will provide complementary and valuable information to experiments. It is thus expected to be very useful to improve our understanding of turbulent reactive flows that developed in such conditions.

Applicant Profile: Master degree or Engineer degree in Energetics or Fluid Mechanics, with a good background in combustion, turbulence and numerical methods.
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