Flame-generated turbulence in combustion for space propulsion

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Turbulent combustion has been intensively investigated during the last decades. The most common research questions involve the burning rate increase driven by the turbulent enhancement of mixing and diffusion. However, there are few research works focused on the opposite interaction i.e. how chemistry influences turbulence. The lack of research in this direction is caused by the limited number of mechanisms with which chemistry can influence turbulence. In most atmospheric air-breathing turbulent combustion applications, the only relevant effects are the dissipation increase due to the higher viscosity and negative turbulent production due to positive velocity gradients. These processes pose few additional challenges compared to non-reactive constant density flows, which justifies the lack of dedicated research on this sort of interactions. However, in certain applications, where chemistry is very fast compared to turbulence, fluctuations in pressure and velocity can be coupled, activating alternative mechanisms for turbulence generation. Combustion chambers of space propulsion engines are the ideal environment for such phenomena to take place. Due to the high pressures and the absence of inert gases, the turbulent Damköhler numbers are very high and flame-generated turbulence is viable. To investigate this phenomenon, a series of Direct Numerical Simulations (DNS) with a massively parallelized solver have been conducted at the Leibniz Computing Center (LRZ). Turbulent mixing and combustion in a typical injection configuration for modern rocket combustors have been simulated to analyze the turbulent kinetic energy transport budget. The statistical analysis of these simulations enables the observation of the physical motivations behind flame-generated turbulence. With these results, it is possible to improve the understanding of turbulent combustion with high Damköhler numbers and support modelling alternatives. In the present work, closure models for the transport terms associated to flame generated turbulence have been developed and validated using the generated DNS databases.

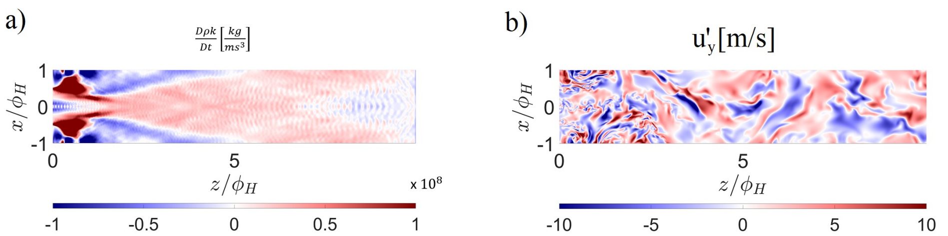

Figure 1: (a) Turbulent kinetic energy transport (Red indicates turbulence generation and blue turbulence destruction) (b), Instantaneous velocity field

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