Turbulence and combustion performance for space propulsion applications

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Turbulence and combustion can promote or inhibit each other. These interactions are crucial for the design and development of burning devices for various applications. The present work addresses the effect of turbulence in the performance of combustion chambers for space propulsion engines. Combustion in such an environment is characterized by high pressures, with the subsequent speed up of chemical reactions. Due to the high Damköhler numbers, exotic interactions between chemistry and turbulence take place. Reversed energy transfer, flame-generated turbulence or non-deterministic chemical equilibrium are few examples of the complex non-linear dynamic processes that have been observed in high-pressure combustion applications. These phenomena are vastly unexplored and understanding their influence in the propulsion performance is fundamental to optimize the design of modern thrust chambers. This is the research object of the present paper. Direct Numerical Simulations (DNS) of a turbulent methane-oxygen non-premixed flame at high pressure were conducted with a massively parallelized solver to create a vast database for turbulence research purposes. The operating conditions were chosen to resemble those of a scale rocket combustor at the Technical University of Munich, which has been extensively studied during the last decade. The results are analyzed to investigate the impact of the inlet turbulence on the characteristic velocity of the exhaust gases. The sensitivity of the combustion chamber size to inlet turbulence is studied to quantify the improvement of the chemical energy conversion process. The influence of turbulence in the combustion development is studied using both averaged statistics and instantaneous fields to discuss the physical motivations behind the turbulence-chemistry interactions. This research work presents novel insights that can be used to support the design of future injection systems for space propulsion applications.

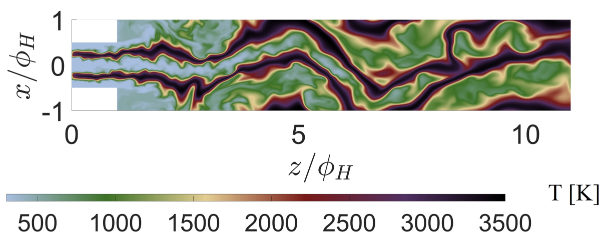

Figure 1: Example of instantaneous temperature field at one of the performed simulations

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