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CHEMICAL TIME SCALES DISTRIBUTION FOR SCRAMJET OPERATION

Abstract

Turbulent diffusion combustion is the most wide-spread way of injecting energy into a technical device.In this case, the most difficult question that arises for simulation purposes is which relationship between chemical kinetics and turbulent mixing characteristic time scales better characterizes the specific application. Based on this knowledge we can establish the type of combustion regime, which, furthermore, helps grasping the main characteristics of the flame physics. One of the most convenient tools for evaluating the turbulence/chemistry interaction is provided by the analysis of the Damköhler number field distribution. The Damköhler number represents the ratio of the time scales of the flow and of the chemical reactions, respectively. Large Damköhler values are associated with turbulent mixing controlled flames, while low Damköhler values corresponds to chemically controlled flames. In the latter case, the system behaves like a perfectly stirred reactor in which reactants and products are quickly mixed by turbulence but the characteristic time scale is imposed by the chemistry. The calculation of the local Damköhler number requires proper definitions of the flow and chemical time-scales. Usually, the flow time scale for turbulent conditions is given in terms of the integral time-scale, although several other possibilities are considered in literature (e.g. Taylor scales, Kolmogorov scale). The assessment of the chemical time-scale is quite challenging, especially in the case of complex kinetic mechanisms. Furthermore, the diffusion flame poses supplementary difficulties compared to the premixed combustion. Literature survey provides several examples of Damköhler number computation, mostly regarding single global chemical reaction. A method for considering more complex kinetic schemes is to express the chemical time-scale in terms of the inverse of the eigenvalues of the Jacobian matrix of the source term. The present work aims at applying this procedure for the calculation of the chemical time-scale (and thus of the Damköhler number) for a complete hydrogen-air mechanism used in the simulation of combustion inside a scramjet. Using this methodology, we hope to assess which chemistry-turbulence interaction model is more appropriate for a specific simulation (finite-rate eddy dissipation concept, flamelet approach, etc.). The research has set forth important variations of the Damköhler number (in the order of hundreds of units) throughout the flow domain. Also, different injection locations have been simulated to grasp what is influence on the Damköhler number distribution field and on the flame sustainability.