Non-equilibrium Effects in Viscous Reacting Gas Flows

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The talk is devoted to advanced theoretical study of viscous flow effects on the rates of non-equilibrium processes such as chemical reactions and vibrational relaxation.

Several macroscopic fluid dynamics models derived from the Boltzmann equation are considered: the detailed state-to-state model accounting for completely coupled fluid dynamics, vibrational relaxation and chemical reactions; multi-temperature models taking into account partial vibrational-chemical coupling; and the one-temperature model for chemically non-equilibrium flows. For these models, some non-equilibrium effects arising in viscous flows and basically neglected in the computational fluid dynamics are discussed. It is shown that in a viscous flow, strong coupling between normal mean stress and rates of non-equilibrium processes (chemical reactions, vibrational transitions) takes place. The rates of chemical reactions and vibrational energy relaxation depend on the velocity divergence and on the affinities of all other reactions. It leads to the violation of the mass action law and Landau-Teller relation in a viscous flow. Preliminary numerical estimations are given showing that this kind of coupling may affect the accuracy of CFD simulations for viscous flows. Brief discussion of the role of electronic excitation in the heat transfer is also presented.