Model Reduction for Reacting Flow Applications

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Abstract: A model order reduction approach based on Galerkin projection, proper orthogonal decomposition (POD) and the discrete empirical interpolation method (DEIM) is developed for chemical reacting flow applications. These applications are challenging for model reduction due to the strong coupling between fluid dynamics and chemical kinetics, wide range of temporal and spatial scales, highly nonlinear kinetics, and long simulation run times. In our approach, the POD technique combined with Galerkin projection reduces the dimension of the state (unknown chemical concentrations over the spatial domain), while the DEIM approximates the highly nonlinear function involved in the chemical source term. The combined method provides an efficient offline–online solution strategy that enables rapid computation and solution of the reduced-order models. The capabilities of the technique are demonstrated by applying it to a two-dimensional problem that models the ignition of a premixed H2-O2-Ar mixture. This problem involves 19 reversible reactions and 9 species. The results show that the obtained reduced-order models have state dimension several orders of magnitude smaller than the original system. For example, a reduced-order model with state dimension of 60 accurately approximates a full model with a dimension of 91,809. For this example, the reduced-order models accelerate solution times by a factor of approximately 450 in the chemical kinetic simulation and a factor of approximately 10 overall. The obtained reduced-order models are used to analyze the sensitivity of outputs of interest with respect to uncertain input parameters describing the reaction kinetics.

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