Reduced Order Modeling of Thermoacoustic Systems Using Mean-Field Synchronization Model

Poster

Rohan K. Nakade, Samarjeet Singh, Jayesh M. Dhadphale, and R. I. Sujith

Department of Aerospace Engineering, Indian Institute of Technology Madras, Chennai, India

Kuramoto oscillators have been widely used to study and model synchronization phenomena in various dynamical systems. These oscillators have been recently used to model the heat release rate of the flame in thermoacoustic systems to study the synchronization phenomena leading to oscillatory instabilities. In such models, the flame is modelled as a population of Kuramoto phase oscillators coupled with each other and the acoustic field in the confinement. These models require a large number of oscillators for accurate predictions, leading to high dimensionality and a loss of analytical tractability. We present a low-order, analytically tractable model for predicting transitions to thermoacoustic instability by using the Ott-Antonsen ansatz. We use Lorentzian distributions to approximate the natural frequency distribution of the phase oscillators obtained experimentally from the chemiluminescence data during the occurrence of combustion noise. We investigate the relationship between the coupling strength and the equivalence ratio and validate the model for the bluff-body stabilized dump combustor and the swirl-stabilized annular combustor. The low-order model accurately captures the continuous and abrupt secondary transitions observed experimentally in these combustors.