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Nonlinear modeling of thermoacoustically driven energy cascade

PRATEEK GUPTA, CARLO SCALO, Purdue Univ, GUIDO LODATO, INSA de Rouen — We present an investigation of nonlinear energy cascade in thermoacoustically driven high-amplitude oscillations, from the initial weakly nonlinear regime to the shock wave dominated limit cycle. We develop a first principle based quasi-1D model for nonlinear wave propagation in a canonical minimal unit thermoacoustic device inspired by the experimental setup of Biwa et al. (JASA, 2011). Retaining up to quadratic nonlinear terms in the governing equations, we develop model equations for nonlinear wave propagation in the proximity of differentially heated no-slip boundaries. Furthermore, we discard the effects of acoustic streaming in the present study and focus on nonlinear energy cascade due to high amplitude wave propagation. Our model correctly predicts the observed exponential growth of the thermoacoustically amplified second harmonic, as well as the energy transfer rate to higher harmonics causing wave steepening. Moreover, we note that nonlinear coupling of local pressure with heat transfer reduces thermoacoustic amplification gradually thus causing the system to reach limit cycle exhibiting shock waves. Throughout, we verify the results from the quasi-1D model with fully compressible Navier-Stokes simulations.

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