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Full-scale simulation and reduced-order modeling of a thermoacoustic engine CARLO SCALO, Center for Turbulence Research, Stanford University, JEFF LIN, SANJIVA LELE, LAMBERTUS HESSELINK, Stanford University — We have carried out the first three-dimensional numerical simulation of a thermoacoustic Stirling heat-engine. The goal is to lay the groundwork for full-scale Navier-Stokes simulations to advance the state-of-the-art low-order modeling and design of such devices. The model adopted is a long resonator with a heat-exchanger/regenerator (HX/REG) unit on one end - the only component not directly resolved. A temperature difference across the HX/REG unit of 200 K is sufficient to initiate the thermoacoustic instability. The latter is a Lagrangian process that only intensifies acoustic waves traveling in the direction of the imposed temperature gradient. An acoustic network of traveling waves is thus obtained and compared against low-order prediction tools such as DeltaEC. Non-linear effects such as system-wide streaming flow patterns are rapidly established. These are responsible for the mean advection of hot fluid away from the HX/REG (i.e. thermal leakage). This unwanted effect is contained by the introduction of a second ambient heat-exchanger allowing for the establishment of a dynamical thermal equilibrium in the system. A limit cycle is obtained at +178 dB.

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