Abstract Submitted
for the DFD15 Meeting of
The American Physical Society

Modeling of piezoelectric energy extraction in a thermoacoustic engine with multi-pole time-domain impedance JEFFREY LIN, Stanford University, CARLO SCALO, Purdue University, LAMBERTUS HESSELINK, Stanford University — We have carried out the first high-fidelity Navier-Stokes simulation of a complete thermoacoustic engine with piezoelectric energy extraction. The standing-wave thermoacoustic piezoelectric (TAP) engine model comprises a 51 cm long cylindrical resonator, containing a thermoacoustic stack on one end and capped by a PZT-5A piezoelectric diaphragm on the other end, tuned to the frequency of the thermoacoustically-amplified mode (388 Hz). A multi-pole broadband time-domain impedance model has been adopted to accurately simulate the measured electromechanical properties of the piezoelectric diaphragm. Simulations are first carried out from quasi-quiescent conditions to a limit cycle, with varying temperature gradients and stack configurations. Stack geometry and boundary layers are fully resolved. Acoustic energy extraction is then activated, achieving a new limit cycle at lower pressure amplitudes. The scaling of the modeled electrical power output and attainable thermal-to-electric energy conversion efficiencies are discussed. Limitations of extending a quasi-one-dimensional linear approximation based on Rott's theory to a (low amplitude) limit cycle are discussed, as well as nonlinear effects such as thermoacoustic energy transport and viscous dissipation.

Jeffrey Lin
Stanford University

Date submitted: 01 Aug 2015 Electronic form version 1.4