

Making positive use of instability in solids and structures to achieve extreme viscoelastic properties

*Dennis M. Kochmann
Graduate Aerospace Laboratories
California Institute of Technology
www.kochmann.caltech.edu*

Abstract:

Engineering mechanics is undergoing a paradigm shift in dealing with mechanical instabilities in solids and structures, away from avoiding instability and towards making positive use thereof. This seminar will highlight how to achieve solids with superior viscoelastic properties by controlled instability. Creating new materials with superior physical properties has become a critical challenge across various disciplines. One of the oldest solutions has been to use composite materials which offer a compromise of the beneficial properties of their carefully chosen constituent materials. Rather recently, it has been shown that exceptionally high stiffness and damping can be achieved in composites by embedding one phase that undergoes a mechanical instability. Upon triggering the instability in the inclusion phase, its negative (incremental) stiffness, stabilized by a stiff surrounding matrix, gives rise to anomalies in the overall (visco-)elastic performance of the composite. This concept applies equally to composite materials and structures. We will review the classical conditions of elastic stability and show that negative-stiffness phases are indeed permissible if sufficiently constrained by a matrix or coating. Next, we show that composite theory predicts such negative incremental moduli to result in extreme overall mechanical properties, and we correlate composite stability and performance. Finally, we present experimental confirmation of the exceptional performance of such composites for inclusion-matrix composite systems.