Mechanical and Aerospace Engineering

Flow Control by Subsurface Crystals

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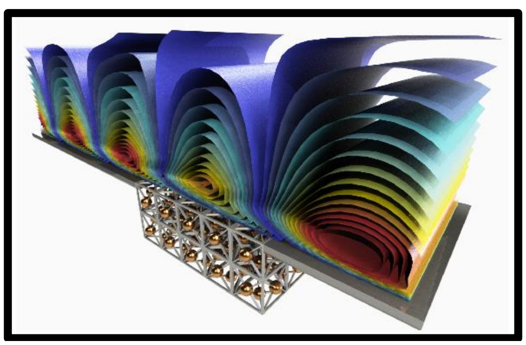
Thursday, May 5, 2016
114 Hochstetter Hall, 3:30 – 5:00 PM

Flow control is a century-old problem in which the goal is to alter a flow's natural state to achieve improved performance, such as delay of laminar-to-turbulent transition or reduction of drag in a fully developed turbulent flow. Meeting this goal promises to significantly reduce the dependence on fossil fuels for global transport. In this work, we show that phonon motion underneath a surface interacting with a flow may be tuned to passively cause the flow to stabilize, or destabilize, as desired. This concept is demonstrated by simulating a fully developed plane Poiseuille (channel) flow whereby a small portion of an otherwise rigid wall is replaced with a one-dimensional phononic crystal. A Tollmien–Schlichting (TS) wave is introduced to the flow as an evolving disturbance. Upon tuning the frequency-dependent phase and amplitude relations of the surface of the phononic crystal that interfaces with the flow, the TS wave is shown to stabilize, or destabilize, as needed. A theory of subsurface phonons is presented that provides an accurate prediction of this behavior without the need for a flow simulation. This represents an unprecedented capability to passively synchronize wave propagation across a fluid-structure interface and achieve favorable, and predictable, alterations to the flow properties. With extension to fully turbulent flow, this concept promises to reduce drag and thus bring about substantial gains in energy efficiency in a wide range of applications such as air, sea and land vehicles and long-range pipelines transporting oil or natural gas.



Reducing flow drag by crystals. When an enlarged and carefully tuned crystal is placed underneath a flexible surface, the flow passing over the surface will become more stable. Contours show predicted instability velocity field when a one-dimensional phononic crystal is installed versus an all-rigid surface.

Bio: Mahmoud I. Hussein is an Associate Professor and an H. Joseph Smead Faculty Fellow in the Department of Aerospace Engineering Sciences at the University of Colorado Boulder. He is also an affiliate faculty at the Department of Applied Mathematics. Dr Hussein holds a BS degree in mechanical engineering from the American University in Cairo (1994), an MS degree from Imperial College in mechanical engineering (1995), MS degrees in applied mechanics (1999) and mathematics (2002), and a PhD degree in mechanical engineering (2004) from the University of Michigan-Ann Arbor. His research focuses on the dynamics of materials and structures, especially phononic crystals and locally resonant phononic metamaterials, at both the continuum and atomistic scales. He was awarded the DARPA Young Faculty Award (2011) and an NSF CAREER award (2013). He is currently an associate editor for the Journal of Vibration and Acoustics and have authored 7 book chapters and over 70 papers in archival journals.

Please contact Dr Mostafa Nouh, mnouh@buffalo.edu, for information or to request a meeting.

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