Synchronized wave motion between a flowing fluid and a phononic subsurface

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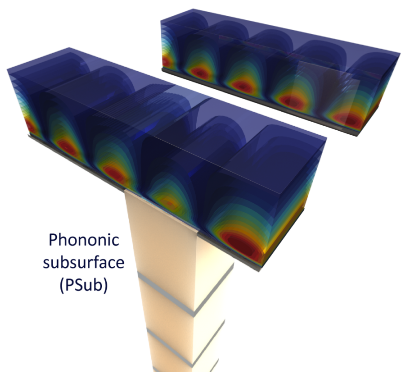
Flow control is a many-decades old engineering problem of a multi-disciplinary nature. It is concerned with devising passive or active means of intervention with the flow structure and its underlying mechanisms in a manner that causes desirable changes in the overall flow behaviour. For streamlined bodies cruising through a flow, such as air or water, there is a key interest in the control of flow instabilities which manifest as fluid waves. These are disturbances or fluctuations in the flow velocity field that if left to grow are likely to trigger transition of the flow from laminar to turbulent, which in turn causes significant increases in skin-friction drag. A rise in drag reduces the fuel efficiency in aircrafts and ships. It is therefore desired to device intervention methods to impede the growth of these instabilities. Alternatively, in some scenarios, the objective may be to speed up the growth of the instabilities and laminar-to-turbulent transition to prevent or delay flow separation. In recent research, we have shown that phonon motion underneath a surface interacting with a flow may be tuned to cause the flow to stabilize, or destabilize, as desired [Hussein et al., *Proc. R. Soc. A*, 2015]. The underlying control mechanism utilizes core concepts from crystal physics, primarily, the principle of destructive or constructive interferences and the notion of symmetry breaking. This is realized by installing a "phononic subsurface" (PSub), which is an architectured structure placed in the subsurface region and configured to extend all the way such that its edge is exposed to the flow, forming an elastic fluid-structure interface. The PSub may take the form of a phononic crystal or an elastic metamaterial, with finite extent, and is typically oriented perpendicular to the fluid-structure interface. It is engineered to exhibit specific frequency-dependent amplitude and phase response characteristics at the edge exposed to the flow. By simulating the 3D nonlinear Navier-Stokes equations, we will present results demonstrating perfectly synchronized passive phased response and energy exchange between the elastic domain of a PSub and the perturbation (instability) field within an interfacing flow. As an example, a flow in a channel retrofitted with a PSub underneath the channel walls will be considered. These results suggest a new paradigm in flow control based exclusively on principles from phononics.



Bio-sketch of M. I. Hussein

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