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Hypersonic boundary-layer instability with localized roughness
OLAF MARXEN, GIANLUCA IACCARINO, ERIC SHAQFEH, Stanford University — Understanding the process of laminar-turbulent transition in supersonic flows has important implications for the design of thermal protections systems for hypersonic vehicles. A localized three-dimensional roughness element inside the boundary layer on the surface of such a vehicle may profoundly alter the instability of the boundary layer, and hence the transition process. However, our understanding of this alteration is far from comprehensive. A numerical investigation of a laminar flat-plate boundary layer with a localized 3-D roughness is carried out. The roughness height is on the order of half the boundary layer thickness. Streamwise vortices behind the roughness deform the boundary layer, leading to a strong low speed and high temperature streak behind the roughness. Moreover, wall-normal as well as spanwise gradients result from these streaks and are responsible for creating additional instabilities of the deformed boundary layer. Simulations have been performed for spanwise symmetric and asymmetric roughness shapes. Excitation of small-amplitude disturbance upstream of the roughness in the simulation allows to trigger the instabilities. Growth rates and amplitude functions will be compared for the different roughness shapes.

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