Distributed Roughness Receptivity in a Flat Plate Boundary Layer
Doctoral Dissertation Defense

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Abstract

Surface roughness can affect boundary layer transition by acting as a receptivity mechanism for transient growth. Some of the work in the field of roughness-induced transient growth predicts a “shielding” effect, where smaller distributed roughness displaces the boundary layer away from the wall and shields larger roughness peaks from the incoming boundary layer. The present work describes an experiment specifically designed to study this shielding effect. Three roughness configurations, a deterministic distributed roughness patch, a discrete roughness element, and a combination of the two, were manufactured using rapid prototyping and installed flush with the wall in a flat plate boundary layer. Naphthalene flow visualization and hotwire anemometry were used to characterize the boundary layer in the wakes of the different roughness configurations. The distributed roughness initiated small amplitude disturbances that underwent transient growth. The discrete roughness element created a set of high- and low-speed streaks in the boundary layer at a sub-critical Reynolds number ($Re_k = 151$) and tripped the boundary layer at a higher Reynolds number ($Re_k = 220$). When the distributed roughness was added around the discrete roughness, the wake amplitude decreased at the sub-critical Reynolds number, and transition was delayed by two boundary layer thicknesses at the higher Reynolds number. This dissertation documents the first detailed measurements of transient growth over streamwise-extended distributed roughness and demonstrates that the shielding effect has the potential to delay roughness-induced transition.

Matthew Kuester is a Ph.D. candidate in the Aerospace Engineering Department working under the supervision of Professor Edward White. His research interests are in the areas of boundary layer stability, acoustics, experimental fluid dynamics, and low-speed aerodynamics. He is currently seeking post-doctoral research opportunities and academic positions for the upcoming fall semester.