Analysis and Prediction of Instability Waves Within High-Speed Flow Over Sharp and Blunt Cones with Plasma Actuation

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Leading edge geometries, such as cones, moving at high-speed undergo intense loading due to the growth of instability waves and turbulent transition. These instability waves are highly spatially coherent. Aerodynamic loading related to instability waves and transition causes large-amplitude vibrations within the underlying structure, which may lead to flight-vehicle failure. We examine the effect of plasma actuation on the pressure fluctuations from the instability waves on the cone surface via theory with flow-fields predicted by computational fluid dynamics. We present predictions for a seven-degree half-angle cone at free-stream Mach number of 3.5 with varying nose radii. Nose radii range from 0.038 to 38.1 mm and represent both sharp and large leading edge bluntness. For non-actuated flows, we observe that very small radii leading edges do not alter growth rates. Large radii cones have lower growth rates due to a thicker boundary layer. Spatial coherence of the instability waves decreases with increasing frequency. The effect of the phenomenological plasma actuator adds local heating to the flow-field. The maximum power of the actuator is 100 W. Increased nose radii lowers the relative temperature difference between the actuated and base flow-fields. We find that plasma actuation stabilizes the flow-field and spatial coherence becomes smaller. These results can guide designers to choose appropriate nose radius when combined with structural analysis to minimize unsteady loading in the region leading to transition. In addition, the flow-field variation with plasma actuation can be used to understand the mechanism of temperature effects on stability and transition.

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