Pulsed microjet control of supersonic impinging jets via low-frequency excitation

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Abstract: Several fluid flow problems related to propulsion and power generation exhibit strong acoustic resonances. Produced due to interactions of the acoustics with other underlying unsteady mechanisms such as unsteady heat release or shear flow instability, these resonances manifest as large and sustained pressure oscillations. Active control of such resonances has been shown to be highly effective, resulting in a dramatic reduction in the acoustic resonances using a very small fraction of the system energy. In this paper, a specific fluid flow problem is discussed, that of supersonic impinging jets, and the control of the acoustic resonances that are produced by these jets, via detailed experimental investigations. The actuator used for active control consists of a pulsed microjet, by which it is shown that in a scaled supersonic experimental facility acoustic resonances can be reduced, utilizing a fraction of the mass flowrate needed with a steady microjet. Several parameters related to pulsed injection are varied to evaluate their impact on the resonances, and it is found that duty cycle and pulsing frequency have the most dominant effect on the jet noise as well as on the overall flow field. System identification based models of the uncontrolled and controlled jet are derived to explain the results obtained. The effect of low-frequency pulsing on resonance suppression is explained via the introduction of a controller in the closed-loop whose parameters vary non-linearly with the pulsing parameters.

Keywords: acoustic resonances, supersonic impinging jets, pulsed microjet, low-frequency pulsing

1 INTRODUCTION

Several acoustic resonances have their origin in the instability of certain fluid motions. One of these motions is in the context of impinging high-speed jets, which correspond to high-speed jets that impinge on a hard surface. Experienced by STOVL aircraft while hovering in close proximity to the ground, impinging tones, which are discrete, high-amplitude acoustic tones, are produced due to interactions between high-speed jets emanating from the STOVL aircraft nozzle and the ground [**1**]. The high-amplitude impinging tones are undesirable not only due to the associated high ambient noise but also because of the accompanied highly unsteady pressure loads on the ground plane and on nearby surfaces. While the high noise levels can lead to structural fatigue of the aircraft surfaces in the vicinity of the nozzles, the high dynamic loads on the impingement surface can lead to an increased erosion of the landing surface as well as a dramatic lift-loss during hover. Although the connection between the flow features of the impinging jet and the near-field hydrodynamic and noise field has been explored over a number of decades, and more recently in studies by Alvi and Iyer [**2**] and Henderson and coworkers [**3**, **4**], the nature of this relationship is still not well-understood.

The acoustic properties of a single supersonic impinging jet flow field have been investigated by a number of researchers, including Powell [**5**], Tam and Ahuja [**6**]. Tam and Ahuja have clearly estab-

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