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RESEARCH ARTICLE

Active control of supersonic impingement tones using steady and pulsed microjets

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Abstract In recent years, it has been demonstrated that direct microjet injection into the shear layer of the main jet disrupts the feedback loop inherent in high speed impinging jet flows, thereby significantly reducing the adverse effects. The amount of noise reduced by microjet actuation is known to be dependent on nozzle operating conditions. In this paper, two active control strategies using microjets are suggested to maintain a uniform, reliable, and optimal reduction of these tones over the entire range of operating conditions. In the first method, a quasi-closed loop control strategy is proposed using steady microjet injection and the proper orthogonal decomposition (POD) algorithm. The most energetic spatial mode of the unsteady pressure along the nozzle diameter is captured using the POD, which in turn is used to determine the distribution of microjet intensity along the nozzle exit. Preliminary experimental results from a STOVL supersonic jet facility at Mach 1.5 show that the quasi-closed loop control strategy, in some cases, provides an additional 8–10 dB reduction compared to axisymmetric injection at the desired operating conditions. The second method consists of a pulsed microjet injection, motivated by the need to further improve the noise suppression. It was observed that the pulsed microjet was able to bring about the same noise reduction as steady injection using approximately 40% of the corresponding mass flow rate of the steady microjet case. Moreover, as the duty cycle increased, the performance of pulsed injection was further enhanced and was observed to completely eliminate the impinging tones at all operating conditions.

1 Introduction

While hovering in close proximity to the ground, the short take off and vertical landing (STOVL) aircraft experiences discrete and high amplitude acoustic tones that are produced via a feedback process. These feedback interactions occur thus: instability waves are generated by the acoustic excitation of the shear layer near the nozzle exit, which then convect down and evolve into spatially coherent structures. Upon impinging on the ground, these structures generate acoustic waves, which in turn excite the shear layer at the nozzle exit, thereby closing the feedback loop (Fig. 1; Krothapalli et al. 1999; Alvi et al. 2003). The high amplitude impingement tones are undesirable not only due to the associated high ambient noise, but also due to the accompanied unsteady pressure loads on the ground plane and the nearby surfaces. While the high noise levels can lead to structural fatigue of the aircraft surfaces in the vicinity of the nozzles, the dynamic loads on the impingement surface can lead to an

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