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Using Microjets to Suppress Resonance in a Mach 2 Cavity Flow

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Abstract

An innovative active control approach, which utilizes supersonic microjet actuators, has been applied to suppress the flow-induced resonance in a Mach 2 cavity flow. Two different length/depth ratios, *L/D*=5 and *L/D*=3 respectively, were studied experimentally, using flow visualization, unsteady surface pressure measurements and particle image velocimetry. The effect of microjet control was significant: for the *L/D*=5 case, the reduction is 23 dB in the amplitude of dominant cavity tone and 9 dB in the overall sound pressure level (OASPL). For *L/D*=3, the reduction is 13 dB in the dominant cavity tone and 11 dB in the OASPL. Due to the small size of microjets, 400 μm in diameter, the required mass flow ratios to achieve such reductions are minimal. To the authors' knowledge, the mass flow for the present control scheme is well-below any other approach reported in literature which has produced comparable reductions. Velocity field measurements show that microjets control reduces the reverse flow inside the cavity, as well as the fluctuations of the flow field, and results in a steadier and quieter pressure/acoustic field.

Keyword: *Microjets, Resonance, Flow Control, Supersonic Cavity Flow, Particle image velocimetry*

1. Introduction

Cavity flow has been the focus of research since the 1950s where early studies were conducted by Roshko[1] and Krishnamurty [2]. As flow passes over a cavity, resonant noise as high as 170 dB (or higher) is not uncommon in the cavity, for example, in the aircraft landing gear wells or in the weapon bays of modern supersonic military airplanes. Such resonance is believed to be due to the feedback mechanism, as described by Rossitor[3] for cavity flows. As reviewed recently by Cattafesta et al[4], numerous actuators have been developed with aim of disrupting the feedback loop and thus controlling the related cavity flow unsteadiness. These include passive actuators, such as the leading edge fences by Sarno and Franke[5], leading edge spoilers by Shaw et al[6] and Ukeiley et al[7], and rods in the cross flow by Ukeiley et al[7] and Stanek et al[8]. However, most of these devices are only effective within a limited range of flow conditions and usually have an associated penalty, such as increased drag. Other approaches involve active actuators which use mass, momentum and/or acoustic energy 'injection' with various configurations, such as perforated plates, slits or tubes. Some examples include, normal (to-the-flow) mass injections with perforated plates by Vakili and Gauthier[9], tangential blowing through a slit at the leading edge by Sarno and Franke[6], normal (to-the-flow) powered resonance tubes by Stanek et al[8], and normal (to-the-flow) pulsed rectangular jets from segmented slits by Shaw [10].

In this study, supersonic microjets were explored for cavity control. Supersonic microjets are simply a number of very small diameter jets through which sonic or supersonic jet flows. They are very robust and easy to manufacture and operate. Microjets can be either steady or pulsed, but all cases reported in this study use steady momentum injection. Because of the small size of microjets, they produce a high momentum ratio, relative to the freestream, with a very small mass flow ratio. The high momentum ratio results in a strong potential to disrupt the self-sustained feedback loop in the cavity and the low mass flow requirement makes the use of microjets more viable in practical, industrial applications. More details regarding these actuators can be