Using Microjets to Suppress Resonance in a Mach 2 Cavity Flow

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Outline

- Introduction & Background
- Experimental Setup
- Selected Results (L/D = 5.1)
  - Baseline Cases (No Control)
    - Flow Visualization
    - Acoustics/Unsteady pressures
    - Velocity Field
  - Effect of Microjet Control
- Summary
Background

Supersonic Cavity Flows

- Flowfield governed by a feedback loop
- Leads to a highly unsteady flowfield accompanied by
  - High dynamic loads inside cavity
  - Multiple cavity tones

High Speed Cavity Visualization
(Krishnamurti, 1955)
Rossitor's model (feedback loop)

\[
St = \frac{fU}{L} = \frac{(m - r)}{M \left( 1 + \frac{\gamma - 1}{2} M^2 \right)^{0.5} + \frac{1}{k}}
\]

- \( f \) – Frequency of \( m \)th mode
- \( r \) – Phase constant/lag
- \( k \) – Average convective speed
- \( \gamma \) – Vortical structures/\( \frac{U}{U_{\infty}} \)

(Rossitor 1964)
Motivation

- To better **understand** supersonic cavity flows
- To **control** the unsteadiness of the flow
FMRL Cavity Facility

$M = 2$
$Re = 23 \times 10^6 /m$

optically accessible
Cavity
Test Section
Experimental Setup

L/D=5.1 cavity

Microjet actuators

M = 2

LE    Front Wall    Floor    Rear Wall    TE

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Pressure Spectra

Freq (kHz)

SPL (dB)

L / D = 5.1

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Flow visualization

Wave propagation reveals the feedback loop

L / D = 5.1
Instantaneous Velocity Field

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L / D = 5.1
Large-scale structure

Phase conditioned Velocity Field

\[ < \omega > = \omega - \overline{\omega} \]

Periodical term

Phase lock conditioned term

Ensemble averaged term

Click to Play video file

L / D = 5.1

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Microjet Actuators

- Flow Visualization
- Unsteady Pressures
- Velocity Field

12 microjet with diameter $\phi = 400 \mu m$ normal to the surface

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Effect of Control on Unsteady Pressures

L / D = 5.1

Control Effect Saturates ~ 30 psig
OASPL reduction ~ 9dB
Dominant tone attenuation ~ 23 dB
Effect of Control on Unsteady Pressures

$L / D = 5.1$

Click to Play sound file
Flow visualization

Baseline case
with microjets OFF

Microjets ON
control pressure $P_j=30$ psig
$P_j/P_s=11$

L/D=5.1

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**Fluctuating Velocity Field**

$L/D = 5.1$

**Effect of Control on $V_{rms}$**

Control OFF

Control ON

Aug, 2005
**Vorticity Field**

$L/D = 5.1$

**Effect of Control on $V_{rms}$**

Control OFF

Control ON

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Effect of Control on the Shear Layer

Shear layer Centerline

L/D = 5.1

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Summary

• Microjets can effectively control the flow unsteadiness
  – The pressure/acoustical fluctuations inside the cavity are significantly attenuated
  – A reduction of velocity fluctuations with a weaker reversing flow

• Control approach is *simple, robust* and achieved with *minimal mass flow*. 
Effect of Control on Unsteady Pressures

L/D = 3

Control Effect Saturates ~ 70 psig
OASPL reduction ~ 11 dB
Dominant tone attenuation ~ 13 dB

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Fluctuating Velocity Field

$L/D = 3$

$U_{rms}$

$V_{rms}$

No control

70 psig
As Control Becomes More Effective:
Reverse flow vel. decreases
Control pressure increased beyond saturation:
Reverse Flow velocity increases

Ensemble-Averaged Velocity Field
(L/D = 3)

No control

30 psig

70 psig (optimal)

100 psig

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