Control of Three-Dimensional Cavity Flow Using Leading-Edge Slot Blowing

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Supersonic (Mach 1.4) flow fields over full span and finite span rectangular cavities were compared to investigate the effects of sidewalls on leading edge slot blowing. The full span cavity had a width-to-depth ratio of 6 while the finite span cavity had a width-to-depth ratio of 2. The length-to-depth ratio for both cases was 6. Unsteady surface pressure measurements showed a shift in the dominant mode as the span was decreased. In addition, velocity data along the cavity centerspan showed differences in the turbulence intensities and recirculation region as the cavity became more narrow. Based on previously reported success of leading edge slot blowing on full span cavities, this technique was implemented on a finite span cavity to suppress the pressure fluctuations. The effects of three different slot configurations were characterized by means of the unsteady surface pressure data along the cavity walls and streamwise aligned velocity obtained via stereo Particle Image Velocimetry. The 3 Slot configuration and 1 Slot long configurations reduced the root mean square of the pressure fluctuations by approximately 40% but the former configuration required a smaller blowing rate. Velocity information along streamwise aligned planes elucidate changes in the flow field due to the control such as altering the shear layer location and shifting the peak turbulence levels.

I. Introduction

Flow over a cavity has been a canonical topic of research on self resonating flows for many decades. Their relevance can be seen in a variety of practical applications from landing gear wheel wells to munitions release bays. Pressure fluctuations are generated as the shear layer forming at the cavity leading edge interacts with the aft wall. These pressure waves are emitted upstream and amplify instabilities in the shear layer. Eventually self-sustained oscillations result from the hydrodynamic and acoustic coupling to form large fluctuating surface pressures that can damage both the aircraft structure and sensitive components within the cavity. Therefore a need arises for a control scheme that can reduce the source of the pressure fluctuations over a range of flight conditions and with minimal additional weight.

For over fifty years, researchers have examined many facets of cavity flow from understanding basic flow features to developing complex models to predict flow behavior. These have included attempts to elucidate flow feature trends in the cavity by conducting parametric studies of different geometries. A rectangular cavity, shown in Figure 1, is defined by three geometric dimensions: length $L$, depth $D$, and span $W$. The length and span are typically nondimensionalized by the depth to develop a greater understanding of how parameters relate and to decrease the number of parameters to those that affect flow behavior. Cavity flow can be divided into two general categories: closed and open cavities. When the cavity is long enough, $L/D >13$, the flow reattaches to the cavity floor.1 Recirculation regions appear in the upstream and downstream corners of the cavity. As the cavity shortens, the shear layer interaction with the aft wall is the driving
flow phenomenon. This open cavity scenario occurs when \( \frac{D}{L} < 8 \). The depth of the cavity is a significant parameter in defining the type of tones that develops. Deep cavities, \( \frac{D}{L} < 1 \), are characterized by oscillations in the floor normal direction due to the shear layer excitation of the cavity.\(^2\) These oscillatory modes are aptly named depth modes. Conversely, the tones in shallow cavities, \( \frac{D}{L} > 1 \), are generated by the aforementioned feedback mechanism.\(^3\) In the 1960’s, Rossiter’s parametric study developed a formula that could approximately predict the frequencies of these shallow cavity tones based on the flow conditions, cavity dimensions, and empirically determined constants.\(^4\) Heller and Bliss eventually improved upon Rossiter’s work by showing that the temperature inside the cavity approaches the freestream stagnation temperature.\(^5\) This modified Rossiter equation reads

\[
St = fL \frac{U_\infty}{U} = \frac{n - \alpha}{M\sqrt{1 + \frac{\gamma - 1}{2M^2}}} + \frac{1}{\kappa}
\]

where \( St \) is the Strouhal number, \( f \) is the frequency of the tone, \( n \) is the mode number, \( U_\infty \) is the freestream velocity, \( \alpha \) is the phase lag, \( \gamma \) is the ratio of specific heats, and \( M \) is the freestream Mach number. The ratio of the convective velocity of the structures in the shear layer to the freestream velocity is denoted by \( \kappa \). One of the implications of this equation is that the frequency of the modes is related to the cavity geometry through the cavity length.

The effects of the cavity span have been more difficult to determine than the other geometric parameters because many experimental techniques, such as Schlieren and Particle Image Velocimetry (PIV), require direct optical access. Nevertheless researchers have estimated that the flow is nearly two dimensional when the \( \frac{W}{L} < 1 \).\(^6\) Studies by Maull and East,\(^7\) Rossiter,\(^4\) and Ahuja and Mendoza\(^1\) have shown that the intensity of the Rossiter modes decrease as the cavity narrows. In 2001, Chung\(^8\) conducted a parametric study examining the effects of varying the \( \frac{D}{L} \) from 2 to 43 and the \( \frac{L}{W} \) from 0.5 to 2.0 for Mach 1.28 turbulent flow over a rectangular cavity. That study primarily utilized steady and unsteady pressure sensors to note the increased strength of the trailing edge vortex as the \( \frac{L}{W} \) increases. More recently, Beresh et al.\(^9\) used PIV to examine the effects of span on the cavity flow at freestream Mach numbers 1.5, 2.0, and 2.5 and \( \frac{L}{W} = 1, 1.67, \) and 5. The study was not extensive enough to identify definitive trends. However it was successful in tracking the movement and intensity of the recirculation region and the turbulent shear layer. Unfortunately their field of view was limited by the sidewalls so the cavity floor region could not be examined. While the aforementioned studies provide a wealth of information regarding the spanwise effects on the velocity and

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Figure 1. Cavity Flow Parameters
pressure fields, additional work is needed to identify the flow mechanisms that cause the measured flow phenomena. Once identified, these effects may be leveraged in flow control applications.

Many different control schemes have been implemented in an effort to reduce the pressure fluctuations inside the cavity. Passive techniques, such as leading edge rods, deflectors, and trailing edge modifications, have been shown to be effective at their design conditions. In particular Dudley and Ukeiley's study with a leading edge rod was a precursor to the current work in that the same cavity geometry and flow conditions were investigated. In those experiments, the leading edge rod lifted and broadened the shear layer thereby reducing the peak tones by up to 65%. One key finding of that series of studies was differences in the control effects between cavities that spanned the full width of the wind tunnel and those that only spanned the center third of the wind tunnel. Unfortunately the reduced mechanical complexity of the rod, and other passive devices, comes at the cost of poor performance at off-design conditions. Active control techniques vary from zero net mass flux piezoelectric actuators, resonance enhanced microactuators, oscillating flaps, porous plates, and many others. Detailed reviews of flow control over cavities can be found in Cattafesta et al. and Rowley and Williams.

Steady leading edge slot blowing will be the scheme of choice in this application since they have been shown to have the control authority to modify many flow configurations including large momentum, supersonic flows. Ukeiley et al. found that leading edge blowing slots are effective even in complex cavity geometries, such as finite span cavities, to reduce both the broadband and tonal fluctuations of the pressure. This work also concluded that more significant surface pressure fluctuation suppression was achieved when blowing slots were segmented. Zhuang et al. employed an array of microjets at the leading edge of a cavity in supersonic flow to displace the shear layer and significantly reduce the flow unsteadiness. Lusk et al. followed the work of Ukeiley et al. for a rectangular cavity and found that a five slot blowing configuration reduced the pressure fluctuations, up to 44%, of a full span cavity in Mach 1.4 flow. Segmented slots produced streamwise aligned vortices that interacted with the spanwise aligned structures to produce a highly three-dimensional flow field. The velocity data, in conjunction with unsteady pressure measurements, revealed how this three-dimensionality disrupted the feedback mechanism. This study served as precursor to the current work and as such the experimental results from both will be compared. This comparison will provide details on how the three-dimensional flow field generated by the slot blowing interacts with the three-dimensional flow field produced by a finite span cavity.

The remainder of this paper will present the details of this experimental study. The section on experimental setup will describe the facilities and equipment used during testing. The results portion will show spectra from unsteady pressure measurements and the velocity fields. The final section will present the conclusions drawn from the datasets and future work.

II. Experimental Setup

The experiments for this study were conducted using the Supersonic Wind Tunnel (SWT) at the University of Florida, as shown in Figure 2. Two compressors, a Quincy (model QSI 1000 A/C) and Sullair (model LS-20T), fill two 14.39 m³ tanks up to 1,516 kPa with dry air. A Fisher ED valve is then used to regulate the high pressure air into the plenum of the wind tunnel such that the stagnation pressure is 172 kPa. The PID controller that regulates the valve is capable of holding the stagnation pressure to within 2% of the desired value. These stagnation conditions, in combination with a converging-diverging nozzle, generate a nominally Mach 1.4 flow in the test section with a dynamic pressure of 74 kPa. The test section is 76.2 mm (3”) wide by 101.6 mm (4”) high by 228.6 mm (9”) long. The incoming boundary layer and displacement thickness ahead of the cavity were measured to be 2.4 mm and 0.40 mm respectively. Typically the Reynolds number at experimental conditions is on the order of $10^6$. The test section windows are composed of a 19.05 mm (0.75”) thick glass in an aluminum frame. The ceiling of the test section is made from acrylic that has been coated with an anti-reflective substrate to improve the quality of PIV images. The substrate reduces the reflectance of light at 532 nm wavelength to less than 0.05%, according to the manufacturer's literature.

The relative dimensions of the cavity are crucial in dictating the features that appear in the flow field. In the SWT, the cavity model is composed of multiple modules thereby allowing the length, depth, and width to be manipulated. The sidewall modules are made from aluminum while the cavity floor block is composed of acrylic. The aforementioned anti-reflective coating was applied to this floor module. For these experiments a cavity with a depth of 12.7 mm (0.5”) and a length to depth ($L/D$) of 6 was employed. Two
mounting configurations were required to compare the differences in the flow fields of the full span and finite span cavities. A finite span cavity is denoted as any cavity with a width that does not reach the test section walls. The finite span cavity in this experimental study had a width to depth ratio \( \frac{W}{D} \) of 2. A comparison of the two configurations along with a coordinate system can be seen in Figure 3.

The cavity floor can be outfitted with pressure transducers at various locations to obtain unsteady pressure measurements. Kulite XCQ-062-5D 5 psi differential pressure transducers were utilized in these experiments along the floor. The differential transducers measured the pressure difference between the sensor location and the reference tube, 6.4 mm away. A XCQ-062-50A 50 psi absolute pressure transducer was placed in the aft wall. A diagram of the Kulite locations is shown in Figure 3. The voltage signals from the Kulites were amplified by Endevco 136 DC differential voltage amplifiers and read by a NI PXI4472 card. The signal was sampled at 90 kHz and band pass filtered with a low pass cutoff of 30 kHz and a high pass cutoff of 100 kHz.

To understand the effects of blowing on the shear layer, snapshots of the velocity field were acquired along a streamwise aligned plane at the center of the cavity. A light sheet was formed by double pulsing a dual cavity Litron Nano L 135-15 Nd:Yag laser in conjunction with a spherical and cylindrical lens. The laser light wavelength was 532 nm. The sheet was passed through the cavity floor and was approximately 2 mm in thickness. For Mach 1.4 freestream flow, the time between pulses was set to be 1.2 \( \mu s \). Di-ethyl hexyl sebacate (DEHS) particles were utilized to seed the plenum of both the wind tunnel and the blowing slots. The DEHS oil for the wind tunnel plenum was pressurized using a LaVision Atomizer four-nozzle particle generator and created particles that were approximately 1 \( \mu m \) in diameter, according to the manufacturer. The seed for the blowing slots was pressurized using a Dantec 10F03 seeding generator and produced particles on the order of approximately 2 \( \mu m \). Over the years, numerous experimental setups have been devised to overcome the optical issues due to the cavity sidewalls. This work follows the setup by Beresh et al., in which the cameras were positioned at an angle to capture the shear layer without image occlusion or discontinuity. As shown in Figure 4, the LaVision Imager sCMOS cameras were tilted downward at 30°. These cameras have a chip size of 2560 by 2160 pixels and have a 16 bit digital output. The pixel size is 6.5 \( \mu m \). A Scheimpflug adapter was utilized to angle the focal plane of the Sigma 105 mm lenses to match that of the light sheet such that the majority of the particles were in focus. To increase the depth of field, the
f-number was set to 8. The distortion from the canted camera perspective was remedied using the typical stereoscopic calibration techniques. To capture the region near the leading and trailing edge of the cavity, the stereoscopic angle between the cameras was reduced to 20°. Unfortunately, this shallow angle increased the uncertainty in the velocity data. Overall, this PIV system acquired data at 14 Hz. Lastly, the data was processed using DaVis 8.2.2. The final velocity field was calculated by using an interrogation region of 64 x 64 pixels and then reducing the window to 32 x 32 pixels. A rectangular window with 50% overlap was used to oversample the fields. The images were post-processed to detect and discard spurious vectors using a spatial median filter. Approximately 1000 images were processed for the full span case and over 1500 images were taken for the finite span cases. A running mean at various points in the turbulent region were calculated to ensure that the mean velocity statistics converged to less than 3% for each dataset. Future work will include an uncertainty quantification of the PIV results that will allow the data to be interpreted more accurately.
One objective of this study was to gain insight into the suppression of the pressure fluctuations by injecting air normal to the flow at the leading edge of the cavity. Multiple slot configurations, shown in Figure 5, were tested to determine their effectiveness. The results from the 3 Slot and 1 Slot Long configurations were interesting because they showed the effects of segmenting the slot. The 1 Slot Short case was tested to elucidate the interaction of a jet spanning the middle third of the cavity width with the flow over the sidewalls. A regulator was used to control the amount of compressed air into the mass flow meter, an Alicat Scientific M-250SLPM-D with a range of 0-250 SLPM. A Druck PMP 4015 75 psi transducer measured the pressure in the leading edge block. The mass flow meter was able to read the stagnation temperature of the flow. The slots were varied by changing the face plate of the leading edge (LE) block. The slots are offset from the leading edge of the cavity by 1.59 mm (0.0625”). To acquire PIV data, the flow from the blowing slots was seeded. The mass flow meter was not utilized during these experiments since the oil based seed would be detrimental to it. Instead, the slot blowing conditions were replicated by matching, within 1% of the mean value, the pressure in the LE block.

![Figure 5. Slot Plate Configurations](image)

### III. Results

In this section, the results from the unsteady surface pressure and stereo PIV experiments are presented for each cavity configuration. The unsteady transducers provided time resolved data, albeit at a few discrete locations, that elucidated the changes in the pressure fluctuations of interest. The spatially resolved PIV results provided a temporally averaged, global view of the flow effects as a result of slot blowing.

#### A. Uncontrolled Configurations

In this section, the surface pressure and PIV results for the uncontrolled (baseline) cavity configurations will be presented to elucidate differences between full and finite span cavities.

1. **Surface Pressure Experiments**

   The unsteady pressure along the cavity floor and aft wall surfaces were measured at discrete locations to gain insight into the effects of adding sidewalls. The overall pressure fluctuation intensity plot for both cases is shown in Figure 6. At the measured locations, the pressure fluctuations for the full span cavity were approximately twice that of the finite span case. In this plot, as with all the pressure plots, the root-mean-square of the pressure fluctuations \( P_{rms} \) was nondimensionalized by the dynamic pressure \( q_\infty \) while...
the $x$-location was nondimensionalized by the cavity length $L$. Figure 7 shows the normalized power spectral density (PSD) versus Strouhal number for the full and finite span cavities. In both cases, one sees that the Rossiter semi-empirical equation approximates the frequency of the tones within 10%. In addition, the broadband levels for both cases were similar, especially near the aft wall. In contrast, the dominant mode switches from the third to the second Rossiter mode when comparing the full span to the finite span case.

![Figure 6. Pressure fluctuations in the full and finite span cavities](image)

![Baseline $p_{\text{rms}}$ in the Cavity](image)

![Figure 7. Comparison of pressure power spectral density at $x/L = a) 0.27$, b) 0.42, c) 0.72, d) 1 for the full span and finite span cavities](image)

2. Velocity Fields
   
   The walls of the cavity limited the field of view and caused significant glare. Therefore the data is scant and possibly contaminated near these areas. In all of the velocity plots, the streamwise component is denoted as $U$ and the normal component in the direction away from the cavity floor is $V$. The $x$ and $y$ axes are
nondimensionalized by the cavity depth $D$ for all the plots below. As mentioned before, the data was measured in a streamwise aligned plane in the center of the cavity.

Initially the uncontrolled flow fields of the full span and finite span cavities were compared. Figure 8 shows the streamwise component of velocity along with superimposed streamlines for each of the cases. These streamlines are formed from the streamwise and normal velocity vectors. In the full span case, the recirculation region is positioned near the aft wall. In contrast, this region moves to the middle of the cavity for the finite span case. Beresh et al. saw similar movement of this region in finite span cavities. It is possible that the flow over the sidewalls pushes the shear layer downward resulting in the movement of the region forward.

The vorticity thickness $\delta_\omega$ describes the growth of the shear layer and is shown for both uncontrolled cases in Figure 9. The thickness is calculated by

$$\delta_\omega = \frac{U_\infty}{\partial U/\partial y_{max}}$$

In the plot the $y$-axis is nondimensionalized by the incoming boundary layer thickness $\delta_0$. The spreading rate of the shear layer is the derivative of the vorticity thickness in the streamwise direction $\partial \delta_\omega / \partial x$. The rates were found by fitting the data to lines using the least squares method. They roughly correspond to those reported by Lusk et al. Figure 10 shows the differences in the streamwise velocity fluctuations. The full span case shows the most intense streamwise turbulence region overall which was focused near $x/D = 5.5$ and just above the cavity lip line. In the finite span case, this region shifts downward both in intensity and location. This reduction might be a result of enhanced mixing caused by the flow over the sidewalls. This notion is supported by the normal turbulence intensity plots in Figure 11. When comparing the two baseline cases...
cases, the finite span cavity has a more intense region near the aft wall. The Reynolds shear stress (RSS), in Figure 12, provides insight into the transport of momentum and shows a similar trend to that of the normal turbulent stresses.

![Figure 10. Mean streamwise turbulence intensity fields](image)

![Figure 11. Mean normal turbulence intensity fields](image)

![Figure 12. Mean Reynolds shear stress fields](image)

B. Control Configurations

In this section, the surface pressure and PIV results for the leading edge slot blowing configurations will be presented.

1. Fluctuating Surface Pressures

For the control configurations, the pressure along at the aforementioned four discrete locations was measured as the blowing rate was varied for each slot configuration. The blowing rate was non-dimensionalized using the momentum coefficient, \( C_\mu \), which is given as

\[
C_\mu = \frac{\dot{m} V}{\frac{1}{2} \rho_{\infty} U_{\infty}^2 W \delta}
\]

, where \( \dot{m} \) is the mass flow rate through the slots, \( V \) is the mean velocity of slot jets, \( \rho_{\infty} \) is the freestream density, \( U_{\infty} \) is the freestream velocity, \( W \) is the cavity width, and \( \delta \) is the boundary layer thickness. The average jet velocity was calculated from isentropic relationships using the measured stagnation pressure inside the leading-edge block, and the static pressure inside the test section.

Figure 13 shows the reduction of the \( P_{rms} \) versus the momentum coefficient for each slot case measured at the aft wall of the cavity. Here, the reduction in pressure RMS is calculated as

\[
\% P_{rms} \text{ reduction} = 100 \times \frac{P_{rms, \text{no slot}} - P_{rms, \text{blowing}}}{P_{rms, \text{no slot}}}
\]
where $P_{rms, no\ slot}$ is the $P_{rms}$ for the cavity configuration without any blowing slots in place. $P_{rms, blowing}$ corresponds to the $P_{rms}$ that was measured as the slot configuration and blowing rates were varied. In general, the pressure fluctuations were reduced as the blowing rate was increased up to a certain limit which varies for each slot case. Taking into account the resolution of the plot, the limit for all three cases were very similar. This limit was considered to be the blowing rate where the control was saturated and increased blowing rates had a minor effect on reducing the $P_{rms}$. Table 1 lists these configurations. It is understood that arguments can be made for selecting other configurations as the control saturated cases. The highest $P_{rms}$ reduction was obtained with the One Slot Long configuration which achieves almost a 50% pressure fluctuation reduction. Nevertheless, the segmented 3 Slot case shows a similar reduction in $P_{rms}$ at a lower blowing rate. This result agrees with the work Ukeiley et al.\textsuperscript{21} on the advantages of blowing slot segmentation. Overall the level of these reductions are comparable to those seen for the full span case results which are presented in Lusk et al.\textsuperscript{23}

![Figure 13. Pressure fluctuation suppression for the various slot configurations](image)

Table 1. Control saturation blowing rates for each slot case

<table>
<thead>
<tr>
<th>Slot Case</th>
<th>$C_{\mu}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Slot Short</td>
<td>0.089</td>
</tr>
<tr>
<td>One Slot Long</td>
<td>0.091</td>
</tr>
<tr>
<td>Three Slot</td>
<td>0.090</td>
</tr>
</tbody>
</table>

To further understand these reductions the power spectral density of the control saturated configurations were examined. Figure 14 shows the power spectral density (PSD) of the pressure fluctuations of the control saturated blowing rate for each slot configuration. The PSD has been nondimensionalized by the dynamic pressure while the frequency is nondimensionalized using the cavity depth and freestream velocity. The PSD for the One Slot Short case shows a slight power reduction of the Rossiter tones while the broadband fluctuations remain the same with or without the slot. The 3 Slot and 1 Slot Long configurations brought the power of Rossiter tones to broadband levels of the No Slot configuration.

2. Velocity Fields

PIV experiments were only conducted on the 3 Slot and 1 Slot Long configurations due to the ineffectiveness of the 1 Slot Short configuration at mitigating the surface pressure fluctuations. The mean velocity field characteristics, shown in Figure 15, change significantly with the introduction of leading edge slot blowing. The recirculation regions are not clearly defined in either of the control cases. In all of the finite span cases, the shear layer broadens near the aft wall. The mean velocity fields show how the cavity shear layer in these cases penetrates much deeper into the cavity than the uncontrolled case. The control cases in particular are characterized by a large normal velocity downward in the front half of the cavity. As control is applied, the intense region of streamwise turbulence, plotted in Figure 16, shifts toward the cavity center as well as

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Figure 14. Comparison of the power spectral density for the no slot case and the control saturation configurations

Finite Span - 3 Slot

Finite Span - 1 Slot Long

Figure 15. Mean streamwise velocity fields

spreads out along the streamwise direction. For the 3 Slot case the region of streamwise turbulence is wider than the 1 Slot Long case. Although it should be noted that the obscured camera angle limits determining the exact size of these areas. Also the streak in the plots near the cavity fore wall at \( \frac{y}{D} = 0.5 \) is a result of background reflections off the inside corner of the cavity. Unfortunately neither experimental efforts nor image postprocessing were effective in mitigating these effects. Figure 17 reveals how leading edge slot blowing results in a region of large normal turbulent velocity fluctuations, in contrast to the uncontrolled cases. Interestingly, both slot cases have regions of intense normal turbulence but that region for the 3 Slot case is broader in size than for the 1 slot Long case. The increase in the normal turbulence intensity near the cavity leading edge may be due to the background glare. The Reynolds shear stress, plotted in 18, shows that the 1 Slot long case is more concentrated near the cavity lip line and more intense than the 3 slots case. In Lusk et al.\textsuperscript{23} the authors investigated a full span slot configuration, a 3 slots configuration, and 5 slot configuration. In that work, the full span slot configuration lifted the shear layer much like the 1 Slot long configuration in this work. In contrast, the 3 Slot configuration results from both studies are not similar. In the precursor work, the regions of peak turbulence intensity are located closer toward the aft wall. The vorticity thickness, shown in Figure 19, for the control cases are similar up to \( \frac{y}{D} = 2 \). Thereafter the spreading rates become nonlinear, similar to those shown for the control cases in Lusk et al.,\textsuperscript{23} and significantly different for each slot configuration.

Figure 16. Mean streamwise turbulence intensity fields
IV. Summary

In this study, unsteady surface pressure and stereo Particle Image Velocimetry experiments were conducted to understand the effects of adding sidewalls and leading edge slot blowing to supersonic flow over an open cavity. Data was taken for the full span cavity, finite span cavity, and three different slot configurations. The uncontrolled configurations results showed differences in the overall pressure fluctuation levels and dominant modes for each case through the alteration of the width to depth ratio. This result agreed with many of the findings reported previously in literature. Surface pressure measurements at discrete locations showed the reduction in $P_{rms}$ with leading edge slot blowing in the finite span cavity. In general, blowing through leading edge slots reduced the pressure loads in the cavity by up to 40%. The 3 Slot and 1 Slot Long configurations both mitigated a substantial portion of the broadband and tonal component of the pressure fluctuations. The 3 Slot configuration required less mass injection to achieve higher suppression. Velocity data from the control cases revealed a marked increase in the normal component of velocity as well as changes in the recirculation region location. In addition, the regions of turbulence intensity were spread out and at lower amplitudes for the 3 Slot case versus the 1 Slot Long.
In the future, velocity data at multiple planes inside the finite span cavity will be measured to further gain insight. Initially the velocity along streamwise aligned planes centered between the slots will be measured. In addition, a different stereo Particle Image Velocimetry setup will be developed to obtain the velocity along multiple spanwise planes in the finite span cavity. Both of these datasets could reveal the formation of the streamwise vortices which were generated in the full span blowing case by the segmented leading edge along multiple spanwise planes in the finite span cavity. All of this velocity information will yield deeper understanding on the suppression mechanism for leading edge slot blowing and how the control jets interact with the flow.

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