Coherent Structures and Control in Jet Noise and Shock/Boundary Layer Interaction

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Small perturbation response of coherent structures in free and bounded shear layers

STATUS QUO

Role of coherent structures poorly understood in many applications

- Difficult to discern in experiment
- Computations plagued by uncertainty
- Interpretation is difficult

Initiated detailed study of jet noise and SBLI

- Advanced diagnostics and high-fidelity simulations working tightly integrated

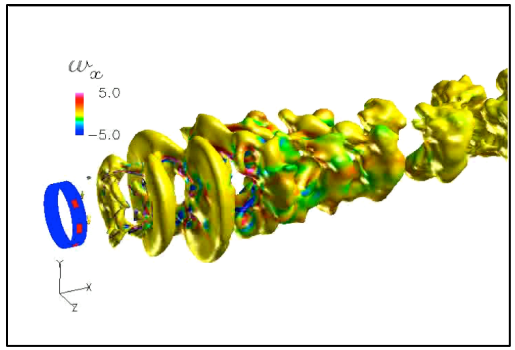
Analysis

- Systematic analysis of no-control and with control, comparison with experiment, near to far field correlations

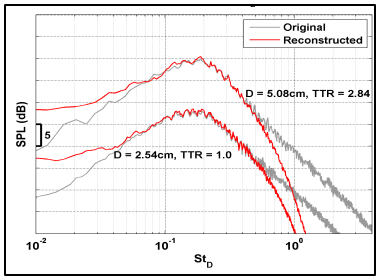
NEW INSIGHTS

Genesis and response of coherent structures

- Impulse analysis of jets identifies key correlations connecting near to far field. Parallel simulations demonstrate universality of hairpin structures in free and bounded shear layers.



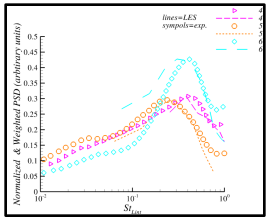
MAIN ACHIEVEMENTS:

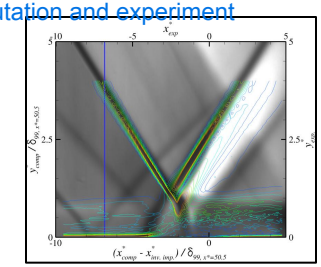


Systematic analysis of noise generation mechanisms and characterization of sensitivity to disturbances

- Analysis of large number of experiments yield insight into key events crucial in the genesis of sound
- Phase averaged visualizations show breakdown of coherent structures
- Low frequency unsteadiness successfully reproduced in high-fidelity simulations – facilitates control strategy development

Tightly integrated computation and experiment





HOW IT WORKS:

- Coherent structures and associated statistics provide insight into dynamics
- This insight is leveraged to characterize response to small perturbations

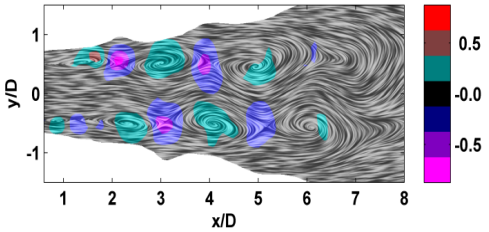
ASSUMPTIONS AND LIMITATIONS:

- Receptivity to only thermal modes explored to date

QUANTITATIVE IMPACT

Current Impact

- Detailed understanding guides strategies for active control
- Small perturbation response yields diagnostic capability beyond control techniques.



Modulated Coherent Structures in Experiment

Planned Impact

- Jet noise understanding and control with active methods
- Supersonic inlet and isolator shock train flow control
- Propose revolutionary techniques to redirect flow field energy

Research Goals

- Develop tightly integrated and capable computational & experimental capabilities
- In-depth understanding of coherent structures physics and role
- Connect the physics of the near field to the far field for jet noise analysis.

END-OF-PHASE GOAL

Highlight Slide Template

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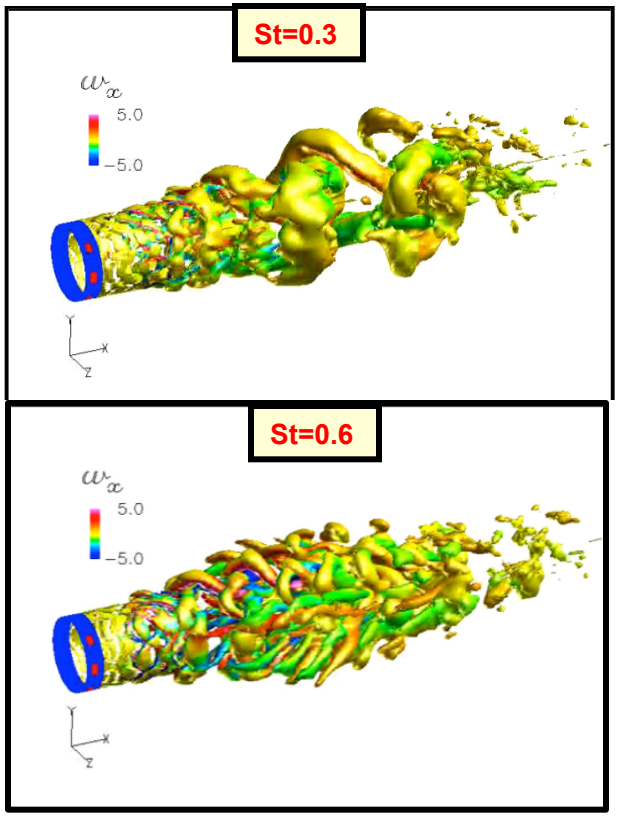
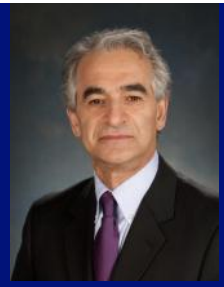
Small disturbances used to control large coherent structures

Synergy between CFD and experiment pays off



- Active control has the potential to be far more attractive than passive control because it can be tailored during flight.
- Small perturbations are particularly exciting, because they can be scaled
- Coherent structures that give rise to mixing and noise have instabilities that respond to small perturbations.
- This research provides insight into how such disturbances can be profitably exploited for desired objectives

Gaitonde and Samimy, Phys. Fluids, Vol. 23, No. 9, 2011



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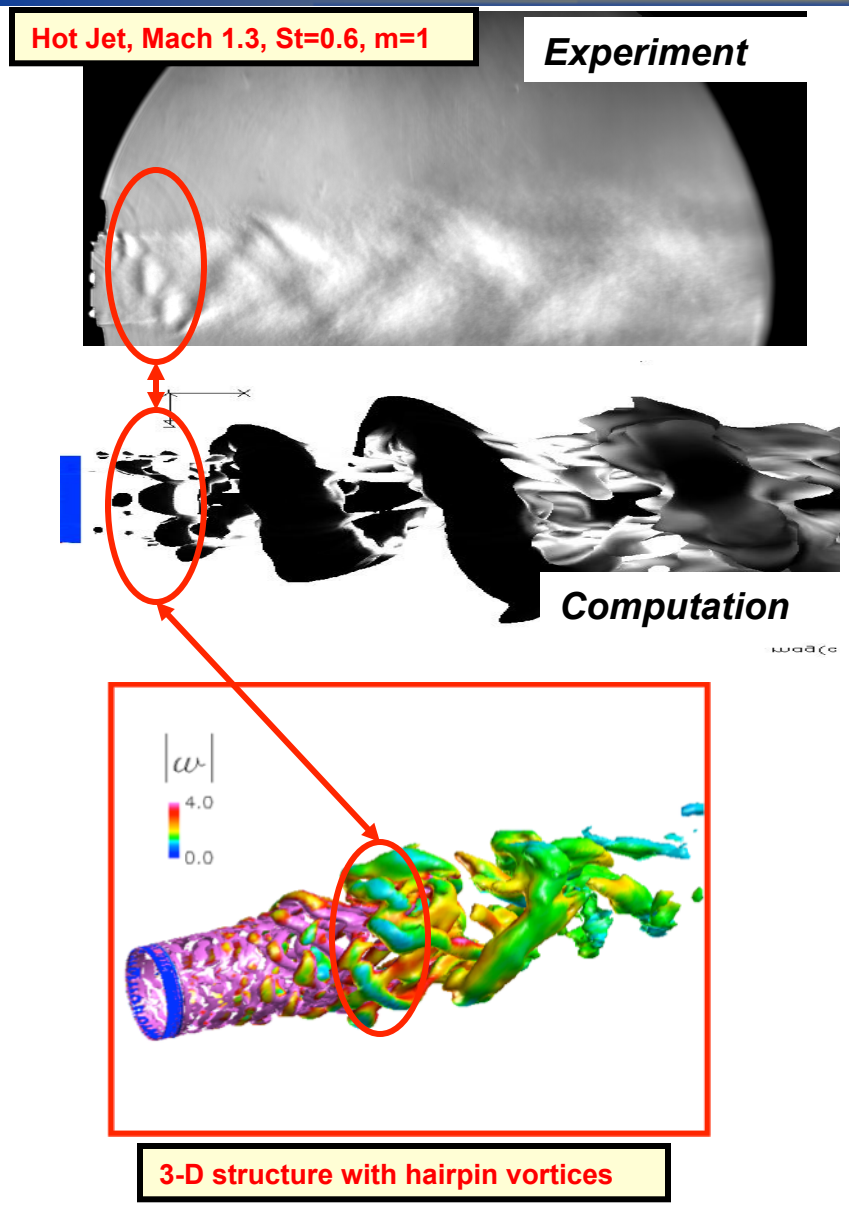

Experiments and simulations coordinated as never before to enhance understanding

Coherent structure spectrum is correlated to sound generation and propagation

Clearer understanding of detailed physics will facilitate tailored open and closed loop control and guide scalability analysis

Simulations and experiments confirm existence and genesis of large structure (helical) comprised of hairpin structures

Experiments and computations together provide unique insight into complex 3-d nature of turbulence in free and bounded shear layers that form the foundation of practical flow fields