NASA Aeronautics Research Institute

Multifunctional Low Pressure Turbine for Core Noise Reduction, Improved Efficiency, and NOx Reduction

NASA Aeronautics Research Mission Directorate (ARMD)

FY12 Seedling Phase I Technical Seminar

July 9-11, 2013

Problem

The last few blade rows in a low pressure turbine (LPT)

- Have low Reynolds number boundary layers
- Are moving to higher loadings
- Suffer boundary layer separation and performance loss.

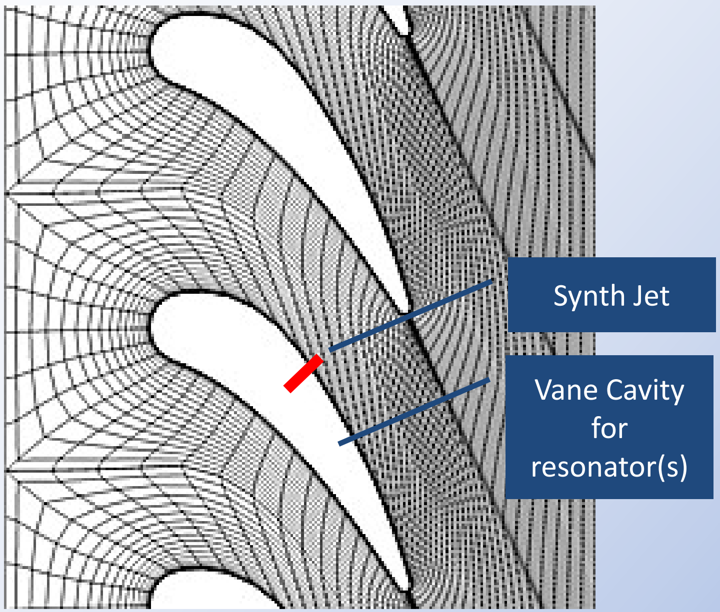
Simultaneously, engine designs are being pushed toward lower noise and NOx emissions.

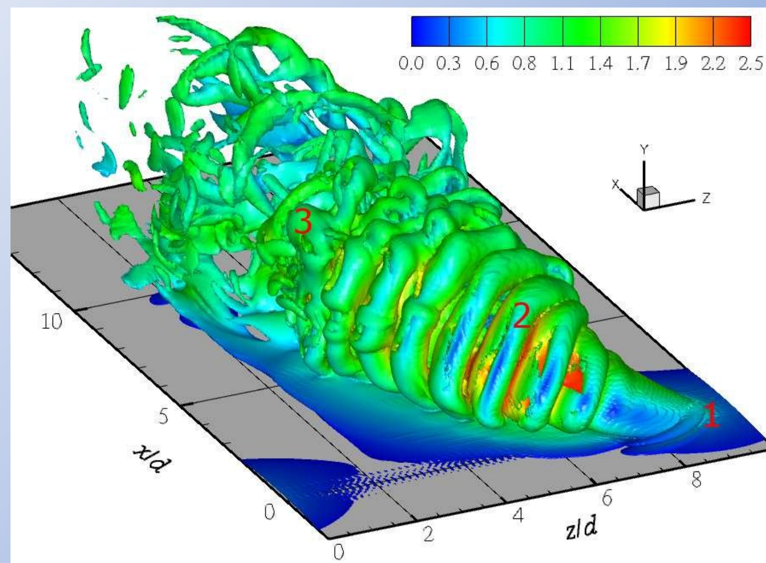
Innovation

The proposed innovation is to embed Helmholtz resonator cavities within the thick, hollow LPT airfoils

- Absorb incident unsteady energy (acoustic, wakes, …)
- Use that energy to create a synthetic jet to energize the boundary layer and reduce low Reynolds number laminar separation
- Reduce NOx emissions by placing a catalytic coating on the cavity, holes, and near-hole surfaces

Concept Sketch





Building on previous work with forced pulsing jets for flow control.

Right: Iso-surfaces of instantaneous vorticity magnitude, colored by velocity magnitude

Curtis Memory, Deryl O. Snyder, and Jeffrey Bons, “Numerical Simulation of Vortex Generating Jets in Zero and Adverse Pressure Gradients,” 46th AIAA Aerospace Sciences Meeting and Exhibit, AIAA 2008-558, January 2008, DOI: 10.2514/6.2008-558

Feasibility

- **Primary**: is the induced synthetic jet sufficient to modify the boundary layer?
- Is the resonator reducing the noise?
- Does this concept have sufficient catalytic impact on NOx?

Technical Approach

- Simplified 3D CFD model of a resonator connected to a channel
- Unsteady Reynolds Averaged Navier-Stokes: Glenn-HT
- Anticipated incident waves (frequency, amplitude)
  - 400 Hz combustor tone, ~ 140 dB
  - 3000 Hz rotor wake, ~ 140 dB
- Resulting synthetic jet compared to literature
- Liner designed & evaluated with duct tools
- Catalytic processing estimated

Potential Impact

- Reducing the boundary layer separation on the last turbine vane could improve turbine efficiency by 2% to 7%
- Core noise is predicted to be a significant contributor to the future engine architectures. The LPT is a candidate for the "soft vane" concept, and might provide 1 to 2 dB reduction on select tones.
- Additional NOx reduction could be beneficial, but hard to quantify before a detailed analysis.

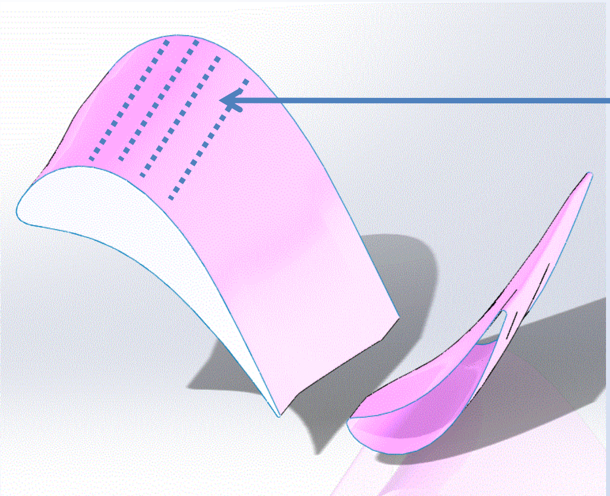
Parameter Assessment

NASA Aeronautics Research Institute

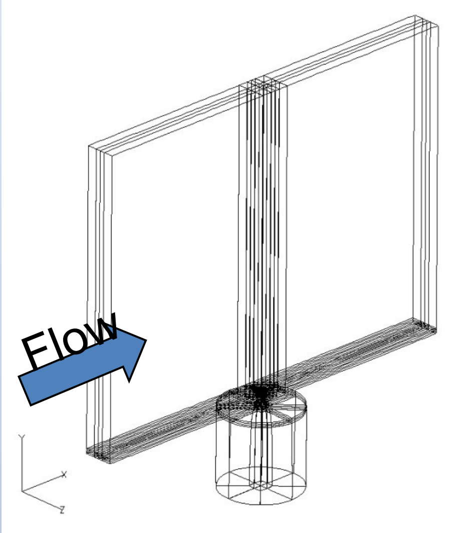
- Conditions at the LPT seem feasible.

DESCRIPTION	*Feasibility*				
Pulsing frequency, f [Hz]		400	400	3000	3000
Average Mach from the injection site to trailing edge		0.2	0.5	0.2	0.5
Reduced frequency of synthetic jet, F=f*Lj–te/Uave	*0.1 – 1.0*	0.18	0.07	1.36	0.55
Jet Reynolds number	*25,000 – 100,000*	65,089	162,722	65,089	162,722
Blowing ratio, B = Vjet/Uave	*>1*	TBD	TBD	TBD	TBD

CFD Domain



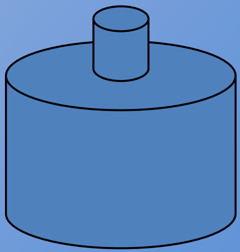
Based on experience with bypass duct soft vanes, apply to the LPT vane, but simplify the geometry for CFD assessment.



Helmholtz Resonator

Frequency, $f = \frac{c}{2\pi}\sqrt{\frac{A}{VL}}$

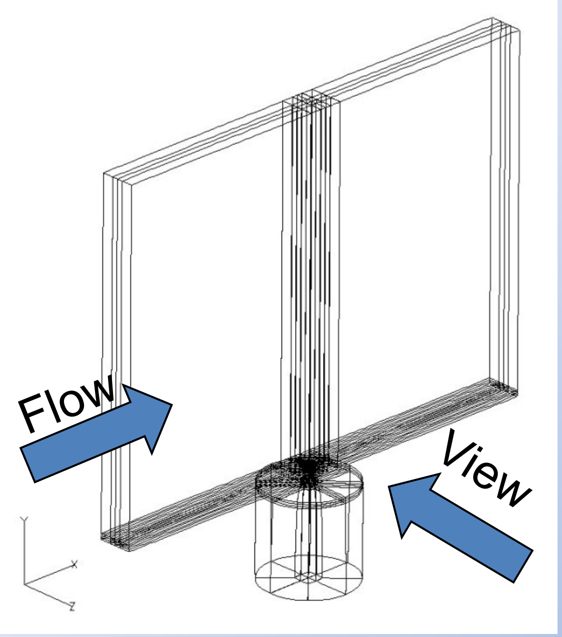
Where,
c = the speed of sound.
L = length of the neck
A = area of the neck
V = cavity volume of the resonator

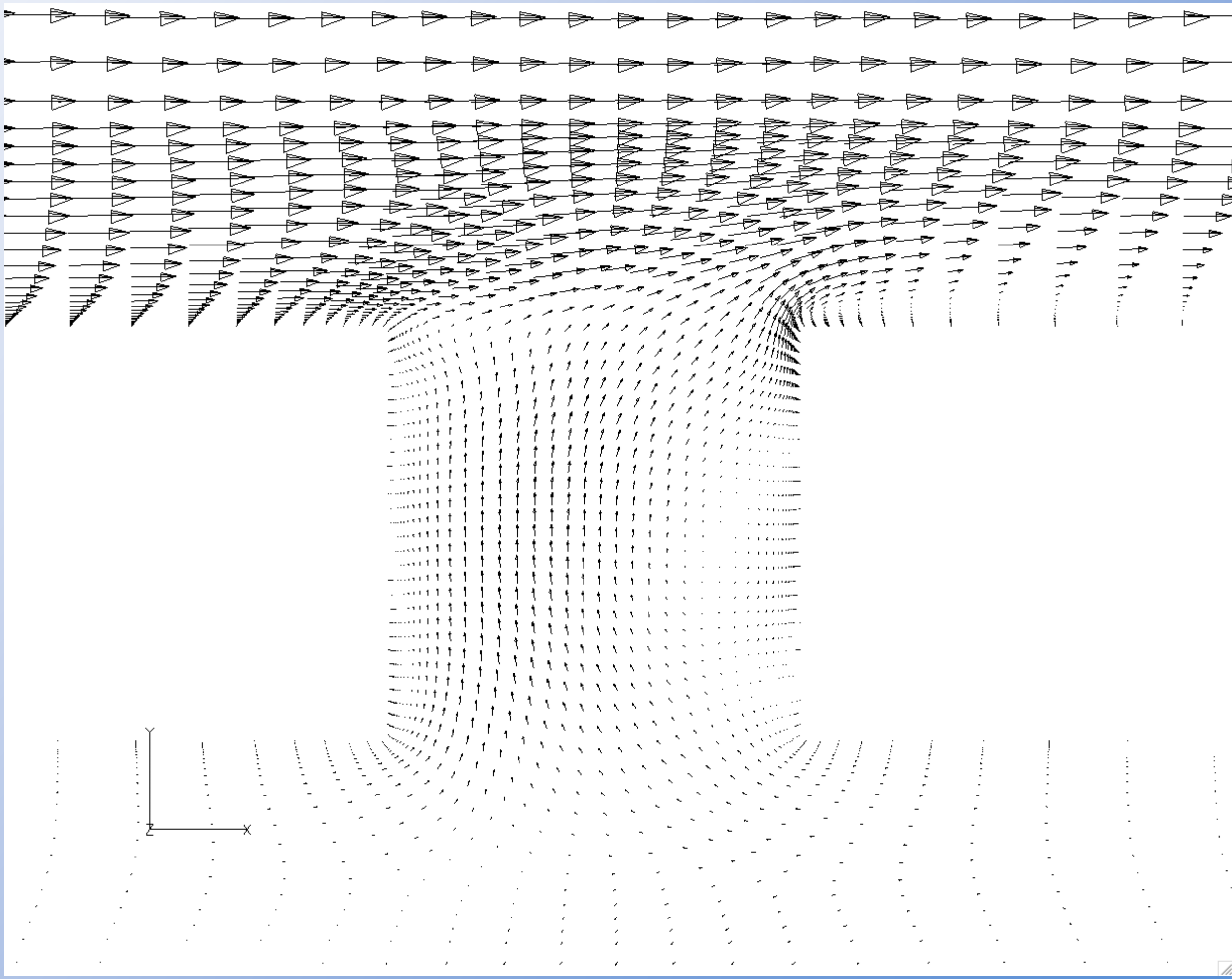


Qualitative Results

NASA Aeronautics Research Institute

Near the peak velocity in the cycle, minimal induced synthetic jet. Currently investigating resonator tuning.





Conclusions

- Determining the feasibility of the induced synthetic jet is key, and is still TBD.
- Available LPT vane volume is sufficient for tens of resonators per span-wise hole spacing, so physically feasible.
- Determination of acoustic attenuation requires accurate model of vane, resonator locations, flow field and incident waves. (TBD)
- Determination of NOx reduction is also TBD.

Dissemination & Next Steps

Dissemination

- Results are preliminary; too early to decide.

Next Steps

- Assess results from the CFD work as it completes over the summer
- Confirm feasibility of the flow control aspect & attempt to qualify the acoustic attenuation
- Complete final report for Sept 30, 2013

NASA