Various Applications of Flow Control

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Active Control of Structural Vibrations and Aerodynamic Performance of Wind Turbine Blades – *Funded by NYSERDA*

Victor Maldonado, Bill Gressick, and Miki Amitay

Wind Energy

- As wind turbines increase in size and power, they become more prone to high amplitude fatigue loads that reduce the operating life of the wind turbine.
- Wind turbines suffer from low energy production at low wind speeds and must be shut down at high speeds to avoid structural damage.

Objectives

- Reduce blade vibration by selectively increasing or decreasing the aerodynamic loads along its span using active flow control via synthetic jet actuators.
- Increase the efficiency of wind turbines by improving their energy capture capability at low wind speeds and relieving unwanted loads at high speeds.

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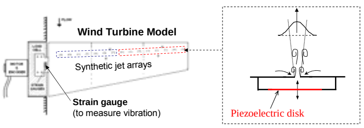
Synthetic Jet Actuators

Glezer & Amitay, "Synthetic Jets", *Ann. Rev. Fluid Mech.*, 2002, 34:503–29.



- Zero-net-mass-flux (ZNMF)
- Allows momentum transfer to the flow
- Diaphragm and cavity are driven near resonance
- Small electric power input
- No plumbing or any mechanical complexity is needed
- Low cost

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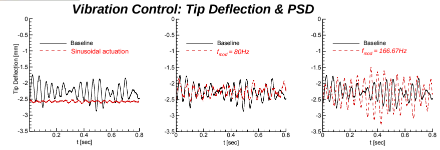
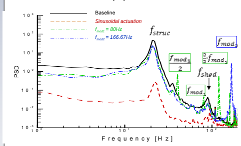
Vibration Control: Tip Deflection & PSD





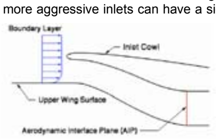
- Without flow control the blade vibrates at a frequency of 21Hz.
- Sinusoidal actuation results in one order magnitude reduction in vibration amplitude
- The baseline spectrum exhibits two distinct peaks corresponding to the structural and shedding frequencies.
- With flow control the spectral content is reduced by up to two orders of magnitude.

Active Control of transonic flow in serpentine inlets - *Funded by Northrop Grumman Corporation*

John Vaccaro and Miki Amitay

Also participating: Joe Olles and Ken Jansen (CFD), and Bill Gressick and John Wen (Controls)

- The inlet to an aircraft propulsion system must supply flow to the compressor with minimal pressure loss, distortion, or unsteadiness. Otherwise, the overall system performance will be reduced.
- For many military applications, the inlet design is also constrained by low observability requirements. To reduce the radar signature from the compressor face, a serpentine inlet is typically used to block line-of-sight.
- This can result is flow separation inside the inlet. Therefore, technologies such as active flow control that can enable more aggressive inlets can have a significant overall system benefit.



Active Control of transonic flow in serpentine inlets

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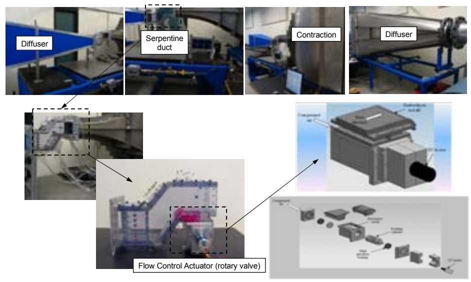
Fully Assembled Inlet Facility



Active Control of transonic flow in serpentine inlets

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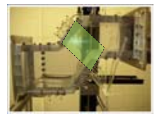
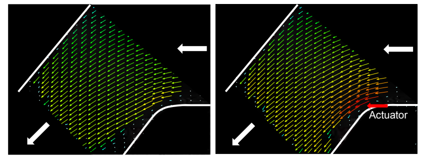
M ~ 0.2

$\frac{\dot{m}_{inlet}}{\dot{m}_{actuator}} \approx 0.7\%$



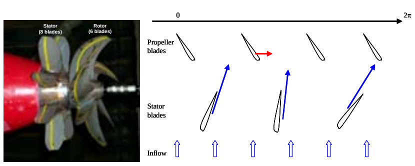


Baseline (no flow control) | Flow control is ON

Propulsor Thrust Vectoring through Stator-Induced Circumferentially-Varying Preswirl - *Funded by ONR*

John Farnsworth and Miki Amitay

- Investigate a methodology of active flow control (via addition of swirl) to provide undersea vehicles with additional maneuvering and control while reducing noise.
- Potential applications: UUV's, Recovery, Synthetic Aperture Sonar, Torpedoes



Propulsor Thrust Vectoring through Stator-Induced Circumferentially-Varying Preswirl

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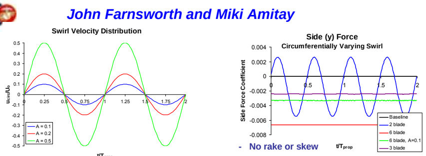
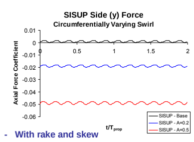


- Except where indicated, maximum circumferential swirl is 20% freestream values with zero mean (A = 0.2).
- Increase in the number of blades results in force increase.
- Fivefold increase in force coefficients compared with the simple blade (no rake or skew).



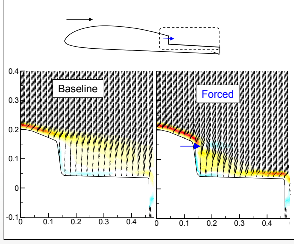
Micro Flying "Bagel" – *Funded by CATS*

Bill Gressick and Miki Amitay

MAVs are limited to 6"×6"×6" and a gross takeoff weight of 100gr.

Active Flow Control

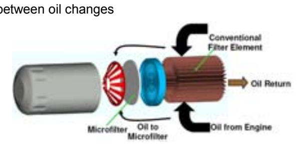
- Flight control is achieved by active control of the flow over the stators.
- Two 20mm 3kHz piezo-discs are installed in each stator (~0.2W each).



SOMS Hybrid Spin-On Filter – Funded by SOMS Technologies (through NYSERDA)

Steve London and Miki Amitay

- Hybrid spin-on filter designed for use standard in automobile engines
- Simple design replaces conventional oil filter with no modifications to engine or installation
- Up to 25,000 miles between oil changes

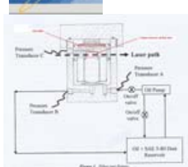


Objectives

- Conduct in-lab testing of the filter to understand the physics of the oil/particles flow field, particles distributions, etc. for "realistic" engine operation.
- Hybrid spin-on filter designed for use standard in automobile engines

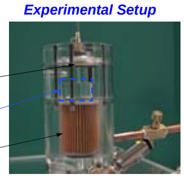
SOMS Hybrid Spin-On Filter

Steve London and Miki Amitay



- State of the art optical measurement techniques (PIV and PTV) are implemented using clear silicone oil and SAE 5-80 test dust.
- Particle concentrations and flow fields after passing through micro-filter will be calculated.
- Hydraulic pump simulates engine conditions, including periods of acceleration and deceleration.

Experimental Setup



SOMS Hybrid Spin-On Filter

Steve London and Miki Amitay

Benefits of Hybrid Filter Technology

- The hybrid spin-on filter improves filtration efficiency leading to the absence of small particles in the engine oil.
- It prolongs oil filter and engine life and can reduce maintenance and operating costs.
- It reduces friction, which increases engine and fuel efficiency.
- Due to the high filtration efficiency (in excess of 25,000 miles), the filter can be used to extend oil and filter change intervals.
- Extended oil drains provide direct and indirect savings.