Thermophone - Aero-Acoustic Tonal Noise Cancellation

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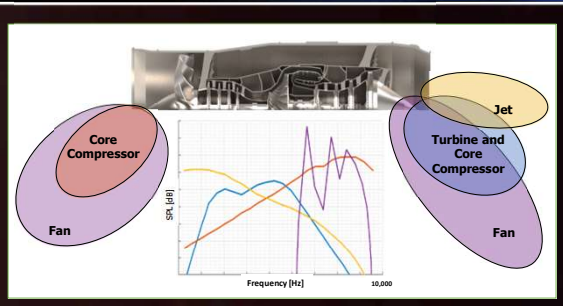
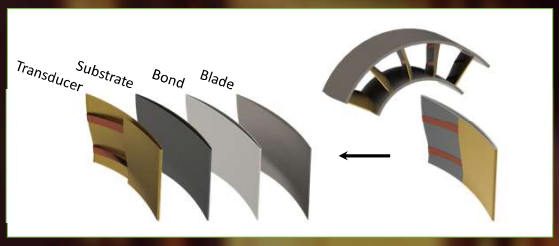


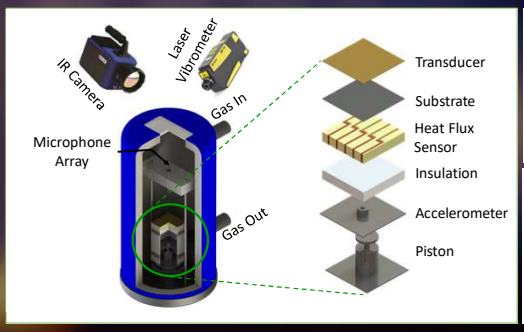
TOP: Sources of noise in a jet engine and their relative SPL
BOTTOM: Layers of heat-flux transducer deposited onto the stators

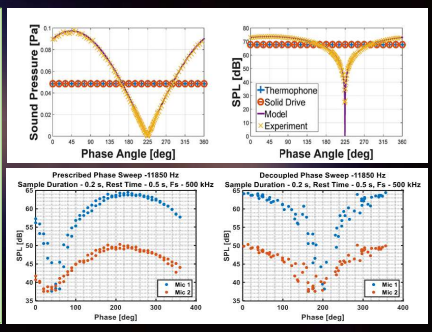


MOTIVATION:
Aircraft noise is significant consideration in both civil and military arenas. Tonal noise resulting from fan rotor-stator interactions is significant contributor to noise production. Strides towards higher bypass ratio engines has further accentuated contribution of fan rotor interactions to overall noise. Elimination of rotor-stator tonal noise has only seen limited success due to complex mechanical environment and variable operating conditions. Computational analysis of acquired noise signal helps to identify the specific frequency range where the tonal noise level is highest and helps to mitigate it by the use of active noise cancellation technology.

METHODOLOGY:
The thermophones are thin strips of electrical resistors which generate sound waves through periodic Joule heating and consequent heat flux fluctuation in the fluid boundary. The thermophones are The design of the thermophone is simple and it offers several advantages over conventional vibro-acoustic sources which are generally used in other noise cancellation procedures. The thermophone consists of an electrically conductive thin layer, where the joule heating takes place, and the substrate on which the thin layer is deposited using conventional deposition techniques. Potential advantages of thermophone loudspeakers may include:
a) Simplicity **(b)** Sound Purity **(c)** Flexibility **(d)** Scalability **(e)** Broad Frequency Range
f) Absence of Resonances
These heat-flux sound transducers offer unique potential of total active noise cancellation from any vibrating surface or acoustic source. They can be placed at locations of rotor interactions and destructively interfere with generated soundwaves at their source.

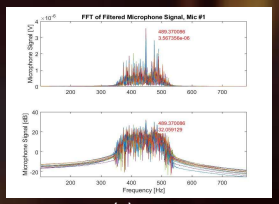
PRELIMINARY MODELLING AND EXPERIMENTAL RESULT:
First ever demonstration of active noise cancelation from co-planner mechanical source using heat-flux transducer resulted in maximum sound pressure amplitude reduction of more than 40 dB, at relative phase angle of 225 degrees for the reference 1.42 cm position. Reduction In maximum sound pressure amplitude was observed over wide range of frequency and measurement locations.





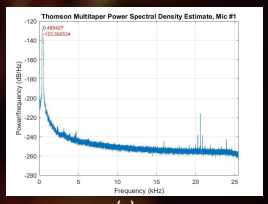
TOP LEFT: Setup for active noise cancellation demonstration
TOP RIGHT: Results obtained from the test setup

(a), (b), (c): Amplitude plot, measurement position and power spectrum density for upstream microphone measurement



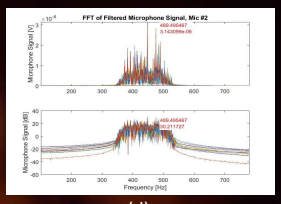
(a)

(b)



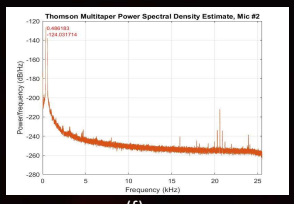
(c)

(d), (e), (f): Amplitude plot, measurement position and power spectrum density for downstream microphone measurement



(d)

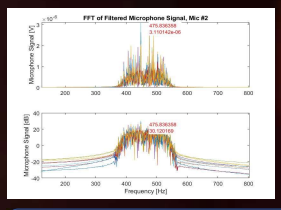
(e)

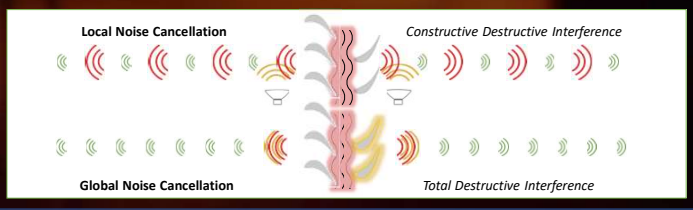


(f)

FUTURE WORK:
- Modeling of phase shift in peak frequency with various changing stator positions and number of stators
- Demonstration of active noise cancellation based noise reduction in lab scale fan setup
- Demonstration of noise cancellation in a dedicated test setup with a 1:1 scale fan
- Design improvement of heat-flux transducers for better efficiency

BOTTOM LEFT: Amplitude plot of microphone signal acquired downstream with one stator (shift in peak frequency is observed)
BOTTOM RIGHT: Schematic of global active noise cancellation for rotor-stator interaction





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REFERENCE:
Julius et al. "Modeling and experimental demonstration of heat flux driven noise cancellation on source boundary." Journal of Sound and Vibration 434 (2018): 442-455