

**Title: Vortex Generator Nozzle and Transient Corona Discharge for Jet Noise Reduction**

Advances in noise reduction of high-bypass coaxial jets typical of modern turbofans have been recently due to the industry adoption of chevron mixer nozzles. These serrated-edge nozzles are applied to the core stream and fan stream, enhancing mixing of the high velocity core jet and lower speed co-annular bypass stream through generation of a counter-rotating pair of streamwise vortices at each chevron. The induced entrainment of the lower momentum bypass flow into the higher momentum core flow reduces effective velocity of the jet [2], which leads to an overall reduction in noise due to the experimentally validated  $V^8$  theoretical sound power law of Lighthill's acoustic analogy [1]. This technique imposes a tradeoff in the noise frequency spectrum, which is an increase in small-scale turbulence in the immediate downstream vicinity of the nozzle exit plane, in turn for a decrease in the shear velocity gradient at the core/fan-stream interface. The result is a variable high-frequency noise penalty dependent on cycle conditions and flow parameters.

New methods are currently being employed, including non-circular nozzle geometries to provide azimuthal noise directionality [5] by interaction with toroidal vortex rings [7]. Also, vortex generators similar to tabs that have been studied in the past, but with a more streamlined design that induces a smaller thrust penalty [3]. A once-prolific design of the mid-70's, the lobed mixer, is also being redeveloped to decrease thrust loss and improve mixing and noise reduction [6]. The potential of the vortex generator to improve the noise reduction of the chevron mixer is a particularly appealing possibility since the technology is expected to scale with boundary layer thickness, not nozzle geometry like the chevron. Unfortunately, these passive technologies lack the benefits of active noise control, which can be toggled to prevent thrust loss and/or power consumption at cruise, and which has potential to more adequately tune to the instability mode resonances and harmonics of the jet. One current active method being developed at UC is Transient Corona Discharge (TCD), and may be combined with vortex generators made of Shape Memory Alloy (SMA) to provide a coupled passive/active and active system.

By employing TCD, the several modes of the shear layer instabilities and columnar jet instabilities, which may be on the order of kHz, the jet may be forced at or near its instability frequencies or harmonics. This is possible due to the very short pulse duration possible with TCD, on the order of 100 ns [8]. By proper integration of the TCD into the nozzle and/or centerbody of the University of Cincinnati Acoustic Test Facility, the ionic velocity induced by the plasma streamers – although the absolute velocity may only be on the order of a few m/s [4] – a pulsatile velocity profile can be created, and the instabilities of the jet altered to potentially reduce far-field emitted noise.

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