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Recently investigated subsonic and supersonic jet noise reduction techniques

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The noise generated by commercial airplanes and high performance military aircraft has been a critical environmental problem for decades. One of the noise sources emitted by the aircraft is jet noise. For an aircraft propelled by jet engines, jet noise radiates while the jet plume is exhausted from the nozzle exit. (Nozzle is the end section of jet engine where air enters into the engine inlet and is exhausted to the ambient from the nozzle.) There are two dominant jet noise source mechanisms, turbulent mixing noise and broadband shock-associated noise. Broadband shock-associated noise is emitted only in off-design supersonic jets where shock cells appear in the jet plume. This research highlight describes the current subsonic and supersonic jet noise reduction techniques supported with promising experimental results from the small scale jet facility at Penn State.

In subsonic jets, turbulent mixing noise is the major jet noise source. By altering the nozzle exit geometry, the turbulent mixing noise could be noticeably reduced. A novel subsonic jet noise reduction device, a zigzag shape ring [1] (patented by Dr. Meyer of DLR in Germany), is proposed to be installed in the end of the inner surface of the nozzle. The zigzag shape ring is designed to disturb the circumference of the jet plume while exhausting from the nozzle exit. Schlieren flow visualizations have shown that a zigzag shape ring is able to induce the streamwise vortices to improve the jet shear layer mixing and amplify the jet spreading angle. This weakens the downstream convecting large turbulent structures resulting in turbulent mixing noise reduction. A parametric study on the geometry of the zigzag shape ring has been conducted to correlate to the corresponding jet noise reduction levels. The optimum geometry of the zigzag shape ring has been experimentally concluded and shown significant noise reduction of around 2 dB in both acoustic near and far fields while comparing to the baseline nozzle. The merit of the zigzag shape ring is the low mechanical complexity, light weight, and easy installation for existing engine nozzles. These make the zigzag shape ring a practical passive flow control device for subsonic jet noise reduction.

In supersonic jets, the jet plume not only contributes to higher noise levels than subsonic jets but also results in the broadband shock-associated noise. By adjusting the jet plume pressure at the nozzle exit, balancing close to the ambient pressure, the shock noise could be reasonably suppressed. An innovative supersonic jet noise reduction technique, nozzle fluidic inserts [2] (patented [3] by Dr. Morris and Dr. McLaughlin of Penn State), has been developed for the active noise reduction control on military low bypass ratio turbofan engines. This technique routes multiple fluidic inserts through the inner divergent surface of a convergent-divergent nozzle. The fluidic injection is designed to deflect the core jet streamlines to result in the jet pressure adjustment at the nozzle exit. The injection flow is able to distort the circumference of the jet plume improving the jet shear layer mixing for significant turbulent mixing noise reduction [4]. By appropriately and individually controlling the operating condition of the fluidic injection, shock noise could be largely reduced.

Substantial noise reductions have been experimentally achieved with up to 6 dB reduction on turbulent mixing noise and around 3 dB reduction on broadband shock-associated noise. For the practical full-scale engine application, the total injection mass flow rate is controlled within 4% of the core mass flow rate and the effective injection pressure ratio is operated around or below the same level as the nozzle pressure ratio of the core flow. This innovative supersonic jet noise reduction technique is an encouraging breakthrough in supersonic transportation research [5]. The development of this technique to full-scale engine application, in collaboration with GE Aviation, is on the way.

References

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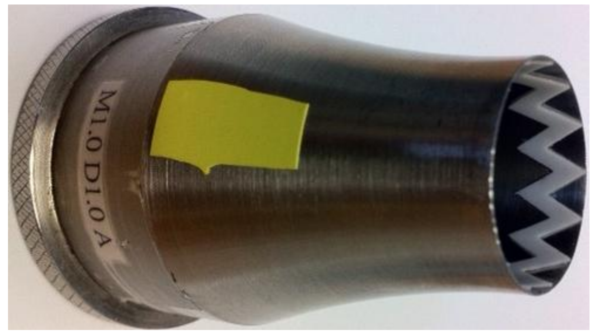
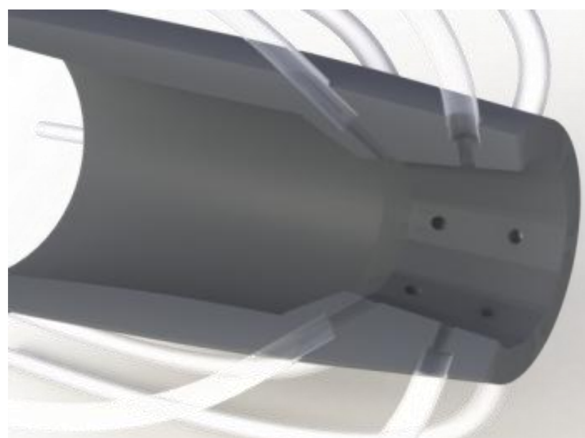


Zigzag shape ring attaching in the end of the inner surface of the nozzle; proprietary to Robert Meyer of DLR in Germany.



Schematic drawing of the nozzle with fluidic inserts; proprietary to Philip J. Morris and Dennis K. McLaughlin [3].