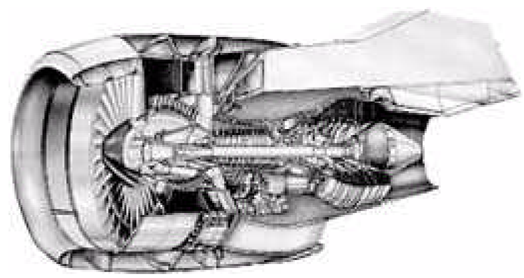
Acoustics and Thrust of Separate Flow Exhaust Nozzles With Mixing Devices Investigated for High Bypass Ratio Engines



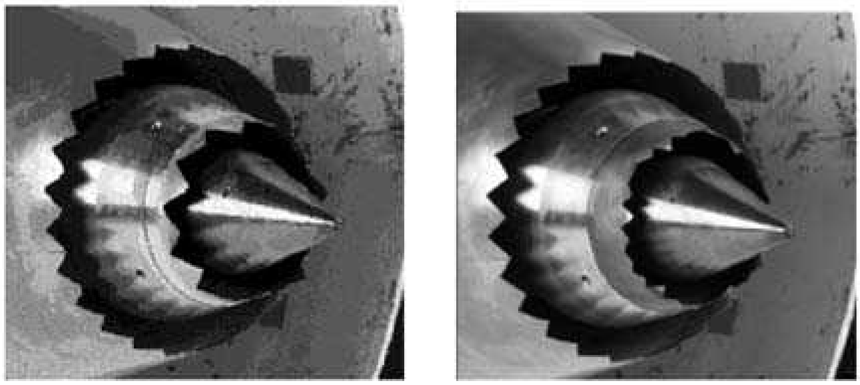
Typical installed separate-flow exhaust nozzle system.

The jet noise from modern turbofan engines is a major contributor to the overall noise from commercial aircraft. Many of these engines use separate nozzles for exhausting core and fan streams. The illustration shows a typical exhaust nozzle system for a bypass ratio of about 5. As a part of NASA's Advanced Subsonic Technology (AST) program, the NASA Glenn Research Center at Lewis Field led an experimental investigation using model-scale nozzles in Glenn's Aero-Acoustic Propulsion Laboratory. The goal of the investigation was to develop technology for reducing the jet noise by 3 EPNdB.[1] Teams of engineers from Glenn, the NASA Langley Research Center, Pratt & Whitney, United Technologies Research Corporation, the Boeing Company, GE Aircraft Engines, Allison Engine Company, and Aero Systems Engineering contributed to the planning and implementation of the test.

New nozzles were designed to reduce the fully expanded jet velocity by mixing (1) core flow with fan flow only, (2) fan flow with ambient flow only, or (3) both flows simultaneously. Depending on the type of mixing attempted, these designs fell into two broad categories: tabs and chevrons. Tabs are severe protrusions into the flow at the nozzle exit plane. Chevrons are also protrusions, but of much less severity than tabs. The aggressive mixing produced by the tabs greatly reduced low-frequency noise, but with the penalty of tab-induced high-frequency noise. Chevrons, which provided a more balanced approach to mixing, reduced low-frequency noise without significant chevron-induced high-frequency noise. Other nozzle designs attempted to shield the core flow by using a scarf fan nozzle and an offset fan nozzle.

A total of 54 exhaust nozzle systems were tested, including various combinations of nozzle designs within each category (tabs and chevrons) for each flow (core and fan). An extensive data base was generated on far-field acoustics, plume Schlieren images, exhaust plume pressures and temperatures, plume infrared signatures, jet noise source locations measured by one- and two-dimensional phased arrays, and thrust performance at a simulated cruise Mach of 0.8.

Several exhaust nozzle systems reduced jet noise by more than 2.5 EPNdB, calculated for a 1500-ft level flyover, without significant thrust loss either at takeoff or at cruise. The following photos show two of the best exhaust nozzle systems.



Left: Chevrons on both nozzles. Right: Chevrons on fan nozzle and tabs on core nozzle.

Because of increasingly stringent restrictions near airports, the noise of an aircraft, much like its range and payload capability, has become a competitive factor. This investigation has generated great interest because of its timeliness and application to current exhaust nozzle systems. We expect the resultant technologies to be incorporated in future turbofan engines.

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[1]Effective perceived noise in decibels.