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Quiet **Quest**

With the standard Leap 1B at idle-power, the noise from the (right) test engine was measured during low flyovers.

> EXPERIMENTAL LOW-DRAG ACOUSTIC LINER FLIGHT-TESTED ON 737 MAX

> ENHANCED HONEYCOMB CORE AND NEW LINER PERFORATION SHAPES TESTED

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As engine and airframe makers wrestle with growing demand for quieter aircraft operations around airports, Boeing and NASA have tested an improved engine-nacelle liner that offers lower noise as well as reduced drag.

Initial results of the tests, completed early in August on Boeing's second 737-7 prototype, are yet to be fully analyzed but already indicate better-than-expected acoustic and aerodynamic performance, say the researchers. The technology could be applicable to current airliners such as the 737 but also may help reduce noise in next-generation short-duct inlet engines that are in the early stages of development for future aircraft such as Boeing's proposed new midmarket airplane.

Shorter ducts are expected to mitigate the higher weight and drag of larger higher-bypass-ratio engines but have relatively less surface area inside the inlet available for sound-absorption treatment. The new low-drag acoustic liner (LDAL) design, which was evaluated on the 737's right (No. 2) CFM Leap 1B engine, could help offset this disadvantage while simultaneously minimizing the inevitable drag impact of the special noise-reducing liners featured on all modern commercial turbofans.

Developed and tested by NASA over the past seven years, the multi-degree-of-freedom (MDOF) liner represents one of several noise-reduction concepts studied under the agency's Advanced Air Transport Technology (AATT) project. Aimed at technology which, compared to a 737-800 with CFM56-7B engines, could reduce cumulative noise margin by up to -52 dB relative to Stage 4 by the mid-2020s, the liner is being evaluated under the AATT Aircraft Noise Reduction subproject.

NASA/BOEING PHOTOS

Silver tape covers wiring to a noise sensor in the inlet (inset) which was configured with the new low-drag slotted face sheet.

Other noise-reduction concepts in this project include designs for quiet slats and flaps as well as rotor and fan acoustic-casing treatments.

"We began exploring two different features for acoustic liners," says Michael Jones, element lead for acoustic liners and propagation at the NASA Langley Research Center. "The first was trying to find a way to . . . make it absorb over a wider range of frequencies. The second was to reduce the amount of drag associated with acoustic liners."

NASA worked with an MDOF liner concept in which the underlying honeycomb incorporates an embedded mesh within the core chambers. "You can do that in various carefully designed ways to alter the position and resistance of these meshes and absorb sound over a wider band of frequencies," says Jones.

Based on a concept developed by composite specialist Hexcel, the configuration was tested in the Liner Technology Facility of Langley's Structural Acoustics Branch. "We used multiple test rigs, but the main one is the grazing flow impedance tube (GFIT), which we used to evaluate the different acoustic properties of the various designs," Jones says. The GFIT has a 50.8 X 63.5-

mm (2 X 2.5-in.) cross-section and can test acoustic liners more than 600 mm long at near-atmospheric conditions up to Mach 0.6. Multiple sound-mounted speakers can be used together to generate a 150-dB single tone.

"The phenolic core is the usual [configuration], but the difference is the embedded mesh," Jones says. "We were able to take advantage of the positioning of the mesh in that core to wherever we wished, and we are also able to change its DC flow resistance," he adds.

DC flow resistance is the ratio of the pressure drop across the sample to the bias flow velocity through the sample and is "the driving parameter that determines how that chamber will behave acoustically," Jones explains.

At the same time, analysis of the relative drag of the various configurations of face sheets in combination with the MDOF core was performed at different airflow speeds and across a full frequency range of 400-3,000 Hz. "That's most of the range we care about," says Jones. Testing of the low-drag configuration, the face sheet of which incorporates elongated slot-shaped perforations arranged perpendicular to the flow instead of the round holes in current designs, was then conducted in various fan rigs at NASA Glenn Research Center.

As the technology readiness level (TRL) of the new liner began to rise, so did Boeing's interest, says Hamilton Fernandez, Aircraft Noise Reduction subproject manager at Langley: "We began working with Boeing three years ago and noticed their interest in acoustic reduction in liners as well as low drag."

After talks with NASA on how to evaluate the new liner, Boeing revived the Quiet Technology Demonstrator (QTD) series first used in 2001 and 2005 to test noise-related advances in propulsion systems. "They suggested doing the test on the 737 MAX testbed, which represented a great collaboration between NASA and Boeing," says Fernandez.

The flight-test campaign amassed 31 hr., around half of which was to accumulate noise data over a phased array of microphones arranged by the end of a runway at Moses Lake, Washington. The 737, which was based at Boeing Field in Seattle, flew to Moses Lake early in the morning on test days to take advantage of still-air conditions.

"The first configuration tested was a baseline production inlet," says Boeing's Belur Shivashankara, senior technical fellow for airplane product development, environment and noise.

After standard-inlet noise measurements were collected, the aircraft returned to Seattle, where the new NASA design was installed in its place on the righthand engine. "The hardwall [of the inlet] was covered with speed tape over the entire acoustic liner to make it ineffective," he says. For the final phase of testing, the tape was removed from the NASA inlet.

The fan containment case also was configured with a hardwall liner "to get a clean comparison of the effects of the inlet treatment, i.e., to try to avoid 'contamination' with other noise sources," Fernandez says. The hardwall fan containment case therefore was used for all three main configurations.

"We flew with the test engine at the power condition required and the other engine at idle so the basic noise level was low compared to the test engine," Shivashankara says. "The acoustic phased array is a collection of over 830 microphones which allow us to pinpoint where the noise comes from. From this, we can create noise maps—like heat maps—which allow us to add up where the noise is coming from and what is the contribution that's being made by the inlet."

Using a production inlet as the basis for the tests "helps us understand the benefit of the NASA MDOF liner for future compact nacelles compared to our production design," Shivashankara says. "With these compact designs, you get less real estate, so we are interested in acoustic liners that could help increase noise reduction per-unit area."

Testing confirmed the slotted face sheet of the LDAL reduced the amount of drag rise by 30% compared to the normal increase associated with production acoustic liners. According to Jones, the flight test also demonstrated the new face-sheet configuration could be fabricated using standard production and safety standards. Acoustic expectations were modest, mostly due to the relatively small area of the LDAL.

"We expected as much as about 0.5-dB narrowband attenuation per frequency over a range of about an octave or so, and we were expecting to get as much as 1 dB of attenuation over the same kind of frequency range for higher RPM conditions in the takeoff regime," Jones says.

"Early results suggest we have exceeded the predictions quite well and are actually looking at perhaps 0.5-1 EPNdB aircraft [level] noise reduction," Jones says, while acknowledging that detailed results have yet to be confirmed. "If that bears out, the result would be quite significant to us and provide great hope." This is also because NASA ultimately hopes to apply the new MDOF concept to the aft bypass duct.

Given the positive results, the LDAL "is a really good example of us trying to push a NASA technology up in the TRL ladder in cooperation with Boeing," says James Heidmann, NASA AATT project manager. "We are always looking for those opportunities, and this fits with the increased emphasis within the NASA Aeronautics Directorate to look for those things that make an impact on the U.S. economy."