Hawker Beechcraft designs quiet turboprops with LMS Virtual.Lab vibro-acoustics tools

Predicting sound levels and evaluating noise-abatement strategies early in development helps reduce cabin noise by half and reduce flight testing 60 percent

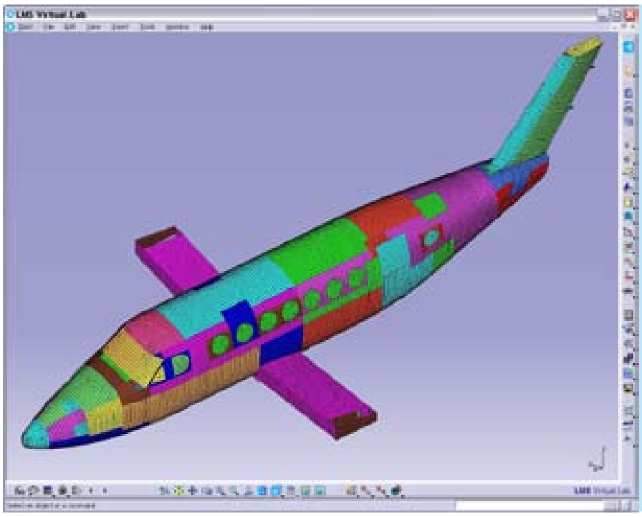
LMS ENGINEERING INNOVATION

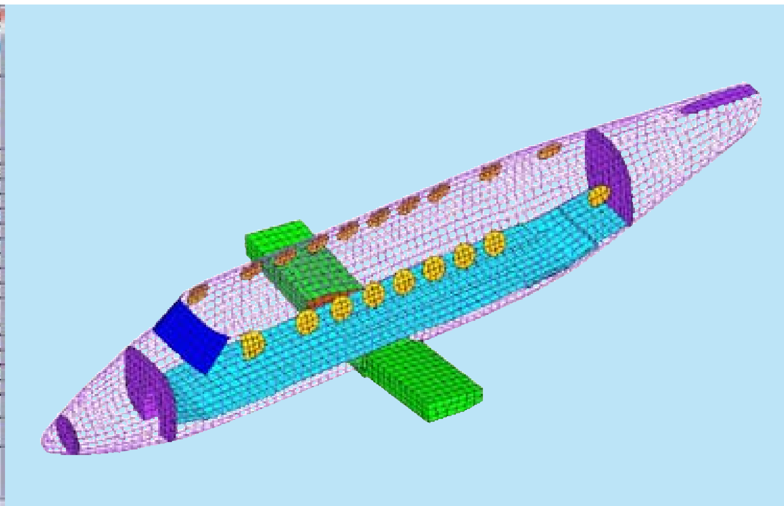
Demand for turboprops is taking off. With lower price tags and 40 percent greater fuel efficiency than jets, gas-turbine-driven propeller planes are enjoying resurgence in the general aviation market. Deliveries have nearly doubled in the past five years. Vying for this growing business segment, planemakers are trying to gain a competitive edge by overcoming one of the major drawbacks of turboprops – propeller noise. In particular, the loudest of these sounds typically is a pulsating, low-frequency "booming" noise inside the cabin produced when airborne pressure waves from the rotating blades impinge on the fuselage and set off vibrations that travel through the aircraft structure and into interior trim panels.
Noises like these often are not detected until flight testing which normally occurs late in the development cycle. With the design essentially frozen, engineers have few alternatives but to add vibration-damping acoustic treatments at various locations on the plane and perform several rounds of flight testing until the noise reaches acceptable levels. This trial-and-error approach is extremely expensive and time-consuming. Each flight test costs tens of thousands of euros and takes weeks to perform. Hawker Beechcraft Corporation found a better way. They lower cabin noise using LMS Virtual.Lab Acoustics technology to predict sound levels and evaluate alternative designs up front in development – instead of waiting for surprises during flight testing. The company is initially implementing the approach in the major interior upgrade of its nine-passenger flagship King Air 350i model driven by twin engines with more than 1,000 horsepower per aircraft. The acoustic technology and processes will then be applied in noise-abatement for the smaller models: the King Air B200GT and C90GTi. The King Air series is the number one turboprop line-up in the world: nearly 7,000 King Airs have been produced since their introduction in the 1960s.

Predicting noise upfront in design

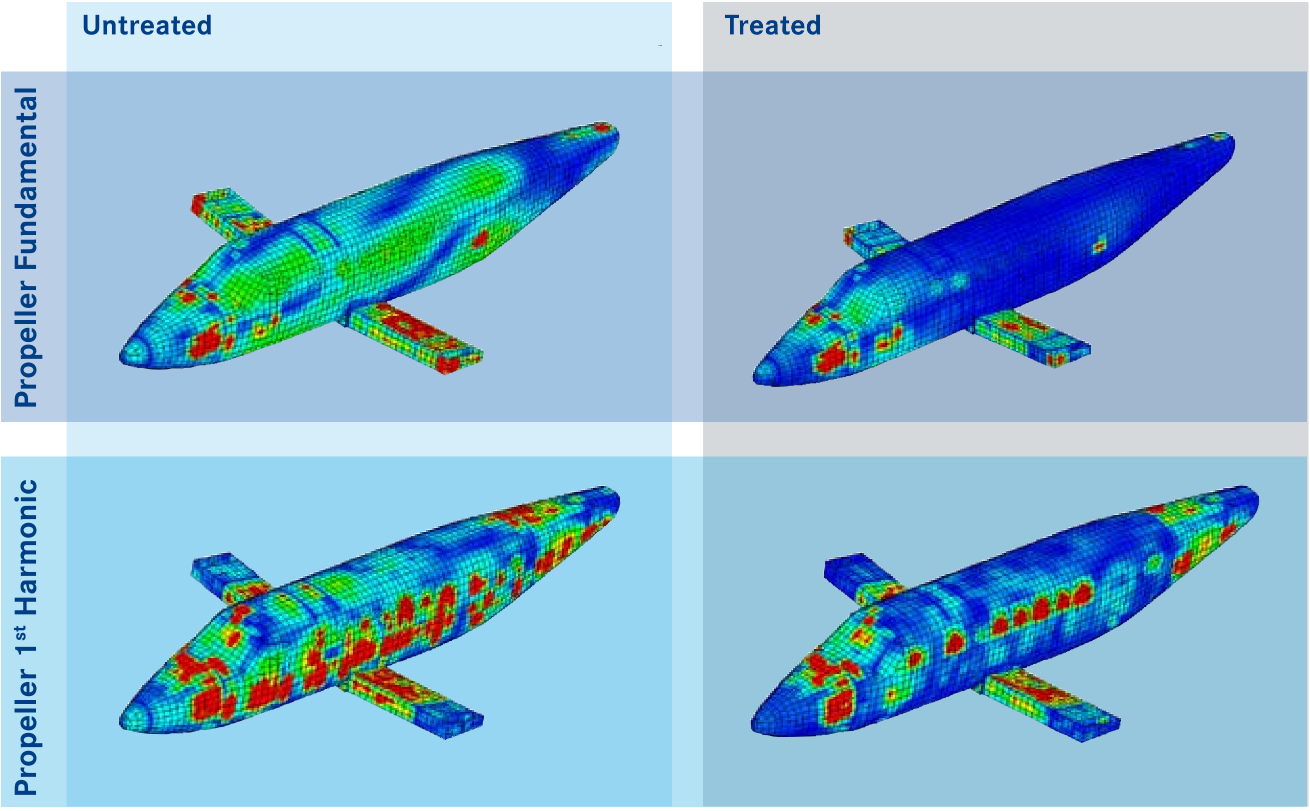
Dr. Indranil Dandaroy, Principal Acoustics Engineer at Hawker Beechcraft, explains that interior cabin noise is determined through simulation in a three-step process. First, the aerodynamic loading on the propeller – essentially the noise emanating directly from the blades – is calculated using a fairly straightforward aircraft industry-standard theory based on the propeller manufacturer's profile data for the specific blade size, span, and rotational speed.

This noise loading data is then entered into the LMS Aero-Acoustics solution, which simulates noise propagation through the air and onto the fuselage as a function of pressure loading versus frequency. The software has fan-modeling capabilities for automatically representing the pulsing action of the rotating blades. And unlike conventional techniques where users must tediously model the air volume, the LMS software is based on the Boundary Element Method (BEM) technology that requires only bounding surfaces of the computational domain to be modeled – in this case, the propeller and fuselage. The approach is not only faster, but also more accurate than conventional methods, since BEM accounts for acoustic radiation of the fuselage into the aircraft interior as well as noise radiating out into the free field. Based on this fuselage pressure loading, the LMS Virtual.Lab Acoustics determines interior cabin noise through a coupled fluid-structural-interaction (FSI) analysis that represents structure-born vibration through the aircraft fuselage and the resulting excitation of the cabin cavity volume. Outputs of this coupled analysis are a vibration contour of the aircraft structure and a sound pressure map showing sound pressure levels throughout the cabin interior.





Acoustic cavity model and fuselage structure model of the King Air 350i used as a basis for predicting cabin noise levels with LMS Virtual.Lab vibro-acoustics software.



Vibro-acoustic contour plots show localized deformation of the fuselage skin as a result of airborne noise from the twin propellers. "Before and after" 3D color contour plots showing fuselage vibration map with noise treatments. Engineers used acoustic simulation tools in accurately determining the effect of various noise-control approaches on interior cabin sound levels.

With vibro-acoustic models of the propeller, fuselage and cabin developed and linked, engineers then can easily explore alternative ways of lowering cabin noise levels. The parametric capabilities of the LMS software facilitates this approach, with engineers readily changing the characteristics of the structural and acoustic models merely by entering the appropriate values for various parameters rather than rebuilding models from scratch. "With vibro-acoustic simulation, trying out different noise-reduction scenarios is extremely fast, often with analysis models changed to explore dozens of alternatives in a few hours versus the weeks required for just a single modification with physical testing," said Dr. Dandaroy.

Tweaking the design for quietness

One of the first areas under investigation with the vibro-acoustic model is the phasing of the twin four-blade propellers. "Sometimes the acoustic pulsations created by two propellers can cancel each other out if the blades are not in alignment – that is, not both straight up at the same time," said Dr. Dandaroy. "Being out of phase by 20 or 30 degrees will often lower noise levels appreciably, but you have to hit just the right angle. Many positions must be investigated to find minimum noise levels, and simulation quickly predicts noise levels for each one."

Next, engineers evaluate the effectiveness of putting passive noise treatment devices at various locations on the aircraft structure to block vibrations. These are mass, spring and damper assemblies – similar to miniature shock absorbers – tuned to absorb vibrations at particular frequencies. Tuned vibration absorbers are attached to the skin or frame, and vibration isolators between the fuselage and interior trim panels. Suppliers provide dynamic representations for these devices, which are entered into the LMS acoustic model. Similarly, engineers model the effect of stand-off constrained layer damping panels, a viscoelastic layer attached to the inside surface of the aircraft skin to aid in damping vibrations.

"Simulation with LMS vibro-acoustics lets us try different noise treatment combinations to find an optimal solution. The goal is to arrive at the overall quietest aircraft design with the least weight and cost. Performing these studies early in development gives us the freedom to explore many alternatives, correct deficiencies up front in the cycle and avoid unexpected problems during flight testing – or even worse – after delivery. The accuracy and detail of these simulation studies gives us greater insight into aircraft acoustic behavior that we could not get from flight testing," explained Dr. Dandaroy.

Hawker Beechcraft is using LMS vibro-acoustics simulation in developing a major interior upgrade of its flagship nine-passenger King Air 350i turboprop aircraft.

Significant paybacks

Acoustic simulation is paying off significantly for Hawker Beechcraft. Dandaroy estimates that once acoustics simulation is fully integrated into the development process, flight testing for validating cabin sound levels will be reduced by up to 60%. The target for the King Air 350i is to lower interior noise by 4 dBA – 25% more reduction than engineers would be able to achieve without simulation.

Acoustics simulation will also be performed using the same noise-abatement approach for the other aircraft models of the King Air series. Plans are also to apply LMS vibro-acoustic technology to air duct acoustics, turbulent boundary layer vibrations transmitted into the cabin and other issues related to interior noise levels to give passengers the quietest flight possible.

“We are transitioning from a completely test-based, trial-and-error method to a faster, more effective upfront simulation-based acoustic approach to noise reduction on many fronts,” stated Dr. Dandaroy. “Cabin quietness is a major customer satisfaction issue in general aviation, and state-of-the-art acoustics simulation will certainly let us to strengthen our leadership position in this competitive market during the coming years.” ■

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