CASE STUDY

Brüel & Kjær
BEYOND MEASURE

DLR REFINES AIRCRAFT CABINS BY ANALYSING NOISE PATHS

DLR is Germany's national research centre for aeronautics and space. Their Experimental Methods department set out to investigate noise transmission and propagation on the Airbus A320 family of aircraft. Brüel & Kjær's multi-field microphone measured the uncertain sound field inside the aircraft cabin, and between the fuselage and the lining.

DLR

CHALLENGE

Investigate noise transmission and propagation on the Airbus A320 family of commercial aircraft, while improving the methodology of flight tests

SOLUTION

Relating external vibration and pressure to interior noise, using multi-field microphones to measure the uncertain sound field inside the aircraft cabin, and in the small areas between the fuselage and lining

RESULTS

- Link established between coherent fluctuations in the turbulent boundary layer and the noise experienced in the cabin
- Improved test methodology

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> *Dr Carsten Spehr, Institute of Aerodynamics and Flow Technology*

BACKGROUND

As Germany’s national space agency, DLR has responsibility for the forward planning and implementation of the German space programme, as well as international representation of Germany’s interests. Approximately 7000 people work for DLR’s 32 institutes, at 16 locations in Germany, as well as offices in Brussels, Paris, Singapore, and Washington D.C.

DLR’s facility at Göttingen employs more than 400 experts in the foundation- and application-oriented field of aviation research.

CHALLENGE

Together with other DLR departments, DLR’s Experimental Methods department undertook the first of three flight tests with Airbus Hamburg in May 2011, to simultaneously measure excitation, transmission, and the noise propagation into the cabin of an A320.

“Airbus asked us what the optimal aircraft noise level is,” explains Dr Carsten Spehr of the Institute of Aerodynamics and Flow Technology. “And of course this is difficult to answer. Other passengers make noise, so it’s actually quite pleasant to have a nice, deep noise that masks the noise of the other passengers. So the research we do here is to find the optimal cabin comfort for planes.”

“The purpose was not to improve existing aircraft, as the A320 is good and sells well – but the next generation will be different. So we needed an understanding of the physics, and how the noise gets into the cabin,” says Dr Spehr.

The intention was also to improve this kind of flight test. Since the 1980s, flight tests have normally used different aircraft at different times and can’t correlate between them, as they don’t have the same database. So here, DLR were trying to improve on this with a new, consistent method.

Challenging measurement ‘rooms’

The main issues for interior acoustics are cooling system noise, fan noise, the turbulent boundary layer, and overall airframe noise. “There are two ways for the acoustic energy to come from outside to inside: either through the shock mounts and the structural coupling, or through the air between the structure and the lining,” says Dr Spehr.

Microphones help to distinguish between these different sources. However, aircraft are difficult ‘rooms’ for acoustic measurements because they are reverberant, long and thin, and give a very different acoustic response depending on the direction and location of the measurement. “For these kinds of tests, we don’t know if the sound-field is diffuse or something else,” says Dr Spehr.

“We also put microphones between the aircraft structure and the lining. And what are the conditions like there? We don’t know, so we use the multi-field microphone,” says Dr Spehr.

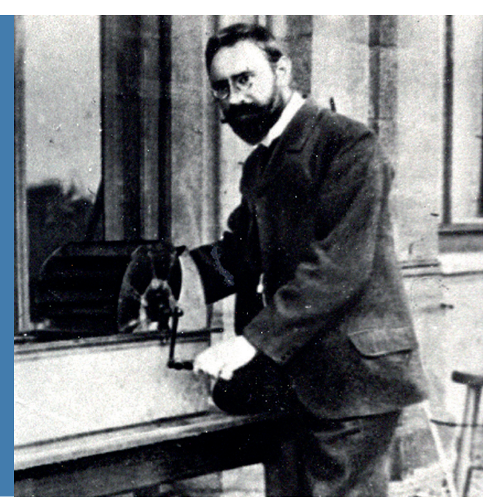
SOLUTION

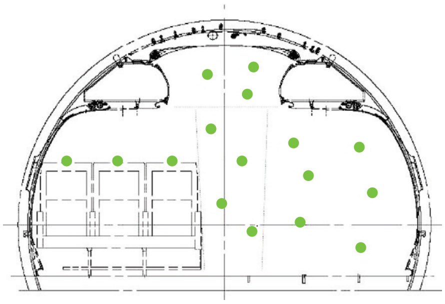
Multi-field microphones were placed along the longitudinal section of the aircraft, facing upwards in the positions taken by the passengers, in an F-frame array that covered a cross-section of the aircraft.

DLR also developed their own arrays of multi-field microphones for closed test sections. “The area is small, so we couldn’t use a normal preamplifier,” says Dr Spehr. ”Because they are smaller than ½”microphones, multi-field microphones are easy to use in such a confined space.”

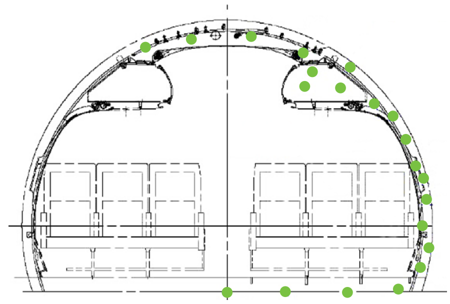
The cradle of aerodynamics

DLR Göttingen is the cradle of modern aerodynamics. In 1907 the first state-run research facility for aeronautics was founded here. Many foundations of modern aviation were researched in Göttingen. Ludwig Prandtl (pictured) developed the aerofoil theory, Hans Pabst von Ohain tested the forerunner of the first jet engine, and the swept wing was invented – a prerequisite for modern aviation. Most of the wind tunnels in the world are based on the Göttingen type.





Distribution of microphones in the cabin



Distribution of multi-field microphones in the cavities between the cabin and the fuselage

Three false windows held the pressure sensors in the airflow, recessed by 0.3 mm

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DLR measured the transfer paths with accelerometers, and the turbulent boundary layer with pressure sensors placed in three dummy windows. "If you measure aerodynamic flow distributions then you want a high spatial resolution, which means you want to have a really small surface. We measured the flow in the turbulent boundary layer with a pressure sensor recessed behind a hole of 0.3 mm. These pressure sensors have a low dynamic range, but you can measure even high pressure, and they are very small," explains Dr Spehr.

In all, the testing used 65 multi-field microphones, 154 accelerometers and 30 pressure sensors.

Multi-field microphone

There were no problems setting up the multi-field microphones. As Dr Spehr says, "They use a standard CCLD input, so you know that there are no problems. Sensitivity is usually an issue, as normally ¼" microphones are not so sensitive, so it was really nice to have small microphones with the same sensitivity as ½" microphones."

"Aircraft are reverberant, and not the same in different directions, where there are different dimensions, but we didn't have to think about that. We knew we would make an error in every direction, so to minimise this error it is best to have an omni-directional microphone that doesn't care about that."

"When doing these kinds of tests, there are also sometimes issues with electromagnetic interference, but with the titanium build, we didn't have any problems at all, even on the inside of an aircraft where there is a 400 Hz electrical field – which is a quite strong – we didn't have to even think about it."

RESULTS

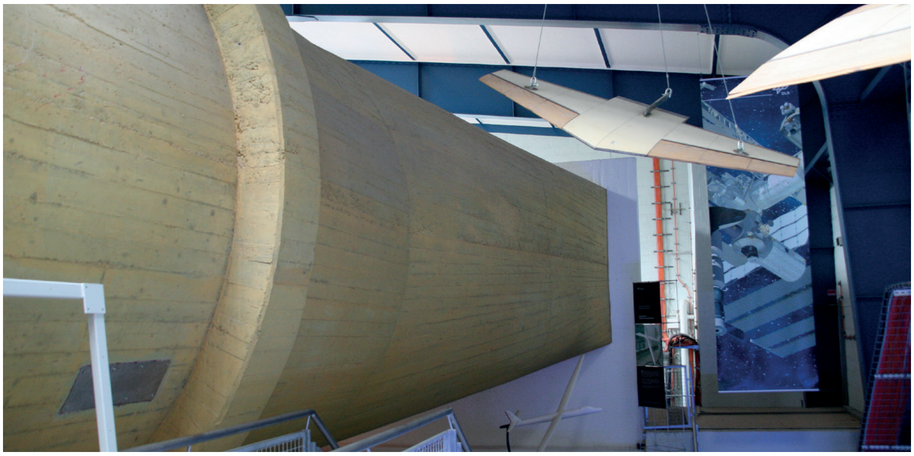
By combining sound measurement results with those from pressure sensors and accelerometers, the tests established the link between coherent fluctuations in the turbulent boundary layer and the noise experienced in the cabin.

Multi-field microphones can accurately measure sound from any direction, and in any type of sound field

Multi-field Microphone benefits

Easy to fit into small areas

- Don't have to think of the angle that the sound is coming from, or the sound field
- No problems with electro-magnetic interference
- Small and lightweight



"We have different types of mikes," says Dr Spehr. "Mostly ¼" mikes from Brüel & Kjær, including a special version designed for measuring in a cryogenic environment (100 Kelvin). This has been used in a great research project. A colleague of mine developed a new measurement technique in that, so it is a great success story."

DLR's wind tunnel is transonic, meaning up to 1.5 Mach, which is fast and loud. They need microphones with a high dynamic range that can operate at 176-180 dB.

In the aerodynamic part of the measurement – the turbulent boundary layer – the coherence in acoustic waves is quite large, which as Dr Spehr explains, is significant. "If you have coherent fluctuations, then they can excite the fuselage, and that can create noise you can really hear."

"At four different speeds at the same flight level in cruise conditions, you would expect 1 mm of aluminium to have the same transmission. However, this is not the case. There is a 3 dB difference with just a 10 percent speed Increase," says Dr Spehr.

CONCLUSION

"If you consider this in the airframe design stage, you can adapt the modal distribution of your fuselage to the turbulent boundary layer and ensure that you don't have this coincidence. So if you know that this is your normal speed, then you can adapt your fuselage and make sure that it is not in coincidence with the hydrodynamic coincidence outside. So the interesting point from this is that even without adding mass or anything else, you can really change the behaviour," explains Dr Spehr.

"It was a nice flight test, and the analysis is still ongoing," says Dr Spehr. "I have had some more requests because it was such a success."

Convincing stakeholders to buy equipment is an issue, so when DLR was procuring their multi-field microphones it was important that stakeholders were convinced of the advantages, and of their high quality. As Dr Spehr says, "It doesn't make sense to have cheap microphones in a flight test that costs millions of Euros, so the multi-field microphones are good value."

The multi-field microphones were an optimal solution for DLR: "The only possible alternative to a multi-field microphone would be to use ½" microphones, where we would then have to consider whether it was a free-field condition or any unknown condition. So it was perfect that at the same time that we made the technical requirements for the flight test, Brüel & Kjær came out with the multi-field microphone, so we didn't have to search long before our answer came along. For cabin noise the multi-field microphone is perfect."

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