Needs for future experimental testing in Aeroacoustics

– DNW Symposium Future Needs - The next 20 years –
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Outline

• Future challenges in aircraft noise
• Needs for future aeroacoustic testing
  • facility wise
  • process-wise: is it necessarily “experiment” vs. “numeric”?
• Conclusions
Noise sources – the classical view on modern tube & wing a/c configurations

Short to medium range aircraft, BPR 10-12, approach

![Bar chart showing engine and airframe noise sources](image-url)
Installation sources – a view on modern tube&wing a/c configurations

Short to medium range aircraft, BPR 10-12, approach

“complete“ source breakdown

good estimate?

Engine/airframe source breakdown: Airbus 2015

Delfs 2016
Classical component noise research – sufficient?

? How does the generation sound at components change when operated under actual a/c installation conditions?

? What is single component noise reduction technology worth if installation is ignored?

? How does the presence of an actual a/c change the radiation of the component sources?

! Component source testing important but insufficient.

! Installation effects (source wise + radiation wise) need to be considered too.

⇒ (best) use very large acoustic facilities to arrange for representative
  * aerodynamic interactions of components (moderate requirement on wt size)
  * acoustic radiation effects (severe requirement on wt size)

⇒ (alternative) think of new ways of using mid size facilities
How about true a/c noise reduction / FP2050 goals?

- a/c noise reduction limited when restricting to low noise component technology at conventional aircraft
- Drastic a/c noise reduction realistic only if aircraft configuration is taken into account: a/c configuration ↔ noise reduction technology

? How do we know whether our guesses (based on preliminary design empirical models) are correct for „cool“ low noise a/c?

⇒ High fidelity simulation of complete a/c (!extreme challenge to HPC!)
⇒ Experimental simulation of complete a/c (!extreme challenge for model technology!)
Testing complete aircraft noise in wt

Test environment for the investigation of Noise and Performance of complete aircraft including new aircraft configurations

Key technologies:

- Acoustic windtunnel of excellent quality and sufficient size ($\geq 3 \text{m}$)
- aeroacoustically similar turbofan simulators (ATS)
- pressurized air for the operation of ATS

Example: Installed CROR in DNW-LLF (aeroacoustically similar CROR!)
Testing on complete aircraft for selected sources in wt

NASA ERA program: low noise N2A HWB aircraft validation test

- NASA LaRC 14x22 tunnel equipped with treatment
- aeroacoustically similar jet noise simulators (hot dual stream), „CJES“
- displacement body instead of nacelle: no fan source

Testing complete aircraft noise on half model in wt

Test environment for the investigation of Noise and Performance of complete aircraft including new aircraft configurations

Key technologies:

- Acoustic windtunnel of excellent quality and sufficient size ($\geq 3$ m)
- Aeroacoustically similar turbofan simulators (ATS)
- Pressurized air for the operation of ATS

Example: aircraft in DNW-NWB
Testing on complete aircraft for generic sources in wt

Acoustic Shielding NATO AVT 233
Testing on complete aircraft for generic sources in wt
Testing on complete aircraft for generic sources in wt

Acoustic Shielding NATO AVT 233
Near field measurement?

- complete a/c models (incl. model turbofans) in acoustic wt / closed section wt:
  ⇒ small scales ⇒ very high frequencies ⇒ inflow mics ⇒ geom. Nearfield
- requires inflow mics with omnidirectional characteristics!

⇒ measure + validate in nearfield, simulate farfield
Future Aeroacoustic Test facility = Kevlar walled tunnels?

! Hybrid wind tunnel concepts: acoustically transparent walls.

⇒ potential to measure in farfield?
⇒ complete Kevlar cage test section?
⇒ why does this exist in US and Asia only?
CAA based acoustic open wt corrections (AWB)

use numerical simulation + HPC to correct for (un)steady WT shear layer effects

Extend range of receiver positions by exploitation of numerical simulation

60 m/s

planar shear flow

AWB shear flow

difference (correction)

f = 10 kHz

Diss. J. Jiao, 2017
Acoustic open wt corrections (AWB) using CAA

use numerical simulation+HPC to correct for (un)steady WT shear layer effects

Include tone corrections from scattering based on numerical simulation

TAU + FRPM+PIANO

Diss. J. Jiao, 2017
Large component acoustic testing in open wt
Large component acoustic testing in open wt – validation

CAA of UHBR dual stream jet combined with 2D high-lift wing incl. AWB

PIANO: FES=„Forced Eddy Simulation“

simulate model + test environment validation on raw data „do the whole thing“

Experiment (AWB)

5dB SPL

Q-Criterion

Microphone CAA 270° rel. to chord axis

3D CAA combined noise

3D CAA combined noise

SPL

Experiment (AWB)

(preliminary)
Large component acoustic testing in closed wt wall array measurements

incident surface pressure

actual surface pressure

Monopole - 1000 Hz
Large component acoustic testing in closed wt

incident surface pressure

8kHz

Fast Multipole BEM (FMCAS)

use numerical simulation+HPC to clean up WT effects

actual surface pressure

8kHz

1kHz

1kHz
Large component acoustic testing in closed wt

incident pressure input

actual wall array pressure input

Fast Multipole BEM (FMCAS)

use numerical simulation+HPC to clean up WT effects
Outlook/ more open questions
Is noise reduction by shielding always „good“?

? is rapid (temporal) change of signal amplitude more relevant for perception than a reduction in SPL?

? For tone components installation creates strong amplitude fluctuations: problem?

! Realistic acoustic installation of tone sources important to assess noise impact

• Tone testing in acoustic wind tunnels extremely high challenge
Summary

• low noise a/c component technology remains important, but insufficient
• Installation effects influence overall aircraft noise significantly - source wise and radiation wise
• exp. validation of low noise impact a/c requires realistic engine (tone) sources
• validation of low noise a/c design: new challenges on exp. and num. side
  • more than one component needs to be considered (large domains)
  • small scale aeroacoustically similar turbofan simulators needed
• relevant farfield only by computation (wt tests to validate codes in nearfield)
• numerical Simulation / HPC may be used to „map test conditions to reality“
Conclusions

• Future progress for low noise a/c only when considering complete a/c

• Need possibility to experimentally simulate complete a/c noise in wt!
  • for realistic installation sources and radiation
  • for validation of new a/c concepts w.r.t noise and performance
  • key elements: Acoustic WT, Acoustic Turbofan Simulator, HPC

• Why don‘t we blend more experimental and numerical techniques?
  • simulate actual measurement situation (aero + acoustics)
  • improve wind tunnel correction with numerics and HPC
  • reduce ad-hoc assumptions in beamforming, by enriching with num. sim.
  • use PIV/STB to determine surface pressures from NS equations;
    use numerical simulation to determine sound field