Latest research on the reduction of aircraft noise at the source

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Outline

- sources of aircraft noise
- low noise technology for current aircraft
- conclusions
sources of aircraft noise
Sources of exterior noise at transport aircraft

➢ **Take-off:**
  - engine noise
    - jet
    - fan tonal (+ broadband)
    - (compressor)

➢ **Approach:**
  - engine noise
    - jet
    - fan broadband (+ tonal)
    - combustion + turbine
  - airframe noise
    - high lift devices
    - landing gears
    - installation related sources
Sources of turbofan engine noise

- **Fan noise**
  - Front
  - Rear

- **Compressor noise**

- **Turbine noise**

- **Combustion noise**

- **Mixing noise**

**Components:**
- Fan
- Compressor
- Turbine
- Jet
- Combustion chamber
Parasitic tones at engines

Nacelle de-icing air outlets
Sources of airframe noise at aircraft

- main landing gears
- flap side edge
- slat horn
- slat
- flap
- nose landing gear

"parasitic sources" (construction details)
Parasitic sources at real a/c airframes

- Tone noise from pin-holes in landing gear pins/bolts (hollow for weight reasons)

- Tone noise from pressure release openings

- Broadband excess noise from slat/flap tracks

- Broadband excess noise from recessed geometries
Landing gear noise

- considerable experimental research during past 15 years in EU and USA
- most important source of airframe noise (at certification point)
- very broadband in character (slow roll-off of spectrum)
- $size^2$ scaling of intensity for similar geometry
- $speed^6$ scaling of intensity (compact source components)
- no pronounced directivity due to complex cluster of compact sources
Typical rank ordering of sources at approach

Source: Airbus

**Short range aircraft**

- **EPNdB**
  - Slats
  - Flaps
  - Landing Gear
  - Airframe
  - Engine
  - Total

**Long range aircraft**

- **EPNdB**
  - Slats
  - Flaps
  - Landing Gear
  - Airframe
  - Engine
  - Total

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Installation sources of exterior noise at aircraft

- Gear cavity / flap interference
- Jet / flap interference
- Wing / fan or prop interaction
- Pylon / jet interference
- Gear wake / flap interference
Jet flap interference (JFI)

Flight speed $U_\infty = 60 \text{ m/s}$
Jet speed $U_{jet} = 185 \text{ m/s}$
(cold single stream jet)

F16 with droop nose

AWB

$64^\circ$  $116^\circ$

$SPL_{1/3}$ [dB]

$10\text{dB}$

$S_r = fL/U_\infty$

Numerical simulation

total

sum jet + flap
(each isolated)

Pott-Pollenske, Dierke, Lufo HIT 2011
Low noise technologies for current aircraft
Engine noise reduction

fan noise
- lined ducts
- splice-less casing
- nacelle lip-liner
- swept rotor leading edge, swept stator
- cut-off design
- increased diameter

jet noise
- increased diameter
- internal mixer and/or vortex generators, serrations

Source: Boeing
Elimination of parasitic tones at wings

Approach noise of a current short/medium range a/c

Helmholtz resonator

SPL [dB]

Cruise configuration $v_{\text{rel}} = 105 \text{ m/s}$

$\Delta f = 14 \text{ Hz}$

Baseline

“Low noise”

Michel, DLR

Helmholtz resonator
Low noise nose landing gear

A340 nose landing gear

retro-fitted
~ 2.6 dB reduction

low noise NLG
~ 6.3 dB reduction
Low noise main landing gear

A340 main landing gear

retro fitted
~ 2.5 dB reduction

low noise
8 dB(A) reduction

W. Dobrzynski et al. 2009
Significance of high lift devices for airframe noise

- But: much more difficult to improve, since aerodynamically highly optimized component

- Significance discovered by DLR (Dobrzynski), 1998

⇒ Noise reduction at landing gear of limited effect for a/c if High Lift Devices unaltered
Low noise slat

- Reference
- Low noise setting: -4…5 dB
- VLCS: -4…5 dB
- Adaptive slat: -3…5 dB

EU OPENAIR
Noise reduction on flap side edges

Smooth, hard side edge

Brush side edge

1.6 kHz

W. Dobrzynski et al. 2001
Source noise reduction at complete aircraft

example of common effect of two sources:

For more silent aircraft, sources of about equal strength have to be reduced alltogether!
Conclusions

• All, engine, airframe, and installation sources important
• considerable progress made in engine low noise technology in the past (most important jet + fan)
• highly effective flyable low noise landing gear technology developed
• high lift system is THE challenge for approach noise
• parasitic sources easily removable
• only partial application of low noise technology will have very limited effect
• next generation transport a/c will be dominated by installation sources
• noise driven a/c architectures? High potential of noise shielding.