Applying Aircraft Noise Reduction Technologies at its Source

Progress in Technological Development

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Motivation & Fundamentals
Motivation

- Decoupling of noise impact from traffic growth

- The balanced approach must include
  - technological advances,
  - operational advances,
  - operating restrictions and
  - better land-use planning around airports

Source: Deutsches Zentrum für Luft- und Raumfahrt
Fundamentals: Sound pressure level SPL or L

- Sound pressure or acoustic pressure is the local pressure deviation from the ambient (average, or equilibrium) atmospheric pressure caused by a sound wave.
- The sound pressure level (SPL) or sound level $L$ is a logarithmic measure of the effective sound pressure of a sound relative to a reference value.

$$L = 10 \cdot \log \frac{p^2}{p_0^2} = 10 \cdot \log \frac{I}{I_0} \quad \text{[dB]}$$

- The reference value is set at the typical threshold of hearing of an average human, with $p_0 = 0.00002 \text{ Pa}$ or $I_0 = 10^{-12} \text{ W/m}^2$.

- Halving of acoustic power (sound intensity) corresponds to a level change of -3 dB only.

- A 10 dB decrease in sound level corresponds approximately to a perceived halving of loudness, but: "challenging"
Aircraft Noise
Aircraft Noise = Airframe Noise + Engine Noise

Airframe noise sources

*Dominating sources:*
- Gear
- High lift devices

Engine noise sources

*Dominating sources:*
- Fan / Compressor
- Exhaust jet
Aircraft Noise = Airframe Noise + Engine Noise

**Airframe noise sources**

**Dominating sources:**
- Gear
- High lift devices

**Engine noise sources**

- On approach, the airframe makes as much noise as the engine.
- On take-off, the engine noise dominates

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- Fuselage
- Spoiler
- Nacelle
- Gear
- Empenage
- High lift devices

- Fan
- Combustion chamber
- Turbine
- Jet
- Compressor
- Airframe
- Engine

**Take-off**

**Approach**
Aircraft Noise = Airframe Noise + Engine Noise

Airframe noise sources

 Dominating sources:
• Gear
• High lift devices

Engine noise sources

 Dominating sources:
• Fan/Compressor

Airframe Noise
Airframe Noise

The airframe part with the highest noise level dominates the overall aircraft airframe noise (w/o engine).

In the right diagram (example calculated) the high-lift devices are deflected and causes the highest noise pressure level over the frequency spectra.
**Academic example:**

All airframe noise sources, except high-lift devices, are **switched off** (right picture). Nevertheless the overall airframe noise is not reduced significantly.

**Consequence:** The noise pressure level of all airframe parts must be reduced equally to reach significant overall airframe noise reductions!
Identification of Noise Sources at Aircraft

- Transfer of wind tunnel based expertise into real flight situation
- Reduction of excess noise from “acoustically detrimental” details
- Examples…

- Vortex generators to eliminate hole tones
- Sealing of slat track cutouts
- Foam filler at flap side edge
Measures for Aircraft Noise Reductions

max. -5 dB through realistic partial fairing
Measures for Aircraft Noise Reductions

-2 dB by fillets in cavities

-5 dB with slat trailing edge modifications

-5 dB by flap side edge modifications

sound intensity $\sim p^2 \sim v_\infty^5$

sound level scales with the fifth power of velocity

3 dB reduction $\Leftrightarrow$ 13% decrease in speed
Measures for Aircraft Noise Reductions

-3 dB far field noise reduction
Aircraft Noise = Airframe Noise + Engine Noise

Airframe noise sources

- Gear
- High lift devices

Engine Noise and Reduction

Engine noise sources

- Fan / Compressor
- Exhaust jet
Engine Noise and Reduction

Cumulative noise level below Stage 4 (ERNdB) in accordance to ICAO-Regulations

"big share"

past (low bypass)  current (high bypass)
Engine Noise and Reduction (jet noise)

1. Core jet
2. Turbulent mixture zone
3. Fully developed turbulent jet

Forced mixing of low and high speed jet:
ø jet velocity reduced!

\[ L_{\text{jet}} \sim v^8 \]

Simple assumption:
Jet sound pressure level scales with the eight power of jet velocity

Halving velocity \( \rightarrow -25 \text{dB} \)

-1 to -4 dB far field noise reduction
Engine Noise and Reduction (fan/compressor noise)

Passive Noise Control for Aero Engines (Liner)
- Perforated upper skin
- Honey comb
- Lower skin
- Pressure fluctuations (sound waves)
- Resonance volume
- Eliminating specific tones
- Air flow
- Perforated wall
- Dissipative compression/expansion

Active Noise Control for Aero Engines
- Sound
- Anti-Sound

-1 to -4 dB far field noise reduction
Operational Measurements
Operational measures for noise reduction

Reducing noise on the ground by around 1-5 dB per flight
Operational measures for noise reduction

Continuous Descent Approach

Increasing the glide slope angle provides further potential of noise reduction

Reducing noise on the ground by around 1-5 dB per flight
Operational measurements of noise reduction

Continuous descent approach with late gear extension (LCDA)
- Thrust = 1844.6 kN
- Speed = 119.4 m/s
- Altitude = 1067.0 m

Segmented continuous descent approach (SCDA)
- Thrust = 4111.8 kN
- Speed = 101.8 m/s
- Altitude = 1178.0 m

Legend:
- - slat 0°-18°
- - slat/flap 15°/22°
- - - gear 0-1
- slat/flap 27°/40°
ground microphones α = 150 (kN·s)/m²

Level of noise reduction depends on CDA-profile
Operational measures for noise reduction

Unconventional Approaches

Transport aircraft on 3D spiraling approach

Altitude = 4500 m
Speed = 82.5 m/s
Thrust = 18551.9 kN

Relocating approach in less noise sensitive areas
Other commonly applied noise management measures include:

- avoiding fly-over sensitive sites such as hospitals, schools, hometowns
- using continuous descent approaches and noise abatement departures
- avoiding use of auxiliary power units by aircraft on-stand
- towing aircraft or electrically driven landing gear instead of using jet engines to taxi
- limiting the number of operations or the extent of a critical noise contour
Future Aircraft Configurations

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Future Aircraft Configurations

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Future Aircraft Configurations (example)

Wing shielding to reduce forward emitted noise

Ejector principle to control jet noise

Long intakes with liners to suppress fan noise
Design advantage: Noticeable noise reduction (engine)
Future Aircraft Configurations (example)

Design disadvantage: Deteriorated fuel efficiency
Conclusion
Conclusion

• **Noise impacts increase** with growing air traffic

• **Balanced approach**: Decoupling of Noise impact from air traffic growth

• **Technical and operational improvements** for noise reductions have to be introduced equally to attain the highest potential of noise reduction

• The **change in current aircraft design philosophies** promises a high potential in future noise reductions