NOISE REDUCTION AT FLAP SIDE EDGE AND UNDERCARRIAGE

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Presentation Outline

1. Flap Side Edge
   - Technology development
   - Progress in AFLoNext

2. Landing Gear
   - Technology Development
   - Progress in AFLoNext

3. Flight Test
   - Conduct
   - Results

4. Conclusions
Objectives

➢ Technical solution of flap modification and low-noise treatment integration
➢ Proof of noise reduction potential of different treatments on A/C level
➢ Material specifications wrt. acoustic attenuation target.

➢ Preliminary producability analysis on material.
➢ Effects of FSE cut-out design on local flow field and implications on material specifications.

➢ Improve understanding of landing gear wake and flap flow interaction regarding interaction noise.
➢ Proof of noise reduction potential of different treatments on A/C level
European Research Projects

- European research projects
- German research project

All with focus on airframe noise and establishing data bases for AFLoNext
1. FLAP SIDE EDGE
Flap Side Edge Noise Studies

First attempts to reduce flap side edge noise by means of porous edge treatments were published by Fink in 1980

Fink M, Bailey D. “Model tests of airframe noise reduction concepts”, 6th Aeroacoustics Conference 04 - 06 June 1980 Hartford, CT, USA

First European highlight: RAIN - Reduction of Airframe and Installation Noise

Flap Side Edge Noise Studies

Noise source maps for the 1600 Hz 1/3-octave band show
\ original flap side edge $\rightarrow$ dominant noise source
\ clean flap side edge $\rightarrow$ significant noise reduction, noise levels compare to those of slat tracks and flap track fairings
\ FSE noise is significantly reduced by the “porous” brush edge

same levels, dynamic 12 dB
Flap Side Edge Noise Studies

Flap side edges (FSE) were identified as relevant noise source at approach and landing
\ mechanism of FSE noise is a mix of
\ sharp edges and corners generating vortices
\ cavities acting as Helmholtz resonators

In AFLoNext:
WTT on PFSE using realistic A320 flap geometry in AWB
\ model and design of very realistic A320 FSE WT model to provide representative reference

Airbus A320 FSE

FSE model (scale approx. 1:1.4)
Wind Tunnel Model

WTT on PFSE using realistic A320 flap geometry in AWB

\second FSE model provided to test low-noise technologies including porous material

\modular model design realised.
\to eliminate single noise sources separately
\to investigate spanwise extension of porous material (limitation given by flap structure).
\to assess noise reduction \textit{wrt.} the flush FSE (elimination of cavities only)

\target is best noise reduction at minimum modification level of A/C flap
Wind Tunnel Test Data

AWB Test Setup

Test configurations

WTI on FSE noise in the Acoustic Windtunnel Braunschweig (AWB)

- Flap side edge noise was localized and quantified for numerous configurations
- Significant noise reduction is already achieved for clean FSE
- Thickness of porous material can be limited to 40 mm
Preparation for Flight Test

Transfer from Lab to Reality
- Parts mounted into flap end rip
- Outer holes of solid parts closed with cover discs
- Design selected to allow mounting and de-mounting of all parts also on flap installed to aircraft

Required documentation for FT preparation
- Complete documentation
- Stress report(s)
- Assessment of
  - System integration
  - Aerodynamic performance
  - Maintenance
  - etc.

Detailed CAD model
Flap Side Edge prepared for installation
Flap Side Edge prepared for flight tests

Grant agreement no. 604013
2. LANDING GEAR
Landing Gear Noise Studies

European highlight on full scale landing gear research
Demonstration of streamlined full landing gear fairings (2-wheels)


Landing Gear Noise Studies

RAIN project: Reduction of Airframe and Installation Noise
Dobrzynski, W., Gehlhar, B., Buchholz, H., Holthusen, H., A340 Main landing gear noise reduction study, RAIN-TR-02.2-03-R3/DLR/1, 2000

Noise reduction potential with solid fairings on a 4-wheel landing gear
Development and Test of Noise Reduction Concepts

Development of landing gear noise reduction concepts to be tested in flight

- Brake cover
- Torque link fairing
- Leg door fairing

AFLoNext 1:11 scale

AFLoNext 1/11
OPENAIR 1/7.5

Overhead Strouhal number, $St = \frac{f m}{D / v}$
Development and Test of Noise Reduction Concepts

Facing constraints to integrate devices on an existing leg which is optimized for other functions
- Brake temperature – evaluation of the impact of covers on brakes
- Available space, clearances and attachments
- Keep design acoustically friendly

Several (> 5) Mock-Up Sessions
Overview of Final Parts Installed on Aircraft

Brake Cover

Torque Link Mesh Fairing

Leg-Door-Cover
3. FLIGHT TEST
Aircraft Configuration and Flight Procedure

Flyover noise source identification and quantification

\ Engine power: flight idle, equivalent to N1 ~ 29%
\ $V_{\text{CAS}}$ 130 and 175 kts
\ Target altitude: 600 ft
\ Lateral deviation ±10°
\ $V_{\text{Wind}}$ < 12 kts
\ 60 t > A/C weight > 54 t
\ No precipitation, no inversion or other anomalous meteorological conditions

\ 31 condenser microphones on 120m x 340m area
\ 250 mics. phased array
\ $50° < \varphi_x < 140°$, $\varphi_y=\pm40°$
\ data acquisition synchronized on basis of GPS time

Grant agreement no. 604013
Data Processing and Analysis

Target: Derive noise source characteristics for a source at rest for comparison to wind tunnel test data

Methodology:

Synchronisation
- acoustic data
- trajectory data
- a/c attitude
- a/c operation

Validity check
- excess noise
- check on trajectories
- specialties

Processing
- De-Doppler
- technical corrections
- Propagation effects and source effects

Acoustic Assessment
- 1:1 comparison of measured data → qualitative assessment
- Energetic subtraction of SPL spectra to isolate sources → quantification of NRT effects
- Analysis of environmental noise, e.g., approach noise
- Certification noise level determination

Acoustic analysis
- SPL spectra
- Interated OASPL ($L_{A,max}$, $L_{AX, SEL}$)
Array data proof noise reduction at the main landing gear

Noise landing gear contributes less to farfield noise
→ Single microphone measured sound pressure level data represent mainly mainly landing gear related noise
Test Results – Landing Gear Farfield Noise

An up to 3 dB noise reduction was achieved by means of the LG fairings.

Porous fairing, 40% open area
Reduce local flow speed $p'^2 \sim u^6$

Solid fairings
deflect flow, protect parts

Gear-wake – Flap interaction
2 to 3 dB

Increase

reduction
Test Results - Flap Side Edge

Farfield noise reduction, especially for rear arc radiation direction

\[
SEL_{korr} = L_{A,max} + \frac{t_{10}}{2} + 12.5 \times \log_{10} \left( \frac{D}{D_{Ref}} \right) - 40.0 \times \log_{10} \left( \frac{V}{V_{Ref}} \right)
\]

Evaluation of the single event noise level shows even an effect for the fish mouth closure

Flaps 3 / 140 kts

2 to 2.5 dB reduction
4. CONCLUSIONS
Summary and Conclusions

Summary
\ Noise reduction concepts to mitigate landing gear and flap side edge noise were matured and flight tested
\ Both concepts showed a significant noise reduction
\ The achieved noise reductions compared well to expectations based on wind tunnel test data and respective predictions.

Conclusions
\ The flight tests showed part of the potential of retrofitting the actual fleet to achieve the noise reductions demanded e.g. by the actual European strategic research agenda Flightpath 2050
\ All tested parts are prototypes with limitations regarding daily operation. Further development is necessary to reach full airworthiness for normal airline operation.
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