DGLR-2006-061

THE AIRFRAME NOISE REDUCTION CHALLENGE – LESSONS LEARNT FROM THE EUROPEAN SILENCER PROJECT -

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Abstract:

With the development of future low noise aircraft engines, airframe noise will represent a major aircraft noise component in the approach phase. Therefore, an extensive research effort in airframe noise reduction was performed in the EC co-financed European project SILENCER ("Significantly Lower Community Exposure to Aircraft Noise"). The work focused on the development of both add-on noise reduction means, and new low noise component designs with respect to both landing gears and high lift devices. Wind tunnel testing of landing gear noise reduction solutions was performed at full scale landing gears, while low noise high lift devices research was performed on complete scale model aircraft. Selected solutions were manufactured and flight tested on an A340 aircraft. For future low noise landing gears a reduction potential of about 5 EPNdB was achieved, while only 0.7 EPNdB could be gained in high lift devices noise through add-on modifications. The corresponding impact on total A340 aircraft noise in full approach configuration was 0.5 EPNdB for low noise landing gear configurations but almost zero for high lift devices low noise add-on modifications. No new low noise high lift component design could be developed towards flight test compliance, because all considered solutions suffered from a degradation in lift performance. Both new low noise landing gear designs and add-on devices caused some increase in aircraft weight and must be subject to a feasibility study prior to a series application.

1. INTRODUCTION

Continuous advances in the development of low-noise high-bypass-ratio engines made airframe noise levels for the aircraft in its approach configuration to be compatible to those of the engines. As a consequence, airframe noise will become ever more important for the reduction of aircraft noise nuisance around airports. Therefore industry, research establishments and academia joined their forces in airframe noise reduction research in the EC co-financed European project SILENCER (*"Significantly Lower Community Exposure to Aircraft Noise"*). In this project different work-packages were dedicated to investigations in engine and airframe noise reduction, the latter focusing on both landing gears and high lift devices, since the overall airframe noise signature is governed by noise contributions from these two airframe components.

In two separate work packages landing gear and high lift devices noise reduction technologies were developed either as add-on solutions or for application in new aircraft designs. The studies focused on the development of noise reduction means for the well known main individual noise sources but were also dedicated to the quantification of potential sources of component interaction noise. Accordingly the respective work packages were organised in the following task structure:

- Development of add-on noise reduction means.
- Development of advanced new low noise landing gears and high lift devices.
- Quantification and reduction of gear-wake/gear and gear-wake/flap interaction noise sources.

This paper summarises the respective major achievements in the different tasks and discusses success and failures in comparison to expectations.

2. APPROACH AND METHODS

Noise reduction studies were based on the knowledge gained within numerous national projects and the earlier EC co-financed research project RAIN (*"Reduction of Airframe and Installation Noise"*). The work was organised to start with CFD studies wherever possible to develop background information on the respective flow fields interacting with airframe components, followed by experimental wind tunnel studies either in DLR's AWB (*"Aeroacoustic Windtunnel Braunschweig"*) or in the DNW-LLF (*"German-Dutch Wind Tunnel – Large Low Speed Facility")* to establish the noise state of the art and noise benefits from component modifications. After all, selected noise reduction devices were developed towards flight compliance, built and subsequently tested on an A340 aircraft for in-flight validation of the predicted noise reduction potential.

3. LANDING GEAR NOISE

Within the EC 4th framework research project RAIN the major noise radiation areas had been identified and protected from the flow through streamlined fairings thus providing a significant noise reduction potential. Wind tunnel testing of such landing gear noise reduction means were performed at full scale in DNW-LLF and thus for realistic component structures and Reynolds numbers. As a consequence these tests provided reliable results showing that landing gear noise could effectively be reduced by about 3 dB through add-on fairings [1 - 5].

3.1. Add-on noise reduction means

However, the fairings' designs were not yet optimised. Further improvements – with respect to noise – were expected even when taking into account airframe installation and flightworthiness constraints to be considered for application on an existing aircraft.

In the SILENCER project, which include A340 main, nose and centre gears, therefore fairing positions and shapes were optimised with respect to noise reduction. CFD tools were used by DLR for aerodynamics analysis and to help optimise the fairing design for minimum noise generation. Hybrid Navier-Stokes grids were generated and the three-dimensional viscous flow field computed employing DLR's unstructured Navier-Stokes Code TAU [6]. The results were analysed with respect to the detection of local flow separation areas and the distribution of local flow velocities (magnitude and direction). The latter information was used to select fairing shapes which do not direct high speed flow onto adjacent gear components. To further minimise the effect of flow displacement by add-on fairings selected areas were perforated thus allowing for a limited amount of air to penetrate through the fairing.

The noise reduction to be expected through such optimised add-on fairings was also estimated by ISVR (*Institute of Sound and Vibration Research*) [7, 8] at component and individual gear level. This noise level information was projected to full flight conditions. Optimised noise reduction fairings were designed and manufactured by MDSA (*Messier-Dowty S.A.*) and Airbus and fully flight tested on an Airbus A340 aircraft by Airbus. FIG. 1 provides front views of the gears with noise reduction fairings.

A340 flyover noise tests were conducted by Airbus, ONERA and DLR with support from MDSA, and the results [9] show good agreement with those obtained from the noise prediction model, when accounting for real aircraft installation effects (FIG. 2). In terms of EPNL the noise reduction potential for all landing gears together is in the order of 2 EPNdB, which however, comes down to 0.4 EPNdB on aircraft level for approach noise certification conditions (assuming current technology noise levels for high lift devices and the engines).

Figure 1 A340 nose and main landing gears with noise reduction add-on fairings for flight test evaluation

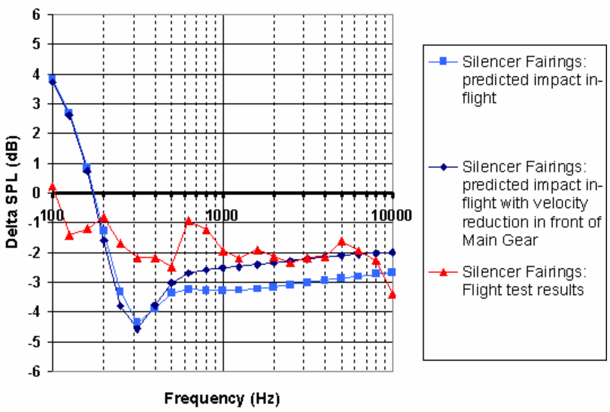


Figure 2 Flight test results on landing gear source noise reduction through add-on fairings

3.2. Low noise advanced landing gear design

The results from extensive wind tunnel noise testing of an A320 landing gear in 1995 proved that a total noise reduction of about 10 dB can in principle be achieved if the entire gear structure can be covered to appear as one streamlined body (see [1]). It is obvious that such a design is not practical in flight due to operational restrictions and locally applied streamlined fairings only provided a limited noise reduction. Therefore a noise reduction concept alternative to add-on treatments was considered.

To maximise the noise reduction potential, an advanced low noise landing gear design should account for aeroacoustics requirements from the beginning. Such a design study was performed in the SILENCER project for both A340 size main and nose landing gears. Specialists from landing gear and aircraft structures, systems, aerodynamics and acoustics (MDSA, Messier-Bugatti, BAE-Systems, Airbus, ISVR and DLR) were involved in the development of advanced landing gears. CFD tools again were used by DLR for aerodynamics analysis in order to support the gear's design. FIGs. 3 and 4 depict the low noise advanced gears' geometry in comparison with the current A340 nose and main landing gear design.

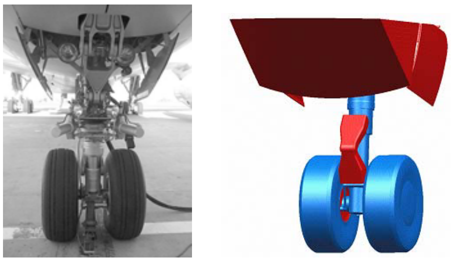


Figure 3 A340 baseline and low noise advanced nose landing gear design

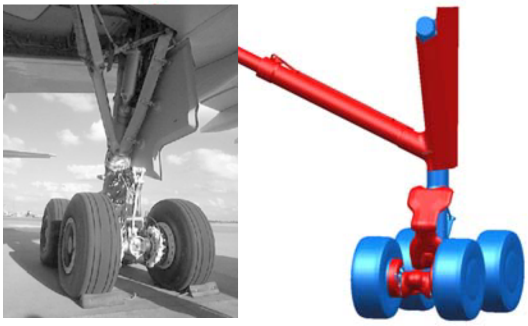


Figure 4 A340 baseline and low noise advanced main landing gear design

Mock-ups of low noise advanced landing gears were manufactured by the industry partners and noise tested in the DNW-LLF by DLR (FIG. 5) to assess the corresponding noise reduction potential [10]. These tests revealed a noise reduction potential of up to 7 dB(A) for the advanced low noise nose landing gear and a reduction potential of about 5 dB(A) for the quietest advanced main landing gear configuration. Again noise estimations were performed by ISVR in order to validate and improve the noise estimation capabilities (FIG. 6).

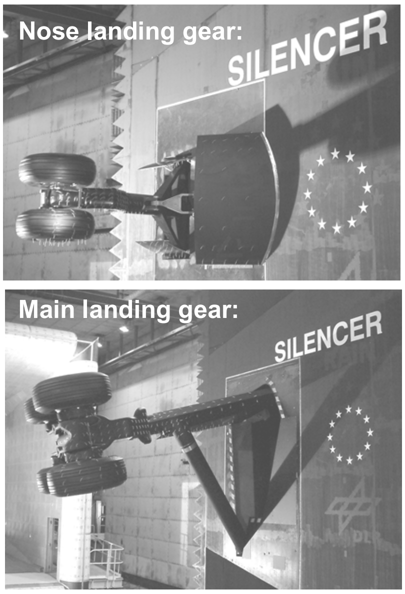


Figure 5 Advanced low noise nose and main landing gear mock-ups installed in the test set-up in DNW-LLF

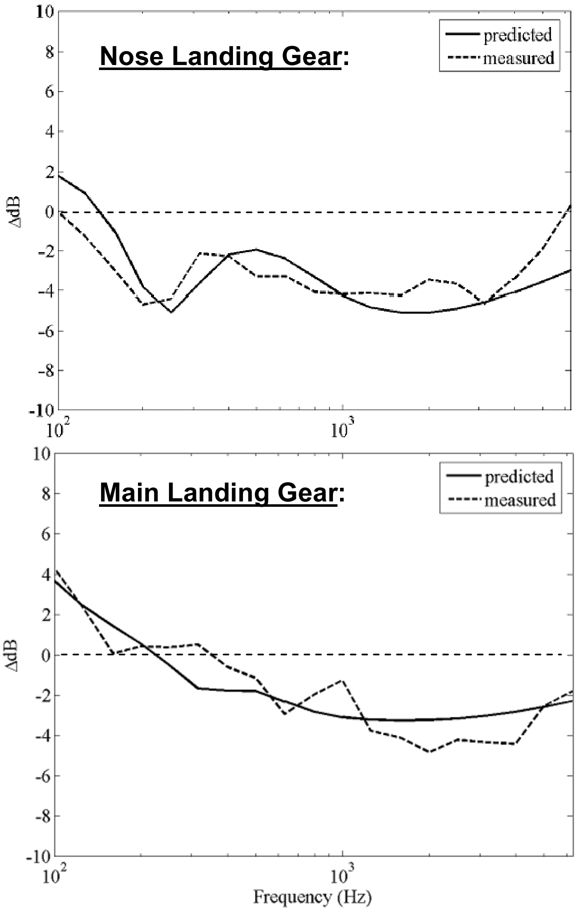


Figure 6 Comparison of measured and predicted noise reduction potential for advanced nose and main landing gears

Since the detailed analysis of noise source localisation results indicated a further noise reduction potential for the main landing gear in particular, a ¼ scaled version of the advanced main landing gear was built and noise tested by means of a microphone array in the ISVR aerodynamic wind tunnel. This scaled gear model was designed to allow for variations of both wheel spacing and bogie length. The results of an extensive study [11] of the effects on noise of different combinations of these parameters revealed that an additional noise reduction could be achieved for a reduced rear wheel spacing when a porous fairing is applied simultaneously between the forward wheels to prevent high speed flow to penetrate into the bogie structure (FIG. 7).

All wind tunnel noise data were projected to full flight conditions by Airbus [12]. For the optimal advanced low noise landing gear configurations a “source” noise reduction potential of 4.1 EPNdB for an A340-300 (for all landing gears together but with centre landing gear retracted) was predicted, which leads to a reduction of total airframe noise levels of 1.6 EPNdB and a total A340 aircraft noise reduction of 0.5 EPNdB (assuming no change in high lift devices and engine noise, respectively). Both new low noise landing gear designs and add-on devices caused some increase in aircraft weight and must be subject to a feasibility study prior to a series application.

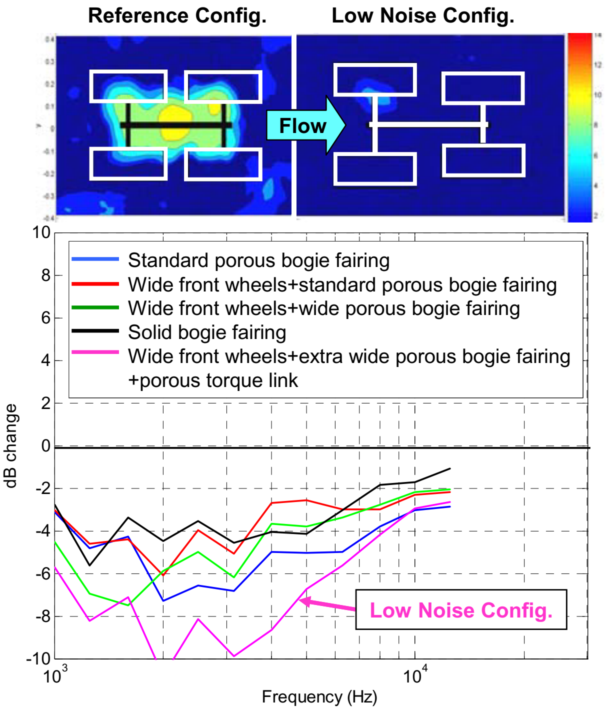


Figure 7 Additional noise reduction over that for the advanced main landing gear through reduced rear axle wheel spacing combined with a front axle fairing

3.3. Gear-wake/gear interaction noise study

For large aircraft it is necessary to employ more landing gears to support the correspondingly high aircraft weight. Some of these gears might have a direct or an almost in-line arrangement under the fuselage. The turbulent wake from the upstream gear will impinge upon the downstream gear and may cause the latter to produce excess aerodynamic noise, in addition to what would have been generated if the flow approaching it had been undisturbed. The interaction noise study comprised (i) gear wake measurements to quantify the steady and unsteady inflow conditions to a downstream located gear and (ii) interaction noise measurements. Interaction noise data then were transposed to full scale flight conditions and were used to extend and validate the noise estimation model as developed in the RAIN project.

To help identify scaling laws, steady and unsteady wake data were acquired on models of different scale. In the larger Airbus Filton wind tunnel an A340 centre landing gear (CLG) was tested at 1/3 scale (FIG. 8) by Airbus and DLR, while the identical design was tested in DLR's AWB at 1/10 scale. From the results of these tests no major Re-number effects were identified.

Figure 8 1/3 scaled A340 centre landing gear in the Airbus Filton low speed wind tunnel

The same set-up was applied in AWB for interaction noise measurements. Interaction noise spectra were found to scale on a Strouhal number basis and levels to increase with flow speed corresponding to a 6th-power law. Significant excess interaction noise only occurs at low frequencies (< 30 Hz at full scale) and thus is almost irrelevant, while a practically relevant noise reduction was observed at higher frequencies [13]. In line gear installation was found to provide maximum noise reduction for higher frequencies and thus would be the preferred arrangement. The reduction of the overall A-weighted noise level for two gears in line, when compared to the self noise of the identical two gears side by side, increases slowly out to a distance of about five wheel diameters where it peaks at a change of about –2.6 dB(A) (FIG. 9). The reason of this unexpected result is that the downstream gear operates in the local flow deficit of the upstream gear wake. This reduction in inflow velocity overcompensates the adverse effect of additional inflow turbulence to the downstream gear.

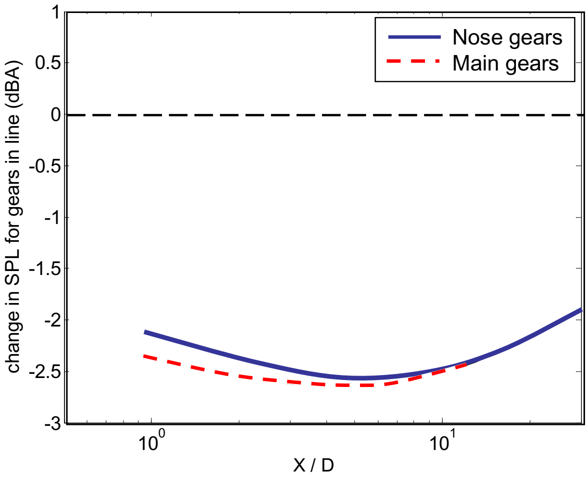


Figure 9 Change in overall A-weighted noise level as function of streamwise separation distance

A dedicated interaction noise model was developed by ISVR and may be applied for noise prediction of different gear wake interaction scenarios, providing inflow turbulence and local flow velocity are known either from experiment or from a turbulence model.

4. HIGH LIFT DEVICES NOISE

In contrast to experimental investigations in landing gear noise reduction no wind tunnel exists, where full scale or large scale high lift devices' noise reduction technologies could be tested under realistic and controlled flow conditions. The latter is of crucial importance since the conservation of the aerodynamic high lift performance is the primary constraint for any low noise modification. Therefore high lift devices noise testing had to be performed on 2D scale models in AWB and on a 1/10.6 scaled complete A340 model in DNW-LLF. Both aerodynamic and noise data were acquired for later assessment of low noise modifications.

4.1. Add-on treatments

From extensive aeroacoustic wind tunnel tests in the RAIN project on a full scale A320 wing section in DNW-LLF [14] numerous sources of excess flow noise were identified, such as

- Fuel tank pressure release openings in the lower wing surface,
- slat tracks,
- cut-outs in the wing leading edge (to accommodate the tracks) and
- flap side edge cavities and related irregular construction details.

Based on this knowledge in SILENCER dedicated add-on noise reduction devices were developed and prototypes manufactured towards flight test compliance.

Tone noise from openings in the lower wing surface:

In the course of previous wind tunnel tests on a full scale A320 wing section the fuel tank pressure release openings in the lower wing surface of an A320 aircraft were identified as sources of high level tone noise caused by flow induced cavity oscillations. EADS-CRC performed a laboratory study to optimise the aeroacoustic decoupling of the various openings in the wing lower surface with respect to the excitation through the external turbulent flow field. It was found that a coarsely perforated cover plate would virtually suppress the tone generation mechanism. Since, however, the blockage effect of such covers were still considered too high further efforts were directed towards solutions which involve vortex generators installed upstream of the overpressure release openings [15].

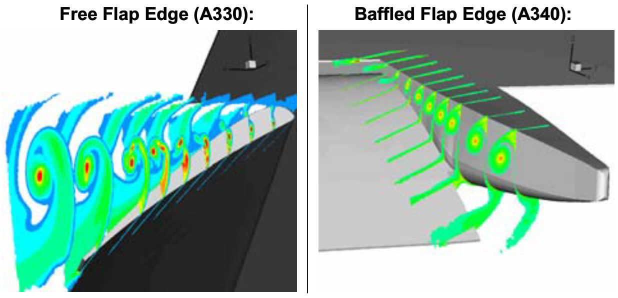
Broadband noise from slat tracks and cut-outs in the wing leading edge:

EADS-CRC also designed and built a combined slat-track/wing-cut-out fairing demonstrator. Driven by the slat actuating system this device folds into the wing leading edge cavity in the retracted position and unfolds to a slat track cover shielding the slat structure and the wing cavity from the inflow when the slats are deployed. FIG. 10 displays a bottom view of this device mounted on a demonstrator.

Figure 10 Low noise slat track/wing-cut-out modification

Broadband excess noise from original aircraft flap side-edges:

At the edges of lifting flaps a double vortex system is generated, which is depicted in FIG. 11 from CFD calculations as performed by NLR [16] for both the A330 free flap side-edge and for the baffled edge configuration of the A340 (the engine pylon acts as an edge fence).



Free Flap Edge (A330):

Baffled Flap Edge (A340):

Figure 11 Calculated flow fields in the vicinity of a free and a baffled flap side-edge, respectively

Flap side-edge noise is generated by the interaction of this vortical flow with the flap surfaces. However, real aircraft flap side-edge shapes are not that smooth as is shown in FIG. 11 for the A330. In fact the edge design is severely jagged through construction details and the side-edge surface features cavities which were found to give rise to significant excess aerodynamic noise (see [14]).

Since in the RAIN project flow transparent flap side-edge fillers or edge replacements made from aluminium foam or brush type edge devices were found to be highly effective in flap side-edge noise reduction, Dornier designed an A340 flap side-edge filler as add-on solution (FIG. 12).

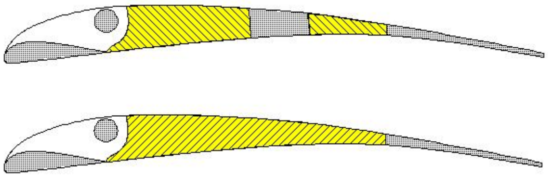


Figure 12 Metal foam flap side-edge cavity fillers for different A340 edge designs

It turned out that brush devices show a significant higher sound absorption than the aluminium foam. For practical reasons, however, aluminium foam was selected as the more appropriate material for real aircraft applications.

For the final in-flight noise test of add-on devices side-edge fillers were installed on the A340 aircraft but the slat-track/wing-cut-outs were simply sealed by means of high speed tape. This latter solution was considered sufficient to validate the corresponding noise reduction potential and thus avoid the effort to manufacture slat track fairings in flight compliance quality. The results of the flight test campaign (see [9]) are presented in FIG. 13. Accordingly a broadband noise reduction of up to 0.9 dB was achieved. This corresponds to a reduction of about 0.7 EPNdB in flyover noise level for high lift wing airframe noise only and comes down to almost zero on aircraft level for approach noise certification conditions (assuming current technology noise levels for landing gears and the engines).

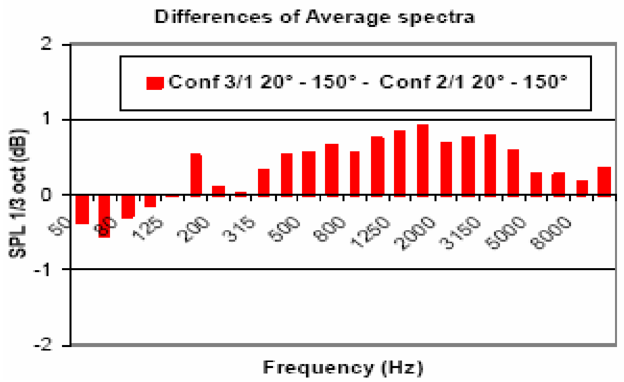


Figure 13 Noise reduction potential of add-on high lift devices modifications from flyover noise measurements (positive values correspond to a noise reduction)

4.2. New low noise devices for future aircraft

The objective of this task was to optimise and validate advanced low noise designs of high lift devices under aeroacoustic, aerodynamic, safety, systems, structural and performance aspects. This work was based on the knowledge gained from the results of different wind tunnel tests. In the RAIN project these were tests on a

- 1/11 scaled A320 aircraft model in the CEPRA 19 wind tunnel [17] (also in a French national programme),
- Full scale A320 wing section in DNW-LLF (see [14]).

In German national programmes tests were conducted on the

- 2D generic 1/6 scaled high lift model in AWB,
- 1/10 scaled ALVAST model of DLR in the AWB,
- 1/7.5 scaled A320 model in the DNW-LLF [18, 19].

These early experiments showed that almost all significant noise sources are located in the leading edge part of the wing, including the slotted slats and their tracks. For high angles-of-attack the slat horn represents an additional intense source of noise and free flap side-edges are major noise contributors for fully deflected flaps.

In order to support the design of noise reduction modifications of current high lift devices, ONERA [20] performed CFD calculations to characterise the flow field around slats (FIG. 14). Similar calculations were performed by NLR for flap side edge flows (see FIG. 11).

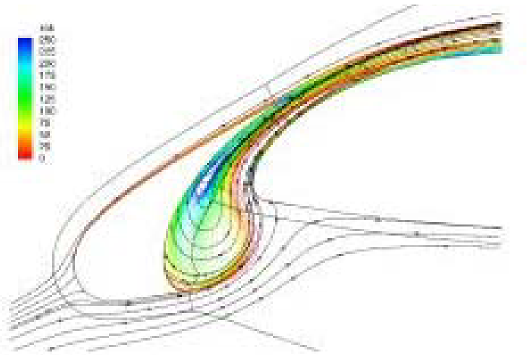


Figure 14 Distribution of turbulence kinetic energy and streamlines in the slat cove region

Based on the findings from the above mentioned projects the following low noise modifications were selected for further investigation in SILENCER (FIG. 15):

- Flow permeable slat trailing edge replacements (brush devices)
- Slat trailing edge serrations
- Slat cove liners
- Flow permeable slat horn replacements
- Application of seals to close the gaps between engine pylons and slat side-edges.

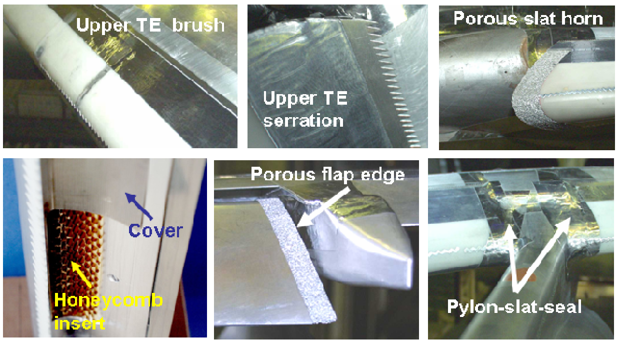


Figure 15 Tested new low noise high lift devices modifications

The calculated slat flow characteristics were used to determine the expected optimal length of slat trailing edge brushes. Trailing edge serrations were designed according to the results from noise tests on wind turbine blades conducted by NLR [21]. The design of absorptive slat cove treatment (liners) was based on experimentally obtained evidence by ISVR [22] with respect to a related slat noise reduction potential. The rationale to apply flow permeable slat horn replacements was based on the experience (in RAIN) that such devices are effective in the reduction of edge noise from lifting surfaces. Since the A340 flap side-edge is shielded by the engine pylon no meaningful noise reduction was expected by the application of similar devices at the flap edges of this aircraft. However, such devices were prepared for testing on an A330 like configuration, i.e. without the outer engines installed.

In this task three test campaigns were conducted in the DNW-LLF, the first two campaigns employing the 1/10.6

scaled complete A340 model and the third campaign employing the 1/7.5 scaled complete A320 model. The first and the third campaigns were performed in the open 8 m by 6 m test section for the aeroacoustic optimisation of selected noise reduction modifications and the second campaign in the closed 8 m by 6 m test section for the verification of the corresponding aerodynamic performance, necessary to achieve the clearance for flight tests. In all test campaigns both noise (farfield and/or microphone array source localisation) and aerodynamic performance (forces and moments) data were acquired.

From the wind tunnel test results it turned out that the noise from the model slat tracks (which featured a vastly different design compared to the original full-scale tracks) tends to mask the noise from the slats themselves. An additional CFD study was performed by DLR and proved that the respective flow fields in the vicinity of the model tracks and the original tracks are quite different [23]. Therefore, improvised slat track fairings were applied during the test conduct, which reduced the noise originating from the slat region by about 2 dB (FIG. 16). Later in the project more realistic tracks were manufactured and in addition treated with fairings.

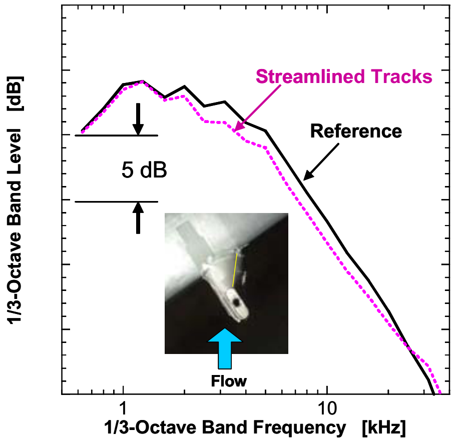


Figure 16 Farfield noise reduction potential of the complete A340 model in landing configuration through streamlined slat tracks

For this improved test condition several slat noise reduction concepts were tested, including soft and stiff slat trailing edge brushes and serrations and different slat cove liners (the latter tested on the A320 model). From the analysis of noise source distributions as acquired through the microphone array by NLR, a small noise reduction could only be demonstrated for the upper soft long brushes (FIG. 17). Local noise reductions were also observed for porous or brush-type slat horn replacements and sealed outboard engine slat/pylon junctions. Slat cove liners did not provide a meaningful noise reduction.

For a combination of the noise-wise optimal high lift devices' modifications, i.e. flexible brushes at the slat trailing edges, slat horn brushes, and a brush "seal" at the outer slat/pylon junction, an overall high lift devices noise reduction in the order of 2 dB was achieved.

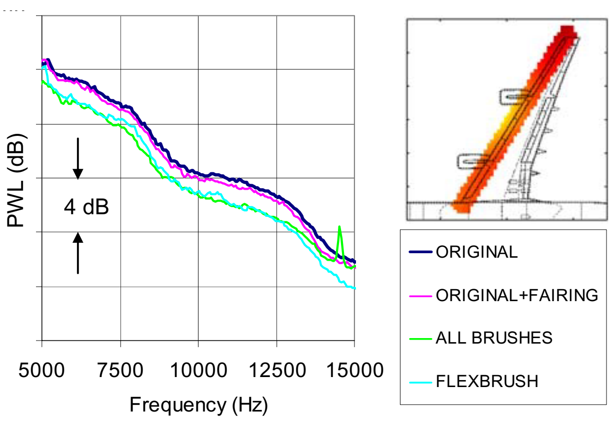


Figure 17 Effect on noise of different slat modifications on slat noise spectra (from integration of array data over the complete slat area)

As expected, flap side-edge farfield noise was found to be not important for the A340 configuration, due to the presence of the outer engine pylons. As a result, a significant noise reduction could only be shown for a porous flap edge, when applied to the A330 aircraft configuration, i.e. for a free side-edge configuration. It is interesting to note that this noise reduction is most pronounced in lateral (azimuthal angle ψ > 0°) direction (FIG. 18).

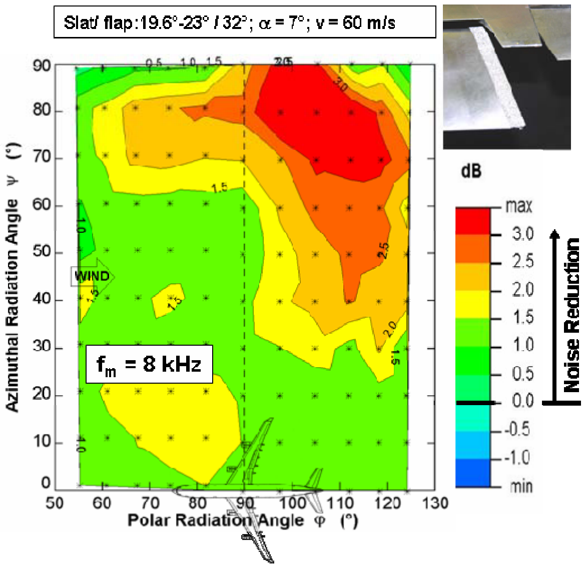


Figure 18 Effect on farfield high lift devices noise level directivity of porous flap side-edge replacements applied to the A330 model configuration (φ = 0° in "flight" direction; ψ = 0° under flight path)

Parallel to the analysis of noise test data finally all aerodynamic test data for the different low noise wing leading edge configurations were evaluated. Unfortunately, it turned out that all noise reduction devices, which provided some noise benefits caused a degradation in high lift performance. This is in particular true for the maximum lift coefficient, which in turn defines the minimum approach speed of an aircraft. There is only one exception: The porous flap side-edge treatment provided a noise reduction (in the free edge configuration) without aerodynamic penalties. However, the corresponding noise benefit could only be demonstrated on an aircraft, which features a free flap side-edge.

As a consequence, none of the solutions tested in the wind tunnel could be proposed for full-scale flight testing at the A340 aircraft.

4.3. Gear-wake/flap interaction noise

An experimental study was performed into gear-wake/ flap interaction noise. Acoustic wind tunnel tests were carried out by NLR and DLR on a 1/13 scaled 2D wing section including a generic main landing gear [24]. The purpose of these measurements was to quantify interaction noise levels and to determine the relevant source noise parameters. In addition, potential noise reduction concepts were tested. An out-of-flow microphone array was used to localise and quantify different noise sources, whereas the directivity of the noise was measured with farfield microphones. The turbulent wake characteristics were determined by means of unsteady pressure transducers on the flap surface.

The test results indicated the presence of interaction noise originating from the flap leading edge for the standard landing configuration (FIG. 19). Interaction noise is most pronounced at low frequencies, where it dominates the noise from the landing gear itself. The gear rather than the cavity was identified as the most important contributor to the turbulent wake impinging on the flap. Among different noise reduction modifications, such as a foam cover around the flap leading edge, brushes attached to the main wing trailing edges, and honeycomb or porous metal liners flush-mounted in the flap leading edge, the latter represented the most practical and effective means (FIG. 20) providing a broadband airframe noise reduction in the order of 2 dB. The foam cover solution in fact provided much more noise reduction (see FIG. 20) but is suspected to significantly deteriorate the flow through the flap gap and thus the systems aerodynamic performance.

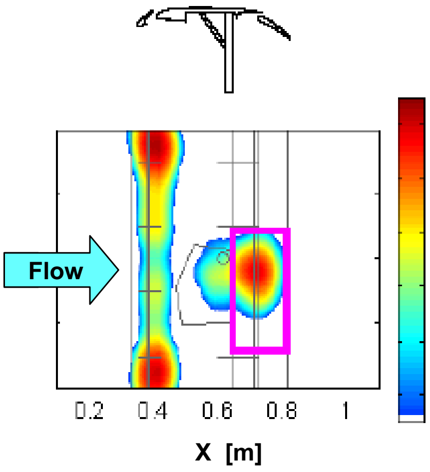


Figure 19 Noise source distribution (red corresponds to high levels) indicating the location of gear-wake/flap interaction effects (additional slat noise sources are due to edge horse shoe vortices)

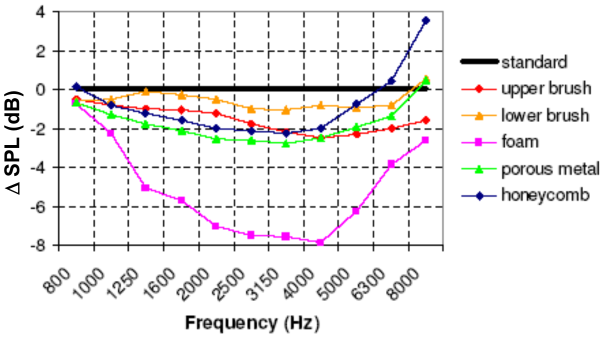


Figure 20 Potential of different measures for interaction noise reduction

5. CONCLUSION

This paper provides a brief description of the research activities related to landing gear and high lift devices airframe noise reduction in the European research programme SILENCER. The related work packages in this project included the development of low noise add-on treatments and low noise advanced components' design as well as the quantification of aerodynamic interaction noise effects.

Noise reduction add-on treatments were designed, manufactured and flight tested using an Airbus A340 aircraft. Low noise advanced landing gears were developed, full scale mock-ups manufactured and noise tested in the DNW-LLF, while low noise new high lift devices were tested at different complete scale model aircraft in DNW-LLF. All investigations in aerodynamic interaction noise phenomena were tested on scale model components in different research wind tunnel facilities.

From the results obtained in these different studies the following conclusion can be drawn:

- Landing gear noise could be reduced by 3 EPNdB through the application of add-on fairings and by up to 5 EPNdB for future advanced gear designs when accounting for aeroacoustic constraints already in the design process. The impact on total A340 aircraft noise in full approach configuration was 0.5 EPNdB. For such advanced landing gears low frequency noise levels will dominate. Although this will not be relevant for noise certification, predominant low frequency noise impact may affect the subjective perception of aircraft noise. Since the atmospheric absorption is not effective at low frequencies innovative flow control technologies might be considered in order to reduce unsteady large scale flow separation from the gear body, responsible for low frequency noise components.

- High lift devices noise reduction was limited to 0.7 EPNdB for add-on devices applied to the A340 test aircraft. The impact on total A340 aircraft noise in full approach configuration was almost zero. All developed new low noise modifications could not be flight tested. While porous flap side-edge replacements proved to be effective noise reduction means for application at free flap edges, no relevant noise reduction potential can be expected from an application of porous edges at the baffled flap side-edges of the A340 test aircraft.

> All tested slat noise reduction devices did not provide the expected noise benefit in 3D (while 2D experiments had shown a reduction potential) and often showed a significant degradation in maximum lift performance. This would enforce an increase in approach speed and thus compensate (or even overcompensate) for small source noise benefits.

Both new low noise landing gear designs and add-on devices caused some increase in aircraft weight and must be subject to a feasibility study prior to a series application.

There are different reasons for the limited success in SILENCER with respect to high lift devices' noise reduction. This is (i) the extremely complex geometry and the associated aerodynamics of high lift configurations, (ii) the technical challenges in implementing low noise modifications at model scale in 3D with the required geometrical accuracy and (iii) the lack of reliable scaling laws at the current stage of knowledge with regard to the major noise generation mechanisms. Larger models with sweep are needed for more realistic experimental conditions to overcome some of these problems.

To cope with the noise reduction goal of 10 dB per operation, as outlined in the „Vision 2020“ and similarly in the NASA QAT programme, much effort must still be spent beyond SILENCER to reduce noise from landing gears and high lift devices towards a level during approach which is expected for future advanced low noise UHBR engines. From this 10 dB noise reduction target 3 dB are considered to be gained from low noise abatement procedures leaving 7 dB to be achieved through source noise reduction. However, this share in reduction potential is optimistic since current investigations in low noise *Continuous Descent Approach* (CDA) procedures show that there is only little benefit at distances less than 5 nm from threshold (to be gained from steep approaches due to increased altitude). Therefore, the primary focus must be on source noise reduction. Although quite a significant step forward in landing gear noise reduction was achieved there is still some way to go. In particular, further efforts are needed to balance the achievements in noise reduction obtained for landing gears and high lift devices so far.

A next step must involve new aircraft configurations with rear fuselage or upper wing mounted engines. This would allow for smaller and consequently quieter landing gears (at the same time utilising shielding effects to reduce engine noise). In addition a further optimisation of noise reduction technologies is necessary and already planned in the new EC co-financed Project TIMPAN ("Technology to Improve Airframe Noise"). Such efforts will involve the investigation of flow control technologies, which are of major importance for low noise high lift devices' designs in particular in order to maintain the maximum lift coefficient for less complex and favourably slot-less high lift configurations.

In fact a best possible low noise high-lift devices design must not only preserve the aerodynamic performance of the baseline reference design, but should yield an increase in maximum lift to allow for a reduction in approach speed which in turn would lead to a significant reduction in airframe noise (relevant for both landing gear and high lift devices noise). At the same time low noise airbrakes are needed as a prerequisite to realize steep descent profiles in that phase of the approach where the landing gears (as major producers of aerodynamic drag) are still retracted.

6. ACKNOWLEDGEMENT

Research for airframe noise reduction as was performed in the EC co-financed "Integrated Platform" project SILENCER made profit from the close co-operation of the specialists in aeroacoustics, aerodynamics, aircraft component and –systems' design from different European partner companies. These were Airbus, BAE-Systems, Dornier, EADS-CRC, ISVR, MDSA, MB, DLR, NLR, ONERA and Sonaca. The contributions from the respective co-workers towards a low noise airframe design are highly acknowledged. Also the support provided by the DNW team within numerous test entries is appreciated.

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