FLOCON Report Summary

Project reference: 213411
Funded under: FP7-TRANSPORT
Country: Germany

Final Report Summary - FLOCON (Adaptive and Passive Flow Control for Fan Broadband Noise Reduction)

Project context and objectives:

FLOCON will demonstrate methods capable of reducing fan broadband noise from aeroengines at source by 5 dB at approach and takeoff conditions, contributing to the European objective of reducing aircraft external noise per operation by 10 dB by 2020. To achieve this, FLOCON will design noise reduction concepts and associated devices able to reduce fan broadband noise from aero engines, assess the noise reduction concepts by conducting lab-scale experiments (to TRL 4), complement the experiments by numerical simulations that are assessing the capability of currently available numerical tools to design low broadband noise treatments and configurations, develop understanding of the mechanisms involved and extrapolate the results to the aero engine environment using state-of-the-art numerical methods, and select the best concepts by balancing noise benefit and integration impact. The impact of scaling from lab- to engine-relevant operating conditions will be assessed, as well as the side / complementary effect of broadband noise reduction features on fan tone noise. Generally speaking, FLOCON will increase the understanding of the flow physics and broadband noise generation and control mechanisms.

Project results:

Publishable summary (status after 48 months)

Objectives

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Achievements after 48 months

In work package (WP) 1, the processing and analysis of hot wire measurements of a fan rotor wake taken in a representative fan stage was performed. DLR has measured the unsteady flow field downstream of the fan of an innovative high bypass ratio fan-module using hot-wire anemometry. The initial measurements were performed inside Europe's largest acoustic chamber, at the fan test bed of the company ANECOM in Wildau under the VITAL program. Additional hot-wire measurements were later conducted together with the partner Rolls-Royce on the same fan test bed to cover a wider range of fan speeds. The hot-wire probes were placed upstream and downstream of the rotor.

The assessment of the numerical and experimental results of the whole project was performed by SN supported by the project management team. It consisted in providing an accurate analysis of the industrial viability of all investigated technologies, associated with a prediction of their noise reduction potential for aircraft / power plant applications. Not only acoustic performance was taken account, other parameters are considered, e.g. the additional weight due to the technology or the impact on the fuel burn. These quantitative parameters were separated from the qualitative ones as the reparability, the feasibility and the interest for other fields of application. The parameters are evaluated using a scale of 1 to 5 from very bad (1) to very good (5). Eleven broadband noise reduction technologies were designed, built and tested in FLOCON and, finally, their noise impact was assessed by means of a virtual aircraft platform, which was applied before for the final assessment of the EU projects SILENCE and VITAL.

In WP 2, the leading edge and trailing edge tests in the ISVR test facility have been completed. The most effective leading edge (LE) treatment for reducing interaction noise has been identified: the ONERA wing design with a wavy LE structure. Respectively, the most effective trailing edge (TE) treatment, the ISVR serrated TE configuration, has been identified. The ONERA design was chosen as stator design for the EADS fan rig, whereas cascade tests with the ISVR TE design have been performed and completed at ECL. Similar noise reductions have been obtained using trailing edge serrations as when used on a single airfoil.

The tandem test using a combination of two single airfoils, i.e. the identified best TE concept from ISVR with the best LE concept from ONERA, has been completed. It is shown that there is added benefit for noise reductions in combining trailing edge serrations for reducing wake turbulence and leading edge serration for reducing the leading edge response.

In WP 3, the designs of the EADS tuneable overtip as well as the SN/FLUOREM casing acoustic treatment have been completed and together with the adaptive spliceless fan casing liner - were manufactured and tested. The vane hardware was equipped with the ONERA leading edge and a GKN designed trailing edge treatment. Both vane modifications were successfully tested. Far-field as well as in-duct noise measurements by EADS were provided for the final assessment.

In WP 4, three concepts for fan broadband noise reduction were developed and tested. All experimental investigations were supported by numerical calculations to prove the theoretical concept design and efficiency.

Based on numerical results, the design of the in-rotor flow channels were done by MTU and USI. New rotor blades were manufactured by USI and provided for tests in the DLR laboratory.

Three concepts for fan broadband noise reduction (the adaptation of vane loading, the circumferential suction of the rotor boundary layer, and the rotor trailing edge blowing) were installed and experimentally investigated by DLR and NLR. The most successful technology in this work package was the rotor boundary layer suction device, leading to reasonably good overall broadband noise reductions up to 2 dB. Tones could be reduced by the same amount of dB. Moreover, a positive impact on the aerodynamic performance was found.

The installation of miniflaps to aerodynamic turning and in turn the decrease of the stator angle of attack was leading to a minor acoustic effect, which is not prominent enough to be further pursued. Numerical calculations of TUB were approving this experimental finding.

The promising rotor wake filling technology was not providing any broadband noise nor even tone noise reduction in FLOCON. The reason for this surprising result is thought to be a radially inhomogeneous wake filling, including hot spots with local overblowing, i.e. regions with accelerated flow compared to the main axial velocity. Numerical assessments of ONERA were indicating quite a potential of broadband as well as tonal noise reduction for the wake filling method.

Final results

The broadband noise reduction concepts developed in FLOCON can be split into four different categories: The first category of concepts turned out to be successful in terms of experimental and numerical assessment as well as the extrapolation to a virtual aircraft platform and will be broadly applicable to the fan stage of all new aero-engine designs. A second category of concepts proofed to be successful in terms of noise reduction potential, but need to be further analysed in order to proof its applicability to a real engine design. A third category of methods was surprisingly low performing in the experimental application, although design as well as numerical results indicated a high broadband noise reduction potential. Finally, the fourth category of technologies simply turned out to not work as expected and should not be further investigated in the future.

FLOCON itself brought each concept up to technology readiness level 4 (validation at laboratory scale). The technologies of the first category are recommended to engine-ready level and an extrapolation to the expected performance at full engine scale was given. Others (categories 2 and 3) need further evaluation to proof their technical applicability or their noise reduction potential in other research projects.

An initial assessment of any penalties related to weight, aerodynamic performance, stress or mechanical complexity was performed with all deployed technologies.

Potential impact:

FLOCON will provide the European aero-engine industry with demonstrated methods to reduce broadband noise at source. In doing so, it will contribute to achieve European aerospace industries objectives for lower-noise aircraft to meet society's needs for more environmentally friendly air transport, and to enhance European aeronautics' global competitiveness.

As a reason of several project delays, the projects duration was extended by pone year. The broadband noise reduction concepts developed in FLOCON will be broadly applicable to the fan stage of all new aero-engine designs. A subset of the methods (to be determined within the programme) will be applicable also to core compressor designs.

FLOCON itself will bring each concept up to technology readiness level 4 (validation at laboratory scale) and recommend a subset for development to engine-ready level.

Recommendations will be produced which contains all the necessary information for further development and exploitation of the recommended noise reduction methods. In particular, the experimentally determined efficacy of the method together with an extrapolation to expected performance at full engine scale will be given, in addition to an initial assessment of any penalties related to weight, aerodynamic performance, stress or mechanical complexity.

Project website: http://www.xnoise.eu/index.php?id=393

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Aerospace Technology

Last updated on 2013-04-29

Information source: SESAM
Collaboration sought: N/A

Retrieved on 2016-01-14

Permalink: http://cordis.europa.eu/result/rcn/55824_en.html