Slat Noise Prediction of a Full Scale Aircraft and Validation with Flight Test Data

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Aircraft noise in the vicinity of airports has become a problem of acceptance for local residents due to its negative environmental impact. Subsequently, noise plays a major role concerning operating limits of the growing air traffic. Programs such as “Vision 2020” and “Flightpath 2050” impose goals to reduce those noise emissions. Besides improvement of air traffic management procedures, aircraft noise reduction is attempted to be achieved by low-noise technologies, the development of which requires validation by experiments and numerical simulations. The quality and accuracy of these simulations is vital in the context of a virtual development and certification and demands for efficient, matured and validated numerical methods for the acoustic assessment of a new or modified aircraft. The development of such a numerical method applied to full scale aircraft is pushed further in the project VicToria and validated for airframe noise prediction.

The broadband airframe noise of an aircraft at approach is dominated by the sound radiation of the deployed slat. The slat noise is caused by turbulent noise sources in the vicinity of the slat gap between the slat and the main element of the wing. A mitigation or elimination of these noise sources can be achieved by a modification of the slat gap. Such a slat gap modification has been studied experimentally for a full scale Airbus A320-ATRA during flight tests in the project LN-ATRA. In order to assess the numerical prediction capabilities of full scale aircraft a numerical investigation is performed in this work while results are compared to experimental data.

An accurate and efficient numerical simulation of airframe noise of a full scale aircraft is a challenging task, in particular due its nature of a multiscale problem. On the one hand the turbulent acoustic sources are notably small at high Reynolds numbers, on the other hand the geometrical shapes of a full scale aircraft, that are affecting the sound propagation, are of considerably greater extend. In order to resolve both structures accurately, a local, hybrid, non-empirical mid-fidelity approach is implemented that realizes a coupling of the Fast Random Particle Mesh (FRPM) method for stochastic, synthetic turbulence with the Fast Multipole Boundary Element Method (FM-BEM). FRPM generates spatially and timely resolved synthetic turbulence in a locally defined source region. The turbulence reconstruction is based on a prescribed flow field and turbulence statistics of a precursor CFD. This flow solution for the entire aircraft at the prevalent flight conditions is provided by a RANS simulation. The RANS simulation is capable of capturing changes in the flow state due to geometrical modifications such as an adjusted slat configuration. The local influence of the reconstructed, volumetric acoustic sources on the discretized aircraft surface is used as a boundary condition for the FM-BEM equation system. For an efficient solution of this equations system the fast multipole method is implemented in combination with iterative solvers. Thus, an entire broadband noise simulation including full-scale geometries is obtained only within a time frame of a few days and moderate computational resources of about 10000 CPU hours.

Numerical simulations of the Airbus A320 are carried out for two different slat configurations. The first configuration features the reference slat setting of 20° deflection, while the second configuration involves an additional tilting of the outboard slat around the slat track hinge in order to realize a closed slat gap. This flow blockage leads to significantly lower turbulence levels and almost vanishing acoustic sources in the slat cove as can been seen by inspection of corresponding RANS solution.

The acoustic simulations are performed for frequencies up to 2kHz and evaluated at an observer plane underneath the aircraft. The acoustic footprint shows a reasonable slat noise characteristic and confirms an overall noise reduction of the sound pressure maximum of 3dB due to the closed slat. Although the actual outboard slat noise is almost annihilated, an investigation of the acoustic surface pressure on the wing reveals a distinct, isolated contribution from the slat side edge vortices that are not affected by the modified configuration.

In addition to the footprint analysis, an acoustic spectrum is evaluated for the reference configuration at a single microphone located 90° underneath the aircraft. A good agreement is achieved to the reference data from the flight tests measurements. A final validation for both configurations will follow after measurement data is available for the low noise configuration.