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AEROACOUSTIC RESEARCH IN EUROPE: THE CEAS-ASC REPORT ON 1999 HIGHLIGHTS

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This paper is a report on the highlights of aeroacoustics research and development in Europe in 1999, compiled from the information provided to the Aeroacoustics Specialists Committee (ASC) of the Confederation of European Aerospace Societies (CEAS). CEAS presently comprises the national Aerospace Societies of France (AAAF), Germany (DGLR), Italy (AIDAA), The Netherlands (NVvL), Spain (AIAE), Sweden (FTEF), Switzerland (SVFW) and the United Kingdom (RaeS).

1. INTRODUCTION

The role of the CEAS–ASC is to serve and support the scientific and industrial aeroacoustics community in Europe. In this context, "Aeroacoustics" includes all the aerospace acoustics and related areas. Each year the committee will highlight some of the research and development activities in Europe. This is the report on the 1999 highlights.

Contributions to this report has been made by the following people: R. J. Nijboer, E. Rademaker and J. B. H. M. Schulten (NLR), W. Dobrzynski (DLR), B. J. Tester (Rolls Royce plc), S. Lewy and J. Prieur (ONERA), H. Bodén (KTH), A. Hirschberg and S. W. Rienstra (TUE).

2. ENGINE NOISE

2.1. TURBOMACHINERY NOISE

The EC funded project reduction of engine source noise through understanding and novel design (RESOUND) addresses the challenge of reducing the noise at source, in particular turbomachinery noise, through (1) engine component aeroacoustic design and (2) novel noise-controlling devices that can be integrated within the engine structure.

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Encouraging progress has been made towards developing and evaluating turbomachinery noise-reduction technologies. The main achievement to date is the application of computational fluid dynamic codes to the design of lower noise turbomachinery components, fan rotors and low-pressure turbine exit guide vanes in particular. Furthermore, the effect of sound diffraction by the splitter of a turbofan engine was successfully modelled [1]. It was found that the effect of diffraction is larger on higher order radial modes than on lower order modes. Also diffraction effects are more important for noise coming from the engine section stator than for noise coming from the outlet guide vanes.

Some significant improvement in the engineering models of fan buzz-saw noise and in the understanding of fan rotor—stator interaction tone noise and the benefits of swept/leant fan outlet guide vanes was obtained. The effect of the stator leading edge suction force on rotor–stator interaction noise was found to be quite significant [2]. A representative advanced ducted fan design was used to study the effect on rotor—stator interaction noise. It appeared that the suction force is most effective when the generated modes have a low circumferential wave number *m*.

An initial evaluation of the most promising active control devices supported by theoretical and experimental feasibility studies was made. One study concerned the effect of an upstream control grid consisting of a rotating ring of 11 cylindrical rods whose interaction with the rotor generates the same spinning modes as the rotor-outlet guide vanes assembly with the same levels, but out of phase. The control grid also generates other propagating spinning modes on harmonics of blade passing frequency (BPF). The measured spectra in Figure 1 show that 2BPF is 6 dB higher, and 3BPF is 15 dB higher with ANC on. However, BPF is the strongest tone as usual, and the overall sound pressure level is decreased by 6 dB.

Substantial progress was made towards the definition, design and manufacture of experimental hardware for verification testing of the down-selected low-noise technologies and the resolution of test facility, rig and instrumentation problems.

Fan noise tests on a datum fan rotor and stator and also combustion noise tests on a low-emission combustor was executed. (Contributed by B. J. Tester)

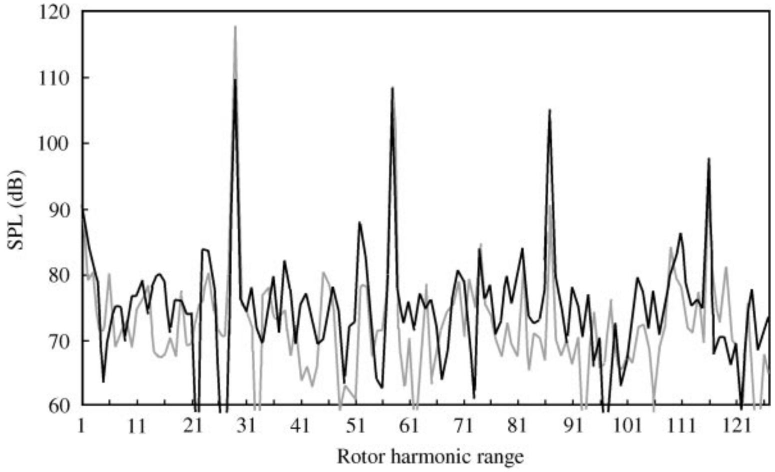

Figure 1. Measured spectra from test of new active-control device for suppressing the blade passing tone due to the interaction between the rotor wakes and the outlet guide vanes. Upstream ring $N = 2500$ rpm. (——) Without ANC; (——) with ANC.

2.2. BASIC RESEARCH IN DUCT ACOUSTICS

Within the BRITE-EURAM project DUCAT (basic research in duct acoustics and radiation) the development of a number of numerical models (FEM, BEM, coupled FEM/BEM, a non-linear propagation model, a ray-acoustics model and a model for liners of extended reaction) have been completed. These models are partially complementary and partially overlapping, which offers the possibility to compare, verify, and choose the best model for each aspect of duct acoustics. The next steps will be the validation of the models by comparing with benchmark models and experimental results, and a comprehensive liner design exercise on a generic turbofan.

An explicit multiple scales solution for modal sound propagation through slowly varying lined ducts with isentropic mean flow has been tested for aero-engine turbo fan inlet duct applications by comparison with Eversman's state-of-the-art numerical FEM solution [3]. Excellent agreement was found in both attenuation and iso-pressure contours, calculated for realistic conditions, inlet Mach number 0·5, dimensionless frequency ka ranging from 10 to 50, circumferential mode numbers m ranging from 10 to 40, wall impedance $Z = 2 - i$, the first radial mode incident (see Figure 2). (Contributed by S. W. Rienstra)

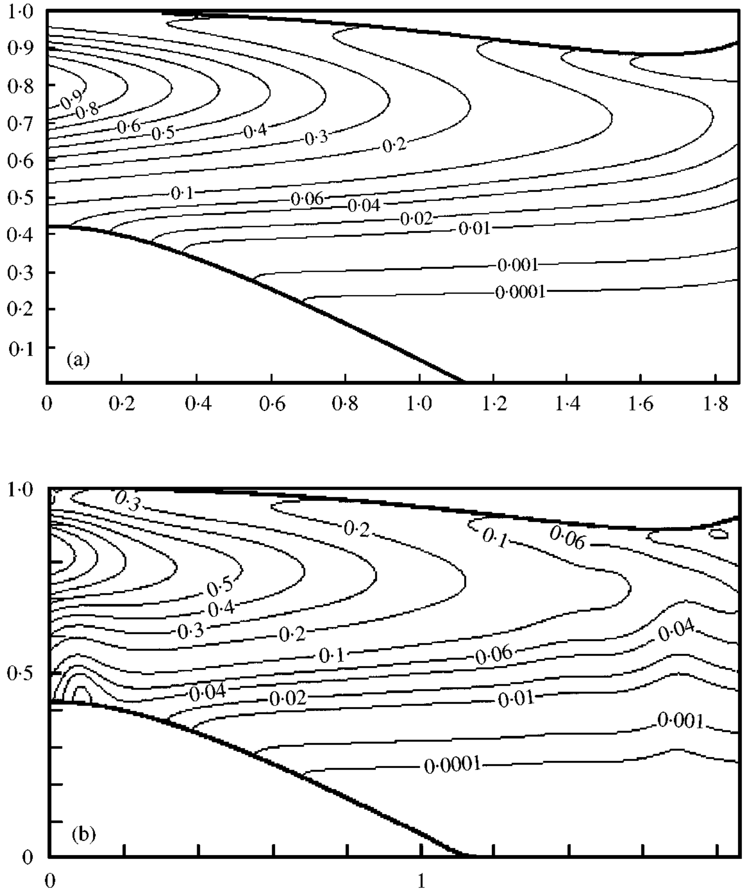

Figure 2. Iso-pressure contours for $m = 10$ and $ka = 16$ from (a) FEM and (b) multiple scales solutions.

3. HELICOPTER NOISE

3.1. CODE DEVELOPMENT

The Kirchhoff code KIM has been applied to study the influence of the thrust on the noise radiation (in level and directivity) of a high-speed helicopter rotor with rectangular blades, starting from ONERA Euler calculations [4]. The aeroacoustic results confirm, at least for this type of blades and in the delocalized cases studied, that the thrust coefficient has a negligible effect on the radiated high-speed impulsive noise.

A code named CONGA able to predict blade vortex interaction noise using blade pressures measured by a small number of sensors has been validated on the basis of wind tunnel tests. The CONGA method is able to reproduce noise contours measured during flight, with a standard deviation lower than 3 dB, starting from blade pressure data measured by only 8 sensors on a blade [5]. (Contributed by J. Prieur)

3.2. LOW-NOISE ROTOR OPTIMIZATION

Within a joint ONERA/DLR project (ERATO), a low-noise rotor optimization methodology was globally verified through dedicated aeroacoustic wind tunnel tests [6]. Furthermore, a high-quality comprehensive database including extensive blade pressure, strain guage, microphone and wake measurements (at DNW using LLS and PIV), has been acquired which will serve for a deeper understanding of the physical phenomena in view of a future low-noise rotor optimization. (Contributed by J. Prieur)

4. AIRFRAME NOISE

4.1. FULL-SCALE HIGH-LIFT WING WIND TUNNEL EXPERIMENT

For the first time the DLR Institute of Design Aerodynamics has investigated the aeroacoustics of a full-scale Airbus A320 aircraft wing in the open-test section of the German Dutch Wind Tunnel (DNW). This project on aircraft airframe noise sources—supported by the German Ministry of Education and Research and by Daimler Chrysler Aerospace Airbus—was aimed at understanding the dominant aeroacoustic source mechanisms of the wing high-lift devices — namely, leading edge slats and trailing edge flaps.

Farfield noise directivities were determined for different slat/flap settings, angles-of-attack and flow speeds, respectively. A planar array of 100 microphones and a 3 m diameter acoustic mirror were used to localize and rank order different HLD component sources. The results revealed the dominance of certain additional noise source related to construction details, which were never reproduced on scaled aircraft models. Slat noise and flapside-edge noise were found to be the dominating airframe noise component (see Figure 3). The research will continue with the development of technically feasible noise-reduction methods. (Contributed by W. Dobrzynski)

5. MISCELLANEOUS TOPICS IN AEROACOUSTICS

In the BRITE-EURAM project FLODAC (Basic research in Flow Duct Acoustics) an aeroacoustical model for low-frequency sound generation from a road tunnel ventilation fan (jet fan) has been developed. The acoustic model included the effect of the proximity to

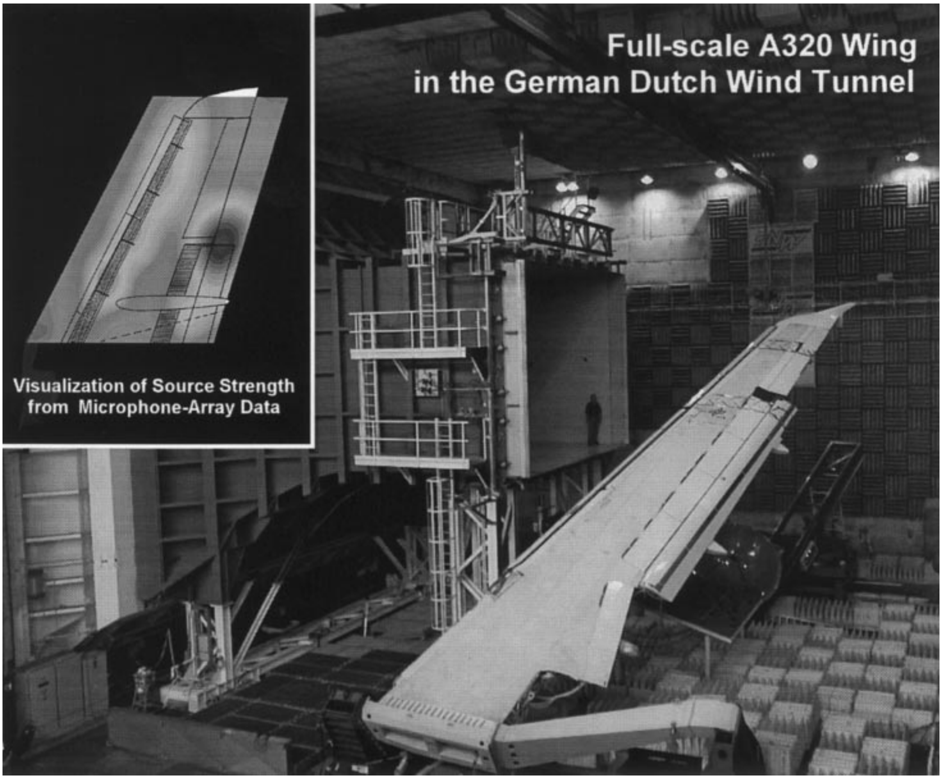

Figure 3. Photograph and source strength visualization from full-scale test of an Airbus A320 wing in the German Dutch wind tunnel (DNW).

the tunnel roof and acoustic interaction between the two duct openings. A comparison between the calculated and measured sound power from the fan showed excellent agreement [7]. The theoretical model developed has been used to give design rules on how to change the fan duct configuration to minimize the radiated sound power. (Contributed by H. Bodén)

The FLODAC project also included studies of aeroacoustics of discontinuities in pipe systems such as bends, pipes bifurcations, wall perforations, diaphragms and diffusers [8, 9]. (Contributed by A. Hirschberg)

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