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AEROACOUSTICS RESEARCH IN EUROPE—1996 HIGHLIGHTS: A SUMMARY OF LAST YEAR'S ACTIVITIES IN THE SIX CEAS COUNTRIES

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This paper is a report on the highlights of aeroacoustics research and development activities in Europe in 1996, compiled from information provided to the CEAS Aeroacoustics Specialists' Committee. The Confederation of European Aerospace Societies (CEAS) comprises the national Aerospace Societies of France, Germany, Italy, the Netherlands, Spain and the United Kingdom.

FOREWORD

In the Summer of 1995, the Confederation of European Aerospace Societies (CEAS), comprising the national Aerospace Societies of France (AAAF), Germany (DGLR), Italy (AIDAA), the Netherlands (NVvL), Spain (AIAE) and the United Kingdom (RAeS) formed the CEAS-Aeroacoustics Specialists' Committee (ASC). This Committee is to serve and support the scientific and industrial aeroacoustics community in Europe. Here "Aeroacoustics" is to encompass all 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 1996 highlights.

1. INTRODUCTION

Aeroacoustics, the science of noise generation and propagation through airflows, is a relatively young discipline compared to other more classical fields of mechanics. Nevertheless, it has seen tremendous progress since its foundations were laid in the form of the first overall aeroacoustic theory by Lighthill in his pioneering work in 1952. The basic understanding of aerodynamically generated noise has increased fundamentally by the subsequent works of Ffowcs-Williams and Hawkings (aeroacoustic significance of aerodynamic surfaces), Powell (concept of vortex sound), Howe (generalization of Powell's theory), Lilley and Ribner (aeroacoustics in shear flows) to mention but a few of the break-throughs in this field.

From the very beginning, the main issues of aeroacoustic research were closely related to aeronautical applications, i.e. the reduction of noise occurring in aerospace technology in general. Since its existence aeroacoustics has gained constantly more and more importance due to an increased consciousness for environmental protection, the increased international competition between airplane manufacturers pushing toward the design of

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internally as externally quieter aircraft, but also due to the need to predict structural loads for fatigue prediction.

In the past it may have been difficult, especially for the external observer, to gain an overview about the various ongoing European aeroacoustics research activities. The latter are mostly organized either as national or EU-wide initiatives, the main scientific contributors of which are recruited from the European aerospace research establishments, the European aeronautical industry as well as various universities. In order to facilitate the insight into current aeroacoustic research in Europe the CEAS-Aeroacoustics Specialists' Committee decided to compile an annual, brief, but informative report highlighting some of the gained achievements starting from 1996. The contributions are intentionally restricted to essentials, yet comprehensive enough to allow also the interested non-aeroacoustician to grasp the main ideas.

2. ROCKET LAUNCHER AND AIRCRAFT INTERIOR NOISE

2.1. SUCCESSFUL CONTROL OF ARIANE 5 LAUNCHER INTERIOR NOISE

In order to reduce the low frequency noise in the Ariane 5 payload fairing, *special acoustic absorbers* of an advanced Helmholtz resonator type (Figure 1) were developed for the particular acoustic environment of the Ariane 5. New measurement systems, utilizing novel impedance tubes designed by the Dornier Company, Friedrichshafen, helped to improve the absorption characteristics of the absorbers. Their efficiency was successfully proven during extensive noise reduction measurements of the payload fairing at ESTEC, Noordwijk, as well as during the actual lift-off of the first Ariane 5 launcher.

2.2. 10–20 dB REDUCTION THROUGH ACTIVE NOISE CONTROL

2.2.1. *Propeller aeroplane interior noise*

Within the framework of the European research program ASANCA II (*Advanced Study for Active Noise Control in Aircraft*) two active noise controllers (ANC) were developed and successfully tested in the Dornier 328 plane. The feasibility of ANC through a whole flight cycle was proven with an average noise reduction of about 10 dB and local reductions up to 20 dB. New control strategies were successfully tested within initial laboratory experiments employing alternative devices such as piezoelectric actuators on the primary structure and/or on the trim panels, as well as loudspeakers and/or shakers in the cavity behind the trim panel.

Numerical/experimental methods for the prediction of active noise and vibration control systems performance were developed. This task focuses on the development of a global vibro-acoustic model having the capability to evaluate the effect of different kinds of such control systems, comprising acoustic and/or vibrational actuators. A finite element model will be used for optimization of possible active noise and vibration control configurations.

2.2.2. *Helicopter interior noise*

The three year European research project RHINO (*Reduction of Helicopter Interior Noise*) mainly involving Agusta, WHL, DERA and ISVR was successfully concluded in 1996, as exemplified by the following highlights. A low frequency ANC system installed on an EH101 civil helicopter led to in-flight reductions of rotor noise of 12 dB. At higher frequencies active vibration control was used on an EH101 gearbox strut in a laboratory setup, resulting in a 40 dB reduction, while an active panel control program yielded 15 dB reduction. Noise path identification techniques were tested and applied inflight to the EH101 and the BK117 helicopters revealing the main paths for gearbox-induced cabin noise to be the gearbox struts. Finally, predictive statistical energy analysis theory was substantially extended and used to forecast the vibroacoustic response of a fifty-plate box test structure and a WG30 helicopter fuselage. The comparison between theory and experiment was remarkably good in both cases.

3. FAN AND JET NOISE

3.1. INAUGURATION OF 1 M CONTRAFAN MODEL TEST STAND IN COLOGNE, GERMANY

A large 1 m diameter contrafan model test stand was inaugurated in the DLR, Cologne (see Figure 2), and first aerodynamic and acoustic tests were carried out. A modal sound field analysis on the inlet and outlet sides (both ducted) was performed. At full operational rotor speeds, the sound pressure levels on the outlet side are about 20 dB higher than on the inlet side. The presumed cause are local supersonic flow regimes in the cascade of the first rotor which prevent upstream sound propagation into the inlet duct. At lower rotor

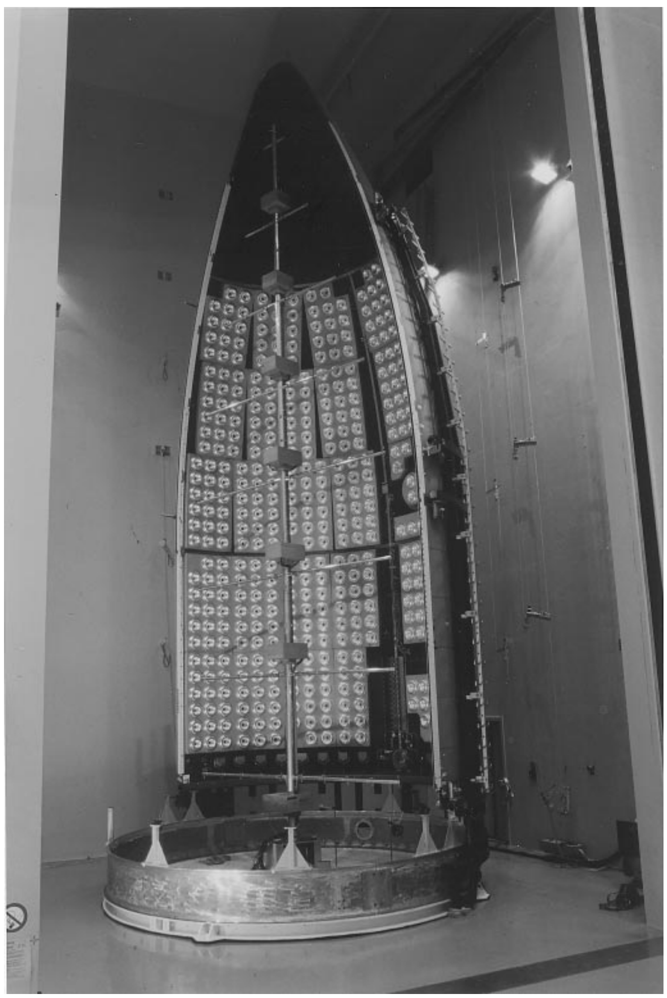


Figure 1. Acoustic absorbers in the payload fairings of the ARIANE 5.

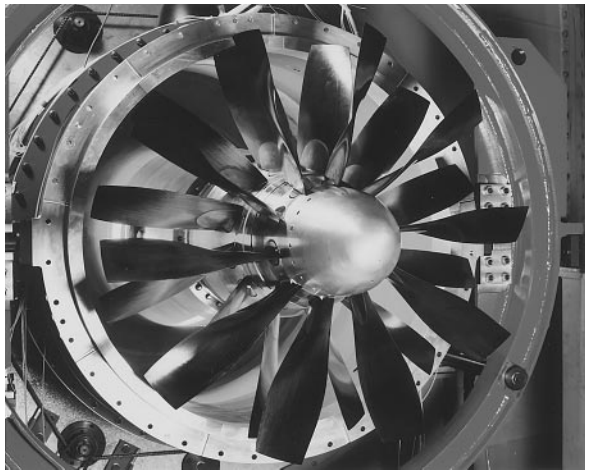


Figure 2. New counter-rotating 1 m model test stand at DLR, Cologne.

speeds, the sound pressure levels in the inlet and outlet side of the fan assume similar values.

3.2. NEW JET NOISE FACILITY IN POITIERS, FRANCE

A new aeroacoustic jet noise test facility has been constructed in CEAT Poitiers by CNES, MARTEL facility. Jets with a nominal exit diameter of 6 cm and of very high temperature and velocity (up to 2100 K and 1800 m/s) can be generated in a semi-anechoic room to simulate the acoustic environment of launchers during lift-off. Two main topics are currently being investigated, namely the characterization of the noise generated when the jets impact on obstacles of simple shape (ONERA), and the optimization of water injection systems to reduce jet noise (ECL, LEA) (see Figure 3).

3.3. NOISE PREDICTION FOR JET-BORNE LANDING

BAe Military Aircraft has been developing prediction methods for the nearfield acoustic environment around and on aircraft surfaces from high pressure ratio, high temperature jets producing vertical thrust (i.e., as in jet borne landing) when close to the ground surface,

Figure 3. Noise reduction for high speed jets by means of water injection.

for both static and inflight conditions. The relevant sources from the jet itself and from the ground and surface flow fields were identified. The jet prediction method assumes both jet mixing and shock noise components, and uses source distributions for both. Reflected or imaged jets in the ground plane are used to account for the influence of the ground surface. The ground flow noise is being modelled as a truncated jet, and the aircraft surface noise is predicted from local flow properties and related to boundary layer flow noise. Model scale hot jet testing on aircraft configurations have been conducted to aid the method development and to measure the acoustic environment for specific configurations.

3.4. SIGNIFICANT IMPROVEMENT IN FAN NOISE PREDICTION CAPABILITIES

A semi-empirical prediction method for broadband noise of subsonic fans was developed and validated at the DLR, Braunschweig. The method is coupled with an optimization code DESI (*Design code for Stochastic Noise Investigations*), allowing the calculation of the near and far fields of stochastic noise sources on the basis of an experimentally obtained turbulence model. The far field of the dominating trailing edge noise is computed by means of the Helmholtz equation while the periodic noise of the fan is calculated by the DLR linear method.

3.5. NOVEL FAN INTAKE LINERS TESTED

The European research project FANPAC (*Fan Noise Prediction and Control*) was completed in 1996. The project, where engine, airframe and nacelle manufacturers, as well as research establishments and universities co-operated, involved the testing of a wide-chord fan with novel intake liners in the Rolls-Royce anechoic fan noise facility, greatly improving the understanding of fan noise generation and identifying research needs on inlet flow distortion, novel acoustic treatment designs, selection of low noise operating points and active noise control.

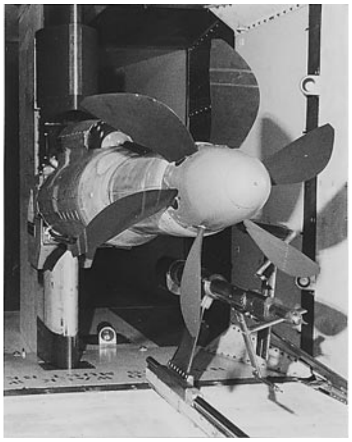
4. PROPELLER NOISE

4.1. SUCCESSFUL CONCLUSION OF EU-FUNDED SNAAP PROJECT

In July 1996, the European research project SNAAP (*Study of Noise and Aerodynamics of Advanced Propellers*) was successfully concluded. European industries, universities and research establishments co-operated closely for more than three years. To validate acoustic computational schemes, two advanced carbon fiber composite propeller models of 0·9 m diameter were aeroacoustically tested for high speed cruise conditions in the ARA acoustically treated transonic wind tunnel, Bedford, England, and for low speed take-off and landing approach conditions in the DNW, Noordoostpolder, The Netherlands.

In the course of the project two computational tools for the aeroacoustic analysis of advanced propellers at angle of attack with tip speeds up to low supersonic were developed. The codes implement a numerical procedure for the solution of the Ffowcs Williams and Hawkings (FW–H) equation in the time domain (CIRA) and in the frequency domain (ONERA). Computations demonstrate that the prediction of the acoustics of advanced (isolated) propellers has reached a fair degree of accuracy (see Figure 4).

In June 1996 the same European research consortium began the new project APIAN (*Advanced Propulsion Installation Aerodynamics and Noise*) in which the acoustics of *installed* propellers will be investigated.



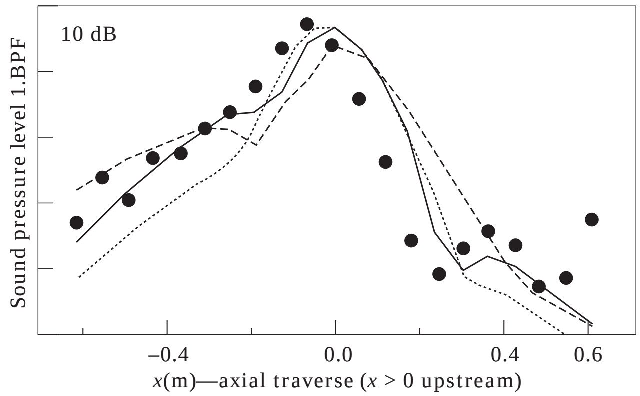


Figure 4. Measured (ARA Wind Tunnel) and predicted *SPL* of the SNAAP Propeller at a simulated flight Mach number 0·78 and $M_{helical} = 1{\cdot}081$. ——, ONERA prediction; - - - -, CIRA prediction; ····, NLR prediction; ●, experiment.

4.2. MINOR ENGINE SHAFT ROTATIONAL SPEED VARIATIONS RAISE PROPELLER NOISE

Analysis of flyover noise data from piston engine powered propeller driven aeroplanes (G.A. aeroplanes) by DLR, Braunschweig showed excessive noise components. To study the phenomenon systematically, dedicated experiments were performed in the DNW under contract to the German Ministry of Transportation (BMV) employing a full scale aircraft powered by a 150 kW piston engine. Tests confirmed the presumption that the additional propeller noise radiation was due to *non-uniform* rotational blade motion. The unsteady flow conditions at the blades which result from a R.P.M. non-uniformity of about 2% (quite typical for piston engines) cause the occurrence of unsteady aerodynamic blade forces. Since this phenomenon is periodic with every two drive-shaft revolutions, additional propeller harmonics occur, raising the overall A-weighted far field noise by up to 6 dB (see Figure 5).

The noise reducing potential of smoothing the rotational shaft motion was also proven in the DNW by coupling a torsional–inertia mass to the propeller. The correlation between non-uniform rotational speed and additional propeller noise was evident. In the spirit of a retrofit to an existing engine/propeller propulsion system this propeller noise reduction potential of several decibels could be exploited either by means of torsional vibration dampers or through the addition of a torsional–inertia mass. DLR, Braunschweig continues to work on this project towards a practical solution.

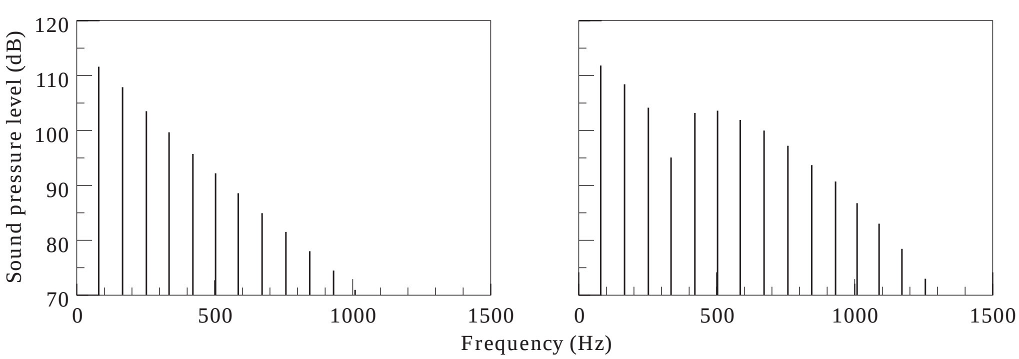


Figure 5. Effect of a 2·5% non-uniformity in rotational speed on the noise spectrum of a 2-bladed propeller at $M_{helical} = 0{\cdot}76$; left, uniform speed; right, non-uniform speed.

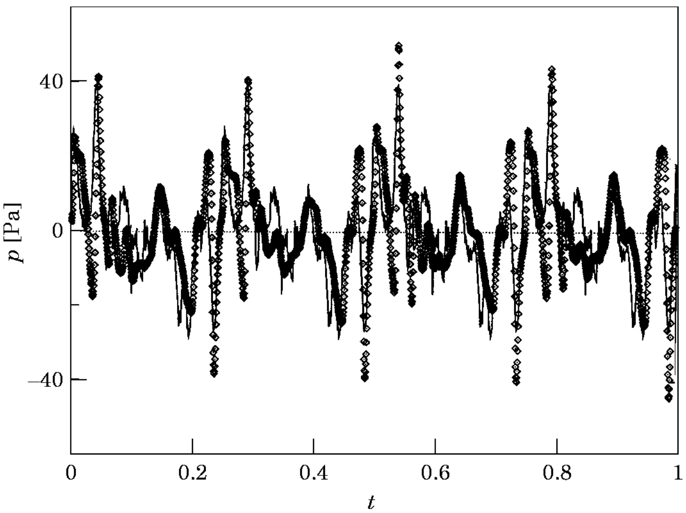


Figure 6. Prediction of BVI noise by using CIRA code. ◇, Numerical; ——, experiment.

5. HELICOPTER NOISE

5.1. EUROPEAN RESEARCH PROGRAM HELISHAPE PROVIDES VALUABLE DATA BASE

HELISHAPE, the *European Cooperative Research Program on Rotorcraft Aerodynamics and Acoustics*, was successfully concluded in 1996 under the leadership of Eurocopter–Deutschland. This major research initiative, comprising all three European helicopter manufacturers (Eurocopter, Agusta and Westland), several Research Establishments and Universities (in all 16 partners) involved parametric model tests in the DNW of rotors with highly instrumented blade tips to generate a quality data base for the validation of aerodynamic and aeroacoustic codes and the assessment of noise palliatives. The aerodynamic blade surface pressure distribution and the related acoustic radiation, as well as blade dynamic characteristics and performance data were simultaneously measured for low speed and high speed level flight, climb and descent at different rates. By employing the laser light sheet flow visualization technique (a DNW development) blade tip vortex geometries and blade–vortex miss distances could be determined.

Specifically, the ONERA–Eurocopter swept back parabolic/anhedral tip 7AD1 blade versus the rectangular 7A tip was investigated with respect to blade–vortex interaction (BVI) and high speed noise, indicating a BVI noise radiation benefit of about 1–2 dB for the 7AD1 rotor compared to the 7A rotor at certain descent angles, and a high speed in-plane noise radiation benefit of 1–4 dB.

To check the capabilities of CIRA's aeroacoustic code (based on the numerical solution of the FW–H equation), a descent flight condition with strong BVI was selected, leading to a good agreement between computed far field acoustic pressure time histories and corresponding experimental signatures, especially for the resulting waveforms and peak values of the signals (see Figure 6). Similarly good noise prediction at strong BVI conditions using previous experimental data were also obtained by the FW–H code of Agusta.

The ONERA aerodynamic/acoustic prediction chain R85-MESIR-MENTHE-ARHIS-PARIS has been applied to HELISHAPE BVI test cases corresponding to different descent flight conditions and successfully correlated to the experiment.

5.2. FRENCH–GERMAN ERATO ROTOR READY FOR AEROACOUSTIC WIND TUNNEL TESTING

Within the ongoing French–German ERATO program (involving ONERA, DLR, ECF and ECD) a low noise rotor has been designed. In 1996 the model blades, instrumented with miniature dynamic pressure sensors, have been manufactured, ready for testing in the DNW and the S-1 Modane wind tunnel in 1997. The theoretically expected gain in noise reduction of several decibels is to be validated through the planned wind tunnel tests.

5.3. ADVANCED AEROACOUSTIC NOISE PREDICTION METHODS FOR HIGH-TIP-SPEED ROTORS

A new integration technique for a supersonically moving Kirchhoff surface was developed by Agusta, which takes multiple emission times into account. It was successful in predicting the noise radiation from high speed rotors (see Figure 7 left). Also a new formulation of the Kirchhoff methodology was developed, based on an extension of the FW–H equation and removing the non-penetration condition. It was applied successfully to transonic rotor noise prediction. One of the main advantages of this new formulation is that it does not require the knowledge of the pressure normal derivative on the Kirchhoff surface.

The Navier–Stokes Solver FLOWer and the acoustic methods of DLR, Braunschweig have been combined into a single modular computer tool termed APSIM (*Acoustic Prediction System based on Integral Methods*). Presently it contains the method based on the linear part of the FW–H equation, implemented according to Farassat's formulation 1 and 1A. Furthermore, the Kirchhoff method with two kinds of integration procedures based on a rotating or nonrotating integration surface is included. The pressure signatures for the UH-1H high-speed rotor in hover flight indicate best agreement with the experimental data when using the Euler/Kirchhoff method (see Figure 7 right).

An ONERA initiative for validating acoustic codes based on the integration of the FW–H equation has been the generation of simple calculation test cases communicated to European research centers enabling cross-checks and comparison of the results in the framework of the HELISHAPE co-operation. The effort on CFD–Kirchhoff calculations is pursued. Very good agreement with experimental data had already been obtained for a rotor with rectangular blades in high-speed forward flight; calculations now address non-conventional blade tip shapes.

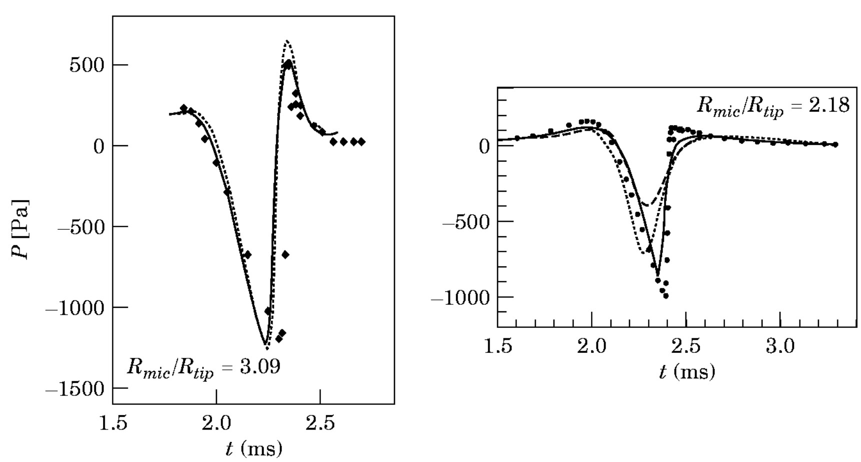


Figure 7. High speed rotor noise prediction for UH-1H rotor; left, $M_{tip} = 0{\cdot}95$ (Agusta result, by using sub- and supersonic Kirchhoff surfaces); right, $M_{tip} = 0{\cdot}90$ (DLR-result). Left: ——, subsonic; ····, supersonic; ◆, experiment. Right: ●, experiment; ····, Euler; ——, Euler/Kirchhoff; - - - -, Euler/Linear acoustic analogy.

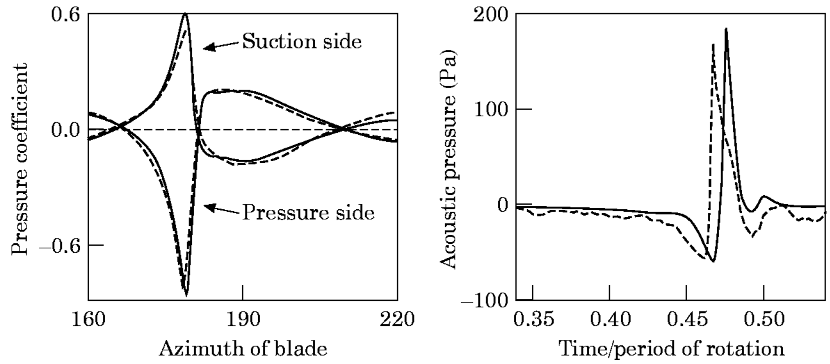


Figure 8. Prediction of BVI noise using ONERA's ARHIS cloud vortex model; left, leading edge blade pressure fluctuations in a blade-vortex collision case, correlation between ARHIS calculations and US Army/NASA experimental data; right, acoustic pressure signal below the rotor for the same case ARHIS-PARIS calculation/experiment correlation. ——, Computation; - - - -, experiment.

5.4. NOISE PREDICTION FOR THE INTERACTION OF A ROTOR WITH AN INDEPENDENTLY GENERATED VORTEX

A significant achievement of ONERA's theoretical work on BVI noise has been realized through the US Army–NASA workshop about the prediction of the interaction of a rotor with an independently generated vortex. Thanks to the ARHIS (*Aerodynamics of Helicopter Rotor Interacting with its Wake*) cloud vortex model, even in the collision case very good correlation with experimental data was obtained with respect to BVI blade pressures and acoustic signatures (see Figure 8). These results validate the aerodynamic modelling implemented in the ARHIS code and the acoustic calculation based on the PARIS (*Acoustic Prediction of a Rotor Interacting with its Wake*) code.

5.5. STUDY ON THE AEROACOUSTICS OF MAIN TAIL ROTOR AND ROTOR/FUSELAGE INTERACTIONS BEGINS

In the fall of 1996 another European research effort, termed HELIFLOW, began, involving the European helicopter manufacturers, several major Research Establishments and universities. The main industrial objectives of the HELIFLOW project are targeted towards the acquisition of acoustic and unsteady aerodyamic data on specific main rotor/tail rotor and rotor/fuselage interference and coupling phenomena, validation of existing wind tunnel test methodologies and their extension towards higher complexity, verification and extension of existing comprehensive theoretical models, and evaluation of the influence of fuselage scattering on the noise produced by the rotors.

6. AIRFRAME NOISE

6.1. FIRST-TIME EVER FULL SCALE NOISE TESTING ON AIRBUS LANDING GEARS IN THE DNW

DLR, Braunschweig, under contract to Airbus Industrie, performed airframe noise experiments, employing full scale landing gears in the DNW (see Figure 9). Farfield microphones, microphone arrays and an STSF-setup were used to obtain both far field and near field data. While the tests occurred in late 1995, extensive data analysis was concluded only in 1996.

The analyses indicated that flow noise from landing gears is largely of broadband nature, ranging from a low frequency of about 80 Hz up to several kHz. One key result was that landing gear noise is not at all a ''low frequency phenomenon'', as previously thought, but

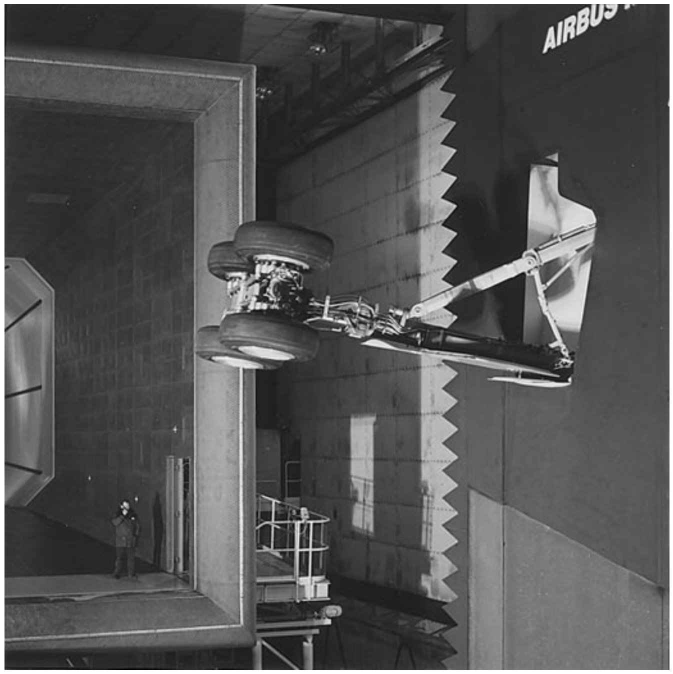


Figure 9. Full scale A 320 landing gear in the DNW for airframe noise studies.

rather has its spectral peak in the mid-frequency range, being of greatest importance for the flyover noise metric EPNL. Flow noise from landing gears is caused by numerous different, though "physically small" sources, which are distributed almost uniformly throughout the gear structure. By means of streamlining certain components, noise reductions of up to 10 dB in different frequency regimes can be obtained. Shrouding entirely the landing gear decreases its noise by more than 15 dB. But even less radical and technically feasible means were shown in the DNW tests to reduce substantially landing gear noise. Airbus Industrie has been supplied with detailed quantitative information about the benefits of certain technical measures.

6.2. AIRFRAME NOISE TESTS ON AIRBUS AIRCRAFT MODEL IN THE CEPRA 19

In order to characterize airframe noise on commercial aircraft ONERA was commissioned by Airbus Industrie to perform tests in the CEPRA 19 anechoic wind tunnel on a 1/11 scale model (see Figure 10). The study was aimed to identify and localize the noise sources, evaluate the far field intensity radiated by each source and to compare the source strengths, correlate local aerodynamic fluctuations with the measured far field, and tentatively predict full scale noise using both experimental data and existing theories.

During the test a new acoustical 2-D imaging technique (focused cross-shaped array of 39 microphones) was used simultaneously with a near field/far field correlation method. The latter implied a model instrumentation with 70 flush-mounted pressure transducers.

Depending on the frequency band considered, source positions were located on landing gears, slats and flaps. In particular, the flap side edge was shown to not always be the predominant source. The far field was measured by using 13 microphones, located on a horizontal circle with a 10° angular increment. The well known discrepancies on directivities between the published flight measurements and Fink's predictions are confirmed by the wind tunnel tests.

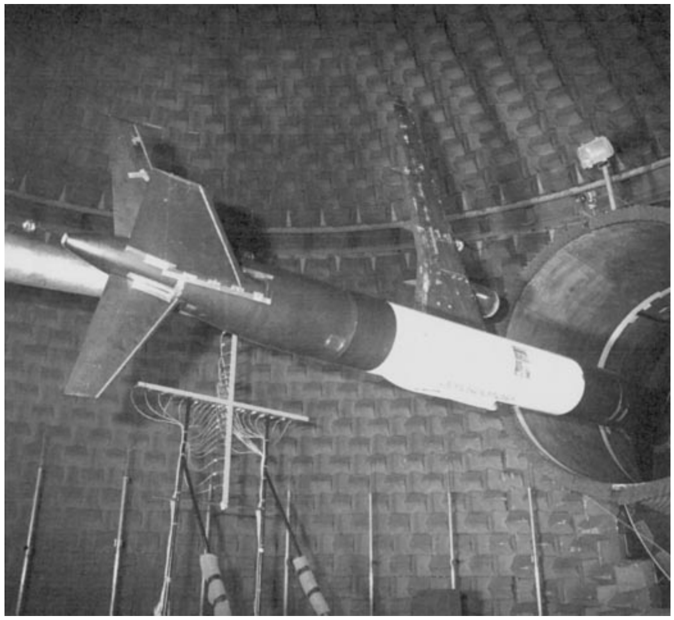


Figure 10. Airframe noise test setup in the CEPRA 19 wind tunnel.

6.3. GROUND BASED MICROPHONE ARRAY LOCATES FLYOVER "AIRFRAME NOISE SOURCES"

Noise source location tests with high performance military aircraft were carried out by the DLR, Cologne (Berlin-Branch) at the test center of the German Ministry of Defense on the airfield of Manching/Germany.

A Tornado aircraft was used to investigate the noise sources during high-speed low-level flyovers. The source locations were determined with a line array consisting of 29 microphones. The flights were performed at an altitude of only 35 m above ground [hail to the brave pilots!] and (a) at speeds of 220, 250 and 275 m/s in unaccelerated flight and (b) with three different engine power settings (flight idle, normal, max dry) at an air speed of 250 m/s over the measuring position. The influence of external stores on airframe noise was studied by alternatively flying with stores and with an operationally clean aircraft. Two surprising results were obtained: namely, (i) airframe noise is louder with the aircraft in the operationally clean configuration, and (ii) jet noise is dominated by a source close to the nozzle exit plane. Flyover noise signatures are shown in Figure 11.

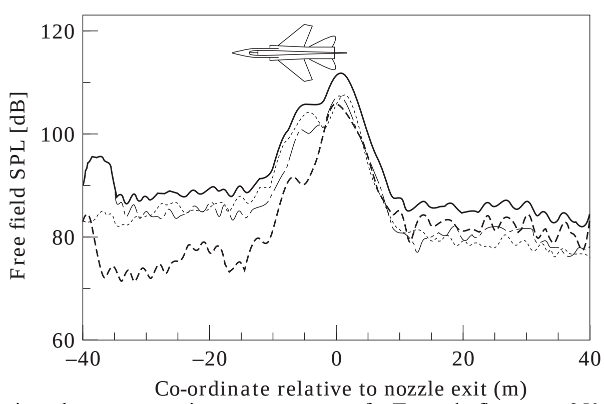


Figure 11. Ground microphone array noise measurements of a Tornado flyover at 250 m/s in an operationally clean configuration. Frequency ranges; - - -, 280–560 Hz; –·–·–, 560–1120 Hz; ·····, 1120–2260 Hz; ——, total.

6.4. SIMULATION OF INFLOW TURBULENCE NOISE ON AIRFOILS WITH A BOUNDARY ELEMENT METHOD

Within the European research project DRAW (*Development of Design Tools for Reduced Aerodynamic Noise Wind Turbines*) the mechanism of noise due to inflow turbulence is considered. Turbulent gusts are represented by thin vorticity layers which are passively convected along the streamlines of the potential flow past a 2-D airfoil at low Mach number. The vorticity distribution along the streamline is chosen such that an observer fixed to the airfoil perceives a time-harmonic variation of vorticity. The sound produced by the motion of vorticity is computed according to Powell's/Howe's theory, by employing an acoustic boundary element method to solve the Helmholtz integral equation.

Simulations have been performed for two airfoils of 12% and 18% relative thickness for different lift coefficients. The results show the same trends as measurements which have recently been carried out in the Small Anechoic Wind Tunnel at NLR, i.e., the increase in airfoil thickness leads to a reduction of inflow-turbulence noise of between 4 and 6 dB in the Helmholtz number range $0{\cdot}74 < He = C/\lambda < 1{\cdot}18$, C being the chord length and λ the acoustic wave length.

7. COMPUTATIONAL AEROACOUSTICS

7.1. NUMERICAL PREDICTION OF NOISE FROM SUPERSONICALLY CONVECTED TURBULENT STRUCTURES IN JETS

Acoustic radiation of shock free supersonic jets is different from that of subsonic jets because of Mach wave emission. Especially intense noise is radiated when turbulent structures are convected supersonically relative to the sound speed of the ambient medium.

Numerical predictions of this intense component have been developed within a dedicated research effort at Electricité de France, Ecole Centrale de Paris and Ecole Centrale de Lyon (ECL), France, from a knowledge of the local flow characteristics of the jet and by using an acoustic model based on Lighthill's acoustic analogy. A compressible k-ε code is employed to obtain the mean velocity and the turbulence characteristics of the flow, the acoustic source model containing one single adjustable constant. Predictions of the far field noise levels and of the spectral directivities are in good agreement with experimental data for both cold and hot supersonic jets.

8. DNW MEASUREMENT CAPABILITY UPDATE

8.1. DNW STARTS MAJOR UPDATE TO IMPROVE AEROACOUSTIC MEASUREMENT TECHNIQUES

8.1.1. *Multichannel acquisition system for dynamic data*

In 1996 DNW continued its major update of the existing acoustic measurement capabilities by expanding the dynamic data acquisition and processing systems, increasing the number of channels from 12 to 50 with a resolution 16 bit. Up to 24 channels can be used with a maximum frequency bandwidth of 100 kHz per channel. When all 50 channels are used the maximum usable bandwidth is still 48 kHz per channel.

Parallel measurements in two different frequency regimes (e.g., for measurements with model surface mounted pressure transducers and microphones) are possible by splitting the channels over two independent acquisition systems which are completely computer controllable and fully integrated with the wind tunnel static data acquisition systems. All unsteady data are stored on hard disk as digitized time domain data. Distributing the tasks over several workstations permits measurement and processing in parallel. To improve both stability and quality of microphone data, DNW installed a fully automated calibration system from B&K.

8.1.2. *Acoustic mirror and microphone array technique for source localization*

For localizing aeroacoustic noise sources on models in the open jet, DNW initiated the development of two new measurement systems, a large "acoustic mirror" and a new type of "acoustic array".

The mirror system is based on an elliptical acoustic mirror with a diameter of about 3 m. The mirror, mounted on a new 5-axis computer controlled traversing system below the open jet, allows one to trace sources in the frequency range between 1 kHz and 40 kHz with a very high geometrical resolution. The complete system will be operational in late 1997.

The other new data acquisition system is a planar microphone array which can be operated directly in the flow to avoid adverse jet shear layer effects. The maximum working range of the new array could be between 200 Hz and (the very high frequency of) 40 kHz. NLR demonstrated the potential of the enhanced array design and of the new processing software during aeroacoustic measurements at DNW on a full scale current collector of a high speed train. The new inflow array should be operational in late 1998.

9. OUTLOOK

The present report on aeroacoustic research highlights in Europe 1996 has shown that there is considerable activity in all the various sub-fields of aeroacoustics. Especially helicopter aeroacoustics and propeller acoustics remain to represent very important issues, as well as fan noise. Remarkable successes were achieved in the rapidly growing field of active noise control and a very strong renewed interest in airframe noise has triggered intense experimental and theoretical research. The numerical description of noise generation and propagation still seems somewhat under-represented but appears to experience more and more interest.

Another aeroacoustics highlight is to be considered the future CEAS-ASC cooperation with the AIAA Aeroacoustics Technical Committee. A formal agreement was signed by Dr. Stuessel, President CEAS 1996 and Mr. Durocher, Executive Director AIAA to hold joint aeroacoustics conferences on an annual basis, with two successive conferences in the US and one in Europe. The second joint AIAA/CEAS Aeroacoustics Conference took place at the Scanticon Conference Center at State College, Pennsylvania, 6 to 8 May, 1996. Six members of the ASC served on the Program Committee with Dr. Sohan Sarin (formerly Fokker) having been the European Co-Chairman of the conference. Of the approximately 130 papers total, about 25 papers were given by scientists from CEAS-countries. This relatively small number of European papers (without Russia) is a reflection of restricted travel budgets. The next joint conference in Europe will be in June 1998 in Toulouse, France, under the European Chairmanship of Dr. Gérard Fournier/ONERA. CEAS announces Sweden and Switzerland as new members as of 1 January 1997.

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