Reduction of Engine Source Noise through Understanding and Novel Design (RESOUND)

Réduire le bruit du moteur à la source grâce à une nouvelle conception

Andrew J. Kempton,
Rolls-Royce plc,
Moor Lane,
PO Box 31,
Derby DE24 8BJ, UK,
e-mail : andrew.j.kempton@rolls-royce.com

The objective of RESOUND is to acquire the technology necessary to support the design of derivative and new aero-engines with noise levels that are 4 dB quieter than those of aircraft currently entering service. This will provide the foundation for the achievement od a mid-term (8 years) objective of reducing aircraft noise levels by at least 6 dB, and allow European industry to complete on an equal footing with the US.
RESOUND addresses the challenge of reducing the noise at source, in particular turbomachinery noise, through engine componant aeroacoustic design and through novel noise controlling devices that can be integrated within the engine structure. Innovative technologies to be evaluated, with the aid of theoritical techniques and experiments at model and full scale, include :

- fan noise reduction through reduced tip speed and pressure ratio optimisation,
- noise reduction with fan and stator axial sweep,
- LP turbine noise reduction through exit guide vane design,
- turbomachinery noise reduction through active stator design.

Based on the technology acquired, RESOUND will deliver a full assessment of the community noise benefits of controlling engine noise at source, through design and with novel active/passive devices.
The reduction of aircraft noise through improved nacelle technology and airframe design is being addressed by complementary projects (RANNTAC and RAIN respectively), and by supporting projects on design methods (DUCAT and TurboNoiseCFD) all of which are coordinated through the X-NOISE thematic network that as been formed as a result of the Environmlentally Friendly Aircraft study (TEFA). Such a combined effort is necessary to meet the competitive challenge of the US industry and the environemental needs of airport communities.

L'objectif de RESOUND est d'acquérir la technologie nécessaire pour permettre la conception de moteurs d'avions dont les niveaux sonores seront de 4 dB inférieurs à ceux des moteurs actuellement en service. Ce projet donnera les bases d'un objectif à moyen terme (8 ans) de réduction du niveau sonore des avions de 6 dB afin de permettre à l'industrie aéronautique européenne d'être sur un pied d'égalité avec celle des Etats-Unis.
RESOUND a lancé le défi de réduire le bruit à la source, en particulier le bruit des turbomachines, grâce à une conception aéroacoustique des composants du moteur et grâce à de nouveaux systèmes de contrôle du bruit qui seront intégrés dans la structure du moteur. Des technologies innovantes ont été évaluées, avec l'aide de théories et d'expérimentations modélisées et en grandeur nature, comprenant :

- la réduction du bruit des ventilateurs grâce à une vitesse réduite en descente et l'optimisation du rapport des pressions,
- la réduction du bruit grâce à un balayage axial du ventilateur et du stator,
- la réduction du bruit de la turbine à basse pression grâce à la conception de guides de sortie à ailettes,
- la réduction du bruit de la turbomachine grâce à la conception d'un stator actif.

Basé sur une technologie acquise, RESOUND donne une estimation complète des bénéfices pour la population en matière de bruit grâce au contrôle du bruit du moteur à la source, au travers de sa conception et de nouveaux systèmes actifs et passifs.
La réduction du bruit des avions due à une technologie de nacelle et une conception du fuselage efficaces est devenue accessible grâce à des projets complémentaires (respectivement RANNTAC and RAIN) et en aidant des projets sur les méthodes de conception (DUCAT et

Despite significant progress in reducing aircraft noise over the past thirty years, further improvements are required if passenger growth is to continue without an increase in noise exposure around airports Increased bypass ratios have reduced jet noise from the dominant levels of the first jet engines, so that now further progress in reducing aircraft noise requires research on a broad range of noise sources, including turbomachinery noise (especially fan noise), combustor noise, jet noise (still very important at aircraft departure) and airframe noise (often the dominant source on aircraft arrival).

RESOUND is a 9 MEuro European research programme launched in 1998 involving 18 partners from industry, research establishments and universities across Europe, with financial support from the European Union. The objective of RESOUND is to acquire the technology necessary to support the design of derivative and new aero-engines with noise levels that are 4dB quieter than those of aircraft currently entering service. Conventionally turbomachinery noise reduction is achieved by increasing rotor/stator gaps increased to reduce interactions, and by selecting rotor and stator numbers so that sound from rotor/stator interaction decays rapidly.
The RESOUND programme investigated advanced methods of reducing turbomachinery noise, namely fan noise reduction through reduced tip speed and rotor/stator design, low-pressure (LP) turbine noise reduction through exit guide vane design, and turbomachinery noise reduction through active stator design.
Other elements of the programme, including combustor noise and the control of fan noise by aerodynamic devices, are not presented here.

Fan noise reduction through reduced tip speed and rotor/stator design

A model fan test programme was conducted in the Rolls-Royce anechoic chamber at Ansty in the UK. Far-field measurements were taken in the controlled environment of a large anechoic chamber. The 0,85 metre diameter model fan operating at supersonic fan tip speeds was driven by a 10 MegaWatt electric motor, and installed with a turbulence control screen to simulate intake flows relevant to the flight case. Two designs of fan rotor were investigated in RESOUND. Low Noise Rotor 1 - LNR1 - was acoustically designed with a 15% tip speed reduction using 3-dimensional (3D) Computational Fluid Dynamics (CFD).

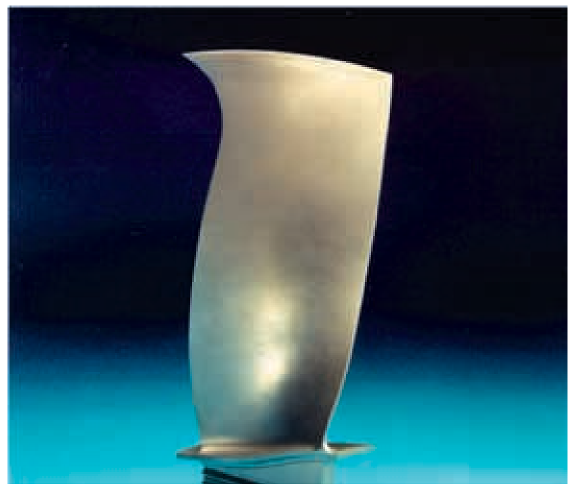


Fig. 2 : Forward Swept Fan LNR2

The rotor was designed to have the same pressure ratio versus mass flow relationship as the datum blade with no reduction in efficiency and adequate stability margin. The rig was tested in November 1999 (see figure 1), and demonstrated more than 4dB improvement in rotor tone noise, as well as reductions in rotor-stator interaction tones (corrected to the same gap/chord ratio). Broadband fan noise benefits were not realised.
LNR2 was designed using 3D CFD to match the datum blade pressure ratio versus mass flow relationship, with the same tip speed as the datum rotor. LNR2 was swept forward (see figure 2) to swallow the shock at the tip and stop it propagating forward as noise. 2-4dB noise improvement was predicted using steady and unsteady Noise CFD for rotor-based tone sources. The rig was tested in July 2000 demonstrating more than 4dB improvement in rotor tone noise.

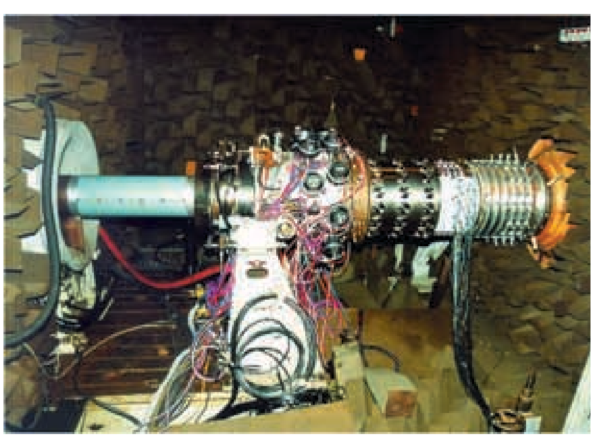
In addition to low-noise rotor designs, a low-noise fan swept outlet guide vane (OGV) was evaluated. The OGV axial sweep noise benefits were evaluated, and a 20 degree sweep selected with 3-4dB benefit on interaction tones predicted. The swept OGV was aerodynamically designed using 3D CFD Navier-Stokes methods to have the same overall aerodynamic loss as the datum OGV. The swept OGV was tested in July 2000, and demonstrated a rear-arc tone reduction of more than 4dB.

LP turbine noise reduction through exit guide vane design

A number of turbine exit guide vane variants were tested on a LP turbine rig at MTU, Germany. The blades were designed to reduce rotor-stator interaction noise using CFD predictions of linear perturbations to non-linear steady mean flow.

Turbomachinery noise reduction through active stator design

Tests were conducted on two different concepts of active stator design, introducing either anti-noise or aerodynamic disturbances to cancel out the fan noise sources. In one test, loudspeakers were located on the duct walls between the stators, while in the other ten of the stators in the ring were modified to incorporate piezo-actuators.



In the tests at SNECMA (see figure 3), both concepts gave significant (~10dB) overall tone reduction for low frequencies, with an angular sector of “silence” achieved at high frequencies.

Conclusions

RESOUND has delivered technology for aero-engine noise reduction that is suitable for application in the short term (fan rotor and outlet guide vane designs, and LP turbine exit guide vane designs) and in the longer term (active stator designs).