Aeroacoustics: an Overview for Air Vehicle Applications

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This issue of Aerospace Lab is dedicated to Aeroacoustics, the field of science that deals with sound generated by air flows and possible interaction with solid bodies. As noise issues became a major environmental challenge over the past decades, the aerospace industries have paid great attention to Aeroacoustics for the design of aircraft, as well as helicopters. An environmentally efficient air vehicle offers a competitive advantage. The worldwide air traffic is expected to double every 15 years and the annoyance to the population living in the vicinity of airports should at least remain the same and even decrease in the midterm. In this context, it is obvious that more flights might be allowed if silent aircraft were used instead of noisier aircraft from a former generation.

Reducing aircraft noise is a major component of the environmental policy on air transport. Over the last 30 years, aircraft noise has been dramatically reduced. This great improvement has resulted from combining technological innovations and international policies on aircraft noise.

The International Civil Aviation Organization (ICAO) has enacted more stringent certification limits since its “Chapter 3” in 1977. The current Chapter 4 (applicable as from 2006) involves a stringency of 10 EPNdB. A recent increase in stringency of 7 EPNdB for Chapter 14 (17 EPNdB cumulative to Chapter 3) will be applicable to aircraft submitted for certification after December 2017. These mandatory requirements come moreover within a comprehensive framework of noise reduction strategies known as the so-called “balanced approach”, a resolution adopted in October 2001 that included 4 pillars: noise reduction at the source, operational procedures, land use and planning management, and aircraft operation restrictions.

In order to cope with the corresponding social demand, both the European Commission and its member States – and especially France, which has a strong aerospace industry – launched ambitious research programs on aircraft noise and notably on noise at the source, thus encompassing in-depth aeroacoustics developments. Of course, most of this work has been conducted under strong coordination, through supportive expert networks: X-Noise at the European level (led by Snecma) and Iroqua at the French initiative (led by Onera).

The articles introduced in this issue of Aerospace Lab often describe work performed within these frameworks. Most of them address numerical simulations and the thorough understanding of noise generation, topics which are directly linked to this “noise reduction at the source”, probably the most conventional axis for noise reduction among those promoted by the “balanced approach”.

A variety of noise sources to be reduced

Several noise sources at takeoff or landing are considered: engine, airframe and installation effects. For high-bypass ratio engines, fan noise has been identified as a major noise source, especially at takeoff, but jet noise again becomes more and more important as fan noise reduction technologies progress. In addition, combustion noise, which is a recent topic as this emerging noise source, is still "inaudible" but would be noticeable when the former sources are mitigated enough. Beyond these sources due to the engines, airframe noise is induced by the turbulence due to the interaction between the aircraft and the flow. Protruding parts, such as the landing gear or high-lift devices, are the major sources of such an airframe noise. Last, forthcoming aircraft or engine architectures could lead to new noise sources. It is a well-known issue for Open Rotors, which are often thought of (and feared) in this regard.

All of these noise components differ by their features, in terms of frequency range and directivity. They are possibly modified by some strong interactions known as "installation effects": for instance, jet noise sources are modified by the presence of the wing or by the fuselage. Acoustic propagation is also affected by reflection and diffraction on these surfaces. If well-used, these effects could be advantageously used for shielding but, on the contrary, they can lead to noise reinforcement.

As is often the case, the ability to derive some reduction technologies for such a wealth of sources stemmed from actual progress in the basic understanding of the phenomena. Therefore, many problems were initially addressed by aeroacoustics through analytical or semi-analytical techniques. As illustrated by some articles in this issue of Aerospace Lab, this tradition is still alive and useful, not only for the advancement of science, i.e., for the understanding of basic mechanisms, but also for its ability to provide industry with fast and somehow reliable sizing methods.

High Performance computing, strong numerical and experimental expertise

However, most of the time, analytical derivations are only suitable for "basic" geometries, such as academic cylindrical jets, simplified airfoils representing wings, or cylinders representing landing gear struts. Indeed, with regard to the sophistication of involved physical interactions and with regard to the complex geometries of actual aeronautical parts, aeroacoustics, maybe more than other sciences, greatly resorts to advanced computational techniques. Nowadays, CAA (Computational AeroAcoustics) is commonly used in the industry and in research centers, and CAA combined with CFD (Computational Fluid Dynamics) is the key tool for accurate acoustic simulations. Thus, the articles presented hereafter strongly insist on particular numerical issues, specific numerical schemes, dissipation and dispersion, new meshing techniques, or innovative formulations for ancient problems.

Comparison with measurements is the second leg required to address the issue of aircraft noise. However, experimental characterization remains essential, either to confirm and drive the numerical simulation or to validate some actual noise reduction technologies. In this domain, France and Europe remain in the lead, with a large set of wind tunnel facilities and especially anechoic wind tunnels dedicated to acoustic tests in the presence of flow. New trends in the experimental domain would be to strive to successfully make simultaneous acoustical and aerodynamic measurements in conventional wind tunnels. This would be a major step, both from a scientific standpoint and from the point of view of competitiveness: scientifically speaking, it would allow us to record correlated acoustic and aerodynamic measurements, paving the way for a better validation of numerical simulations. For industry, it would mean shorter, swifter and cheaper validation processes. In France, Onera is currently working on this new way, through strong developments in de-convolution and de-reverberation techniques.

Aeroacoustics at the crossroad: prospect for integrating engineering and social science

Additionally, regardless of the progress made in the reduction of noise at the source, it is now more and more clearly understood that noise reduction is not only an engineering issue: although dramatic improvements have objectively been achieved over the past 15 years, sensitivity to noise and the related annoyance have increased, at least in Europe, thus triggering a huge amount of work on perception, non-acoustical factors assigned to noise and psychoacoustics.

A new synergetic approach would be to bring these perceptive approaches closer to the technological methods, for instance to precisely determine which patterns or features of noisy events are considered as really annoying, how they are related to physical noise sources and how to deal with them within a genuine acoustic design process. The aviation industry cannot economize on sound design.

These new multidisciplinary ways to address noise issues, beyond aeroacoustics, are also addressed by dedicated French and European experts and especially within the aforementioned networks, X Noise and Iroqua. They may be worthy of being discussed in a future issue of Aerospace Lab ■