IROQUA: A FRENCH INITIATIVE TO REDUCE NOISE AROUND AIRPORTS

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Abstract

This article aims at introducing to Iroqua, a French national framework program dedicated to organize the researches in aeroacoustics. Iroqua was set up in 2005 by 6 major players of the French aerospace industry. This first phase ended in April 2010 and is to be followed by a second one, which will likely start on autumn 2010. In this paper, we browse and summarize some of Iroqua-1's achievements in order to introduce the new perspective that will be adopted for Iroqua-2.

1. General Introduction

Iroqua is a joint initiative launched by Airbus France, Dassault Aviation, Safran, the CNRS and Onera. This Framework Program led by the latter aims at organizing the French researches targeting the reduction of aircrafts' noise, a major societal concern. In this regard, the consortium adopted the European ACARE noise objectives, i.e. to achieve a 10dB noise abatement per operation and to contain the noise in airports areas. Is is worth to mention that tenths of public laboratories and SMEs joint the program once launched.

Basically, the network helped to build common projects between its various members. It also allows surveying the numerous thesis addressing issues in connections with aeroacoustics. Iroqua was quickly identified in the national research landscape as the network for aircraft noise reduction. Therefore, many of the projects built up within Iroqua were granted by traditional research grants providers, such as the Pôles de Compétitivité or the European Commission. However, among these providers, the Fondation de Recherche pour l'Aéronautique et l'Espace (FRAE) took a major role in funding the five first Iroqua's projects – Aerocav, Bruco, Comatec, Combe and Oscar – in the framework of its first call for proposals dedicated to "low noise aircrafts".

In this paper, we browse some of the projects achieved in Iroqua as well as the new perspective with which Iroqua-2 will address the challenge of aircraft noise reduction

Globally speaking, one of the most important features is the successful collaborations allowed by Iroqua. As a matter of fact, the following table displays how some major French aeroacoustics laboratories took advantage from Iroqua through the above-mentioned projects.

	Bruco	Comatec	Combe	Oscar
LMFA	X		X	X
LEA		X	X	X
LMA			X	
LAUM		X		
UTC		X		
ONERA		X	X	X
IUSTI				
INRIA				
CERFACS	X			

Actually many others entities took also part to those projects, including SMEs.

3. Bruco

Bruco was specifically devoted to combustion noise, a source which is increasingly considered as great progresses were made on fan noise this last decade. Combustion noise is of course important when the engines' regime is maximal, i.e. during take-offs. However, this noise source

remained mostly unexplored, tough generally considered as twofold:
- A so-called “direct” noise due to the acoustic waves directly coming from the combustion through the compressor stages,
- A so-called “indirect” noise linked to the entropic mode and to its temperature non-homogeneities which are diffused and act as new noise source.

2.1. Performed work

Among the most significant results achieved by Bruco, EMC2 laboratory build up a dedicated facility for studying the coupling between acoustics and the combustion. In particular, this swirled combustion chamber is driven by a piston which allows controlling the upstream acoustic impedance of the chamber. Therefore, it was possible to find out a given test point where thermo-acoustic frequencies were not excited by the coupling between the cavity modes and the non-stationary combustion. Therefore, it allowed providing a fully characterized reactive flows database with their associated direct noise.
On the other, some Large Eddy Simulations (LES) were performed by CERFACS in order to give account for the EMC2 experimental configuration. The agreement between these computations and the measurements is fairly good for mean and turbulent velocities though the computed pressure levels seem overestimated. Some further explorations are in progress.

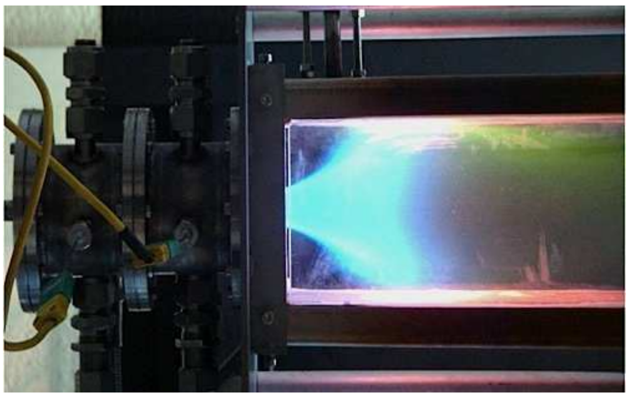

Fig. 1: The dedicated EMC2 combustion chamber

As this EMC2 experimental facility is not suitable to study indirect noise, some analytic developments were performed with the help of one-dimensional models. It helped to give ground to some experimental data previously obtained by the DLR’s entropy wave generator. These analytic models were also used to check LES data obtained on a dedicated Snecma engine.

2.2. Achievements and perspectives

Actually, Bruco gave evidence that the indirect noise contribution is dominant in combustion noise, at least for high-power engines. The achieved facility is also a great outcome of the project as it helped to understand the relationship between the generated noise and the impedance conditions of the chamber. Moreover, the LES computations gave the opportunity to step forward in understanding how far the quality of the numerical simulations impacts the calculated acoustical and entropic perturbations.

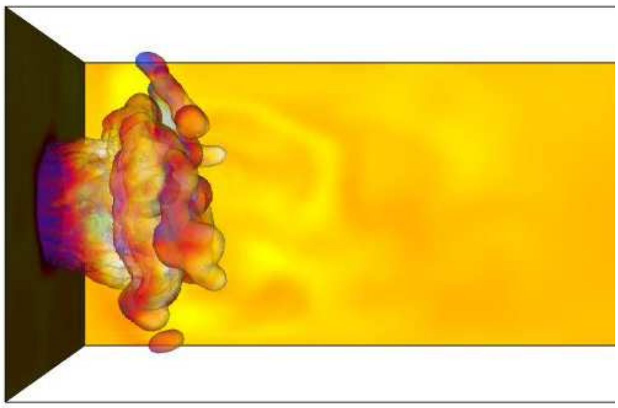

Fig. 2: LES computation of the combustion flame made at CERFACS

3. Comatec

Comatec was chiefly devoted to explore the behavior or liners under grazing flow. Liners – commonly resonant liners - are used in engines’ air intakes and exhausts. Therefore, they endure strong grazing flows. If their impact is quite well understood in presence of acoustic waves alone, this is no more the case when grazing flows are superimposed to the acoustics.

Within Comatec, reference materials were characterized using complementary techniques (Particles Induced Velocimetry, Laser Doppler Velocimetry, microphones…) and measurements were compared to models taking into account the flow. On the other hand, some non conventional materials were also probed.
Comatec implied several entities including laboratories such as LAUM (Le Mans), UTC (Compiègne), LEA (Poitiers), ESPCI/PMMH (Paris), SMEs such as Flowdit, Ateca and agencies as Onera.

3.1. Performed work

The project was actually twofold. One the one hand, some fundamental works were performed on a model material, i.e. a material specifically designed with long and narrow parallel channels (square section 1 mm^2). Actually, it has been shown that under certain conditions, aerodynamic instabilities of the flow over the liner could dramatically amplify the acoustic transmission at the liner resonant frequency. Due to this energy conversion from aerodynamics to acoustics, the apparent transmission loss of a treated duct can be superior to one at this frequency. In order to go further in this kind of exploration, a specific facility has been built which exploits the hydrodynamic analogy. Actually, a water-filled duct with a parietal cavity was excited by an acoustic wave, providing the fact that an air bubble was deliberately maintained at the bottom of the cavity. Thus the motion of the air-water interface was recorded with a fast camera and correlated with the acoustic excitation's characteristics. Follow-ups of this technique are still in progress.

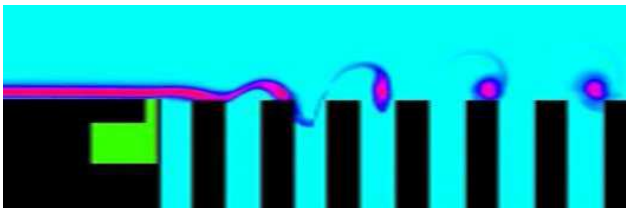

Fig. 3: The flow instability over the model material

On the other hand, acoustical LDV measurements have been performed on ducts treated both by standard – i.e. industrial honeycombs-based – liners and non-conventional liners. In each case various SPL and flows' Mach conditions were applied and two different resistive layers were used: perforated liners or micro-perforated liners. Different families of non-conventional liners were used such as metallic felts, hollow spheres and a Ultra Lightweight Structural Acoustic Panel (ULSAP) recently patented by Onera. In addition to the classical transmission loss measurements, acoustic LDV allows to make a local scan of the acoustic velocity field, in particular close to the orifices of the resistive layer.

Fig. 4: The so-called ULSAP resonators

In summary, it appears that optimal acoustical resistance is achieved with industrial liners covered by micro-perforated resistive layers. Moreover, this resistivity is so-called "linear", i.e. independent from the SPL. This is not the case for simply (coarse) perforated layers for which the resistance departs from this optimal value when the SPL increases.
The same feature is experienced on non conventional liners though these ones show non localized behavior, i.e. behavior that cannot be described by local impedances. This is rather a drawback for their efficiency, especially for liners made with metallic felts or hollow spheres which display a too strong acoustic resistance. This is the case for ULSAP too, but these last materials show broadband absorptions, a feature which is not achieved by classical resonant liners. The forthcoming development will focus on synthesizing liners with the high-level (narrow-band) absorption of classical liners with

the (low-level) broadband absorption of ULSAP.

3.2. Achievements and perspectives

Several results have been achieved in the framework of this project, both from experimental and theoretical point of views. For instance, the detailed observation of the acoustic velocity fields close to the orifices of perforated and micro-perforated resistive layers were performed and analyzed. It helps to provide an onset for understanding why the latter are more suitable for high SPL duct absorption. Moreover, these various experiments help to validate or to give ground to some numerical propagation models and/or methodologies.

4. Combe

Combe was dealing with active control and gather five laboratories in order to study the possibility of achieving noise active control in a duct with high speed flow. This work was clearly aiming at lowering the engines' fan noise which remains insufficiently reduced by passive absorbers.
Actually, though active control had been already tested on full-scale engines before Combe – especially within the European projects Ranntac and Silencer, one can say that the true effect of a high speed flow on noise and active control remained poorly known.

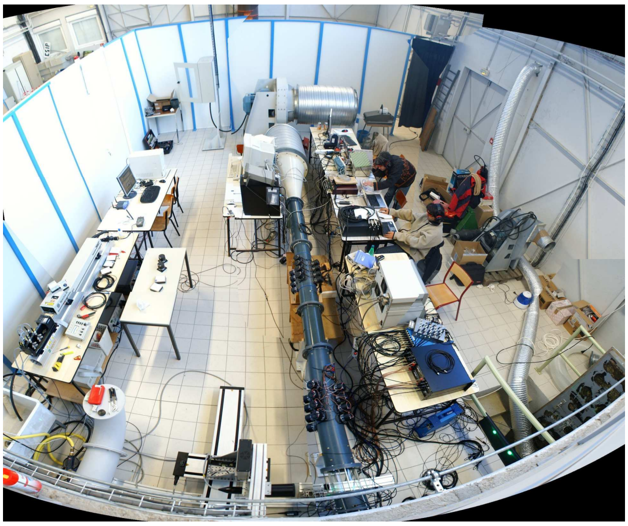

Fig. 5: The common active control facility

4.1. Performed work

The very first objective of the project was to build-up a dedicated facility able to test multimodal active control on ducted noise with flows up to Mach 0.3. Actually, this task became the main fulfillment of the program. From then on, noise active control was attempted with the help of a loudspeakers network along the vein. It helps to understand the previously-observed strong degradation of the control efficiency in the presence of a flow. Therefore, the team developed new algorithm to improve the quality and the range of the control. Moreover, when used in an anechoic chamber, this facility allowed to experiment noise control of the sound diffused from the open vein's outlet.

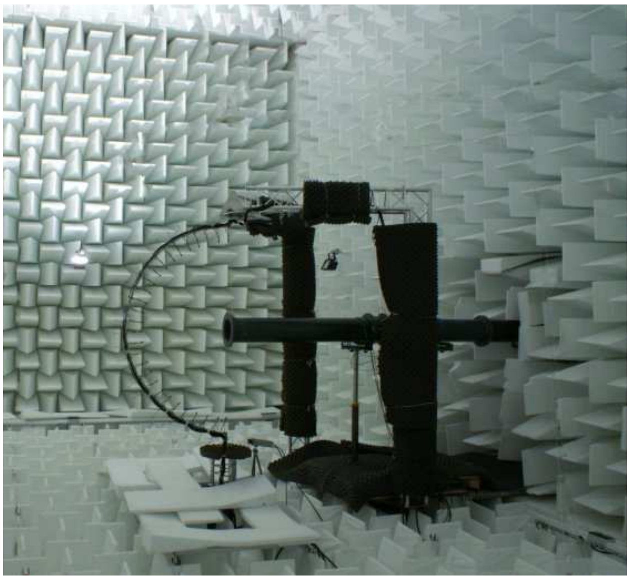

Fig. 6: The facility installed in the anechoic chamber

4.2. Achievements and perspectives

In addition to the aforementioned fulfillments, a major outcome of Combe is the noise control facility itself.
In this regard, it allowed the participation of the involved team in some further developments in a more general framework. In particular, the Combe facility is now in use within OpenAir a comprehensive European research program dedicated to OPtimisation for low Environmental Noise impact AIRcraft.

5. Oscar

Oscar was a program devoted to jet noise and to its reduction through micro-jets. Despite progresses made with large bypass ratio engines, jets are the biggest source of noise at take-offs.

Oscar aimed at validating micro-jets as a valuable noise reduction technique by:

- Achieving the current state-of-art on micro-jets technologies,
- Developing two different pulsed micro-jets coronas,
- Performing numerical simulations to assess the impact of micro-jets on aerodynamics and acoustics,
- Carrying out experiments with steady micro-jets both on cold and hot jets in the MARTEL facility (Poitiers).

5.1. Performed work

In compliance with this program, the state-of-the art on micro-jets was actually updated first. From then on, pulsed micro-jets devices based on two different technologies were made up:

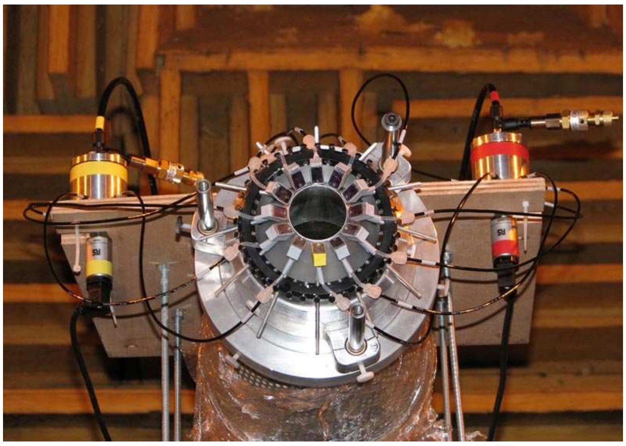

Fig. 7: Micro-valves micro-jets devices around the jet exhaust

The first one was based on self-oscillating micro-valves. These valves are manufactured through chemical etching of silicon layers. Each etched channel is closed by amembrane and in given conditions, a coupling with the fluid triggers self oscillations of the membrane without any external excitation. It leads to high frequency oscillations. In the framework of Oscar, various improvements of the manufacturing process have been carried out to achieve the robustness and the reproducibility of this phenomenon.

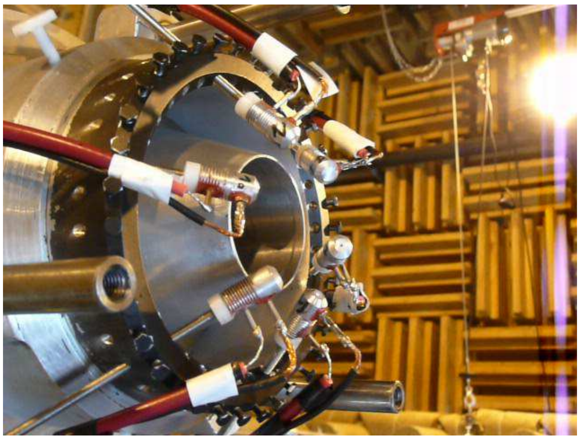

Fig. 8: Synthetic plasma micro-jets devices around the jet exhaust

The second kind of pulsed micro-jets was made with synthetic plasma jets, i.e. air expulsion from a cavity in which a plasma is created with an electrode. Oscar allowed stepping forward in controlling the micro-jet's frequency dispersion as well as its velocity. Nevertheless, some experiments carried out with either the first kind or the second kind of pulsed micro-jets failed to prove the acoustic efficiency of these devices since the frequency and the relative phase of the micro-jets were not sufficiently controlled.

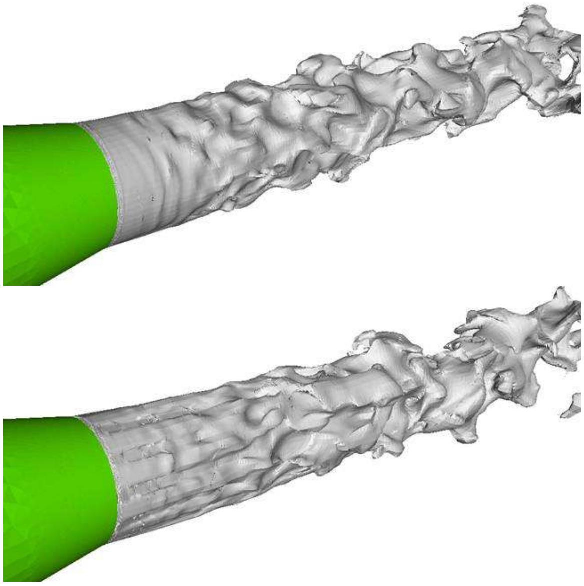

Fig. 10: LES simulation of the jet velocity without (top) and with (bottom) a 3 kHz pulsed micro-jets excitation.

These experimental results were somewhat confirmed by numerical simulations featuring LES computations of the aerodynamic flow and Ffowcs-Williams & Hawking computation of its radiated noise. These numerical simulations gave evidence of a possible broadband noise reduction through pulsed micro-jets, providing the fact that the frequency and phase coherences of this micro-jets are both ensured.

As mentioned, a second part of the project was devoted to get further knowledge on continuous micro-jets. Therefore, some tests were performed with a simple flux jet exhaust equipped with such continuous micro-jets. Experiments made in the MARTEL facility feeded a database of noise radiated in various directions in different configurations (temperatures and flow rates of the jet, number and diameter of injectors as well as the angle of injection).

5.2. Achievements and perspectives

The two most notable results achieved within Oscar are on the one hand the constitution of a valuable database about the impact of continuous micro-jets on the jet noise of engines' exhaust and, on the other hand, the first attempts to assess the impact of pulsed micro-jets on this noise, using two different technologies.

These developments are being followed within the framework of OpenAir, as it is the case for the Combe projects.

6. Iroqua beyond

These above-mentioned projects give an example of what has been done in the framework of Iroqua from 2005 to 2010.

These achievements are primarily resulting of scientific and technical collaborations between public laboratories and private companies in order to address a true public concern, i.e. the aircraft noise around airport which is less and less tolerated by their neighborhood.

Though these efforts are commendable and certainly need to be pursued, they probably fall short to complete their objective as they just represent a technical answer to a more comprehensive problem. The ACARE objective is to lower the *perceived* noise and currently the problem of airlines is to make admissible the noise created by their planes *whatever the actual sound pressure level they produce*. Clearly speaking, it is absolutely not sure that a given plane or a given engine will be considered as less noisy if it just makes less noise.

Therefore, in the forthcoming phase of Iroqua (2010 - 2015), the collaboration will be enlarged to encompass impact and perception considerations. In this regard, engineers and "hard science" teams will be encouraged to work more intensively with experts in psycho-acoustics and, more globally speaking, with specialists in cognitive sciences. In order to increase the efficiency of this broad national collaboration, air traffic regulation bodies as well as airlines will be associated to the process.

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For any comment or follow-up, please contact Laurent Leylekian (laurent.leylekian@onera.fr)

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