Abstracts of the International Conference
ACOUSTIC CLIMATE INSIDE AND OUTSIDE BUILDINGS
held in conjunction with the workshop

"Aircraft Noise Reduction by Flow Control and Active / Adaptive Techniques"

eISBN 978-609-457-704-8
23–26 September, 2014, Vilnius, Lithuania Abstract Number: *acoustic.17*

http://www.acoustic.vgtu.lt/

INCREASE AND DECREASE OF THE NOISE RADIATED BY HIGH-REYNOLDS-NUMBER SUBSONIC JETS THROUGH PLASMA SYNTHETIC JET ACTUATION

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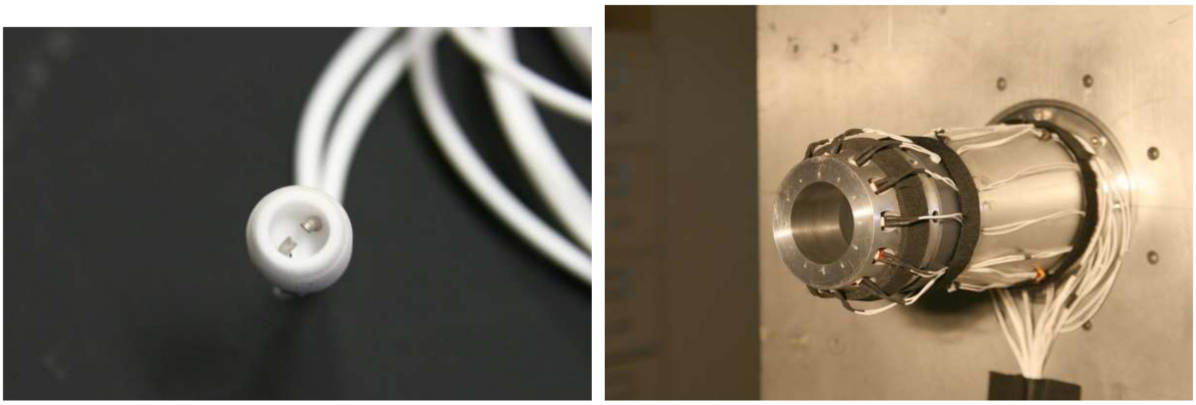
Abstract. Since the discovery of the existence of largescale structures in high-Reynolds-number free shear flows [1] and their role in the radiation of noise to the far field [5], the control of their dynamics has been an important topic for the aeroacoustic community. In the past decades, active noise reduction techniques have been extensively investigated. Continuous fluidic microjets have shown to decrease the far-field overall sound pressure levels of about 1.5 dB in the aft region (Θ = 30°) of high-Reynolds number high-subsonic jets [3]. In order to prevent any thrust penalty due to continuous air injection, other types of actuation are currently being investigated. Recently, Samimy et al. [6] have developed localized arc filament plasma (LAFPA) actuators for jet noise control. Applied on a $M_j = 0.9$, they reported jet noise reduction in the aft region of −0.5 dB to −1.0 dB for actuation Strouhal numbers between 1.5 and 2.0. The present study investigates the use of Plasma Synthetic Jet (PSJ) actuators for the active modification of the noise radiated by high-Reynolds-number subsonic jets.

Experimental setups.

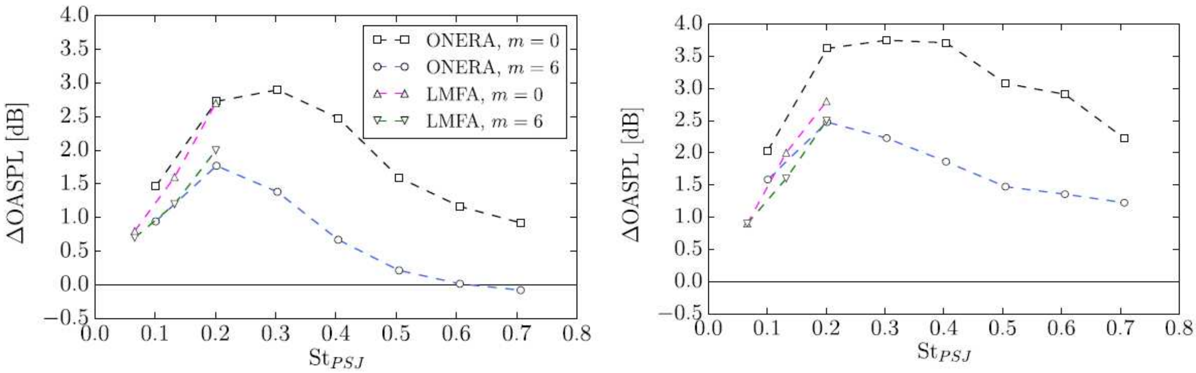
A. PSJ actuator The Plasma Synthetic Jet (PSJ) actuator has been developed at ONERA in the last decade as an actuator providing high control authority over high-speed and high-Reynolds-number flows [2]. Similar to the SparkJet developed at Hopkins University [4], it relies on an energy deposition in a cavity through electrical breakdown between too electrodes, shown in figure 1a. High temperature and pressure rise in the cavity generates a transient exhaust of air through an orifice of the cavity. Equilibrium in the cavity is then retrieved after a suction phase. Depending on the electrical and geometrical design, this actuator may be driven at frequencies up to 4 kHz. For moderate actuation frequencies, transient exit velocities of about 150 m/s can be reached.



(a) (b)

Figure 1: Photographs of (a) the PSJ actuator and (b) the D = 50 mm nozzle equipped with 12 PSJ actuators

B. Jet exit conditions. In this study, a set of 12 PSJ actuators were evenly distributed around the thick lip of a D = 50 mm nozzle, as shown in figure 1b. Various jet exit conditions were investigated, with exit Mach numbers ranging from $M_j = 0.4$ up to $M_j = 0.9$. The definition of the Strouhal number relies on the jet exit diameter D and the jet exit velocity U_j as $St_{PSJ} = f_{PSJ}D/U_j$. Consequently, because of the nozzle diameter and the actuation frequency limit of the PSJ actuator, actuation Strouhal numbers close to 1.0 could only be reached for jet Mach numbers close to $M_j = 0.6$. The Reynolds numbers of these turbulent jets are around $RE_D = 7x10^5$.



(a) Θ = 30◦ (b) Θ = 90◦

Fig. 2. Variations of broadband overall sound pressure levels (ΔOASPL) in dB at (a) Θ = *30*° and (b) Θ = 90° between reference cases and actuated cases at various actuation Strouhal numbers St_{PSJ}, azimuthal actuation (m = 0 and m = 6) and for two campaigns (ECL-LMFA and ONERA), for $M_j = 0.6$.

Results.

Aerodynamic and acoustic measurements were performed both in the ECL-LMFA anechoic jet facility and in the ONERA Toulouse jet facility, as part of the European projects ORINOCO and OPENAIR. PIV measurements and hot-wire anemometry showed large aerodynamic interactions between the microjets and the main subsonic jets. These measurements allowed to shed light on the coherent structures generated by such PSJ actuation. Following these aerodynamic studies, an analysis of the far-field noise of these actuated jets was conducted. Despite some slight differences in jet exit conditions, microphones radial location and actuator properties, part of the acoustic results obtained both in the LMFA anechoic facility and in the ONERA jet facility are presented together in figure 2. Large broadband acoustic response of the jets studied in both facilities was observed for actuation Strouhal numbers close to 0.3. Axisymetric actuation (m = 0) provided the greatest increase in OASPL of about 3 dB at Θ = 30°and less than 4 dB at Θ = *90*°. Driving every other PSJ actuator 180° out-of-phase (m = 6) provided a less important acoustic response of the jets in all directions in terms of broadband OASPL, but allowed an apparent doubling of the actuation Strouhal number, observed on the far-field spectra. With such actuation strategy, slight noise decrease of about −0.3 dB was observed at Θ = *20*° (not shown here) on a $M_j = 0.6$ jet for actuation Strouhal numbers greater than 0.6, corresponding to an apparent actuation Strouhal number of 1.2.

Conclusions.

Aerodynamic and acoustic measurements were performed on high-Reynolds-number subsonic jets actuated with 12 distributed Plasma Synthetic Jet (JSP) actuators, with an emphasis on a $M_j = 0.6$ jet. Large aerodynamic and acoustic response of these jets were observed in two different facilities, suggesting a certain robustness of the action. The present results show that PSJ actuation is able to influence the aeroacoustic sources of high-Reynolds-number subsonic jets, and to modify their far-field noise, with the capability of both increasing and reducing the broadband noise.

Keywords: high-Reynolds number high-subsonic jets, plasma actuators, jet noise control.

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