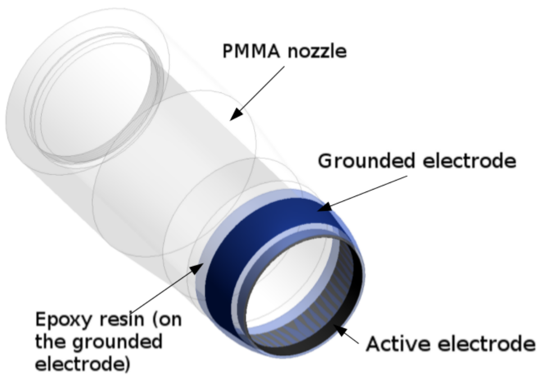
EXPERIMENTAL INVESTIGATION OF NANOSECOND PLASMA ACTUATORS EFFECT ON A SUBSONIC JET NOISE

Laurentie Jean-Charles, Jordan Peter, Benard Nicolas & Delville Joel
Institut PPRIME, Poitiers, FRANCE

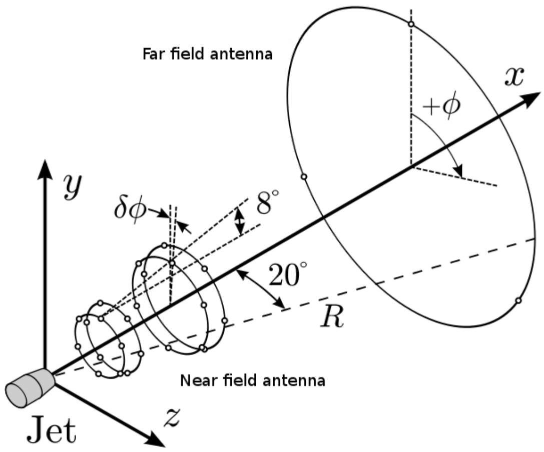
Abstract
Many passive or active methods have been investigated to reduce the noise radiated by round subsonic jets. In this paper, we are presenting a new approach in the area of noise control based on nanosecond plasma actuators. Polar and azimuthal measurement are performed for both far field and near field regions in order to analyse the hydrodynamic and acoustic perturbations induced by this type of actuators.

INTRODUCTION

This paper investigates the near field and far field response of a subsonic free jet (0.3<M<0.9) to a nanosecond plasma actuator. It is commonly admitted that modifying the initial region of a jet can increase or reduce its produced noise. For a subsonic jet, this noise is mainly produced by the turbulent mixing layer in a region of about two potential core length [1, 2]. Measurements of the acoustic and the hydrodynamic pressure fields in this region can provide information on the radiated noise. Some authors proposed numerical models that give a radiated sound, produced by a near field source, very closed to experimental results [3]. Among the active noise control methods one popular approach is the fluidic micro jet actuators placed downstream, just after the output lip of the nozzle. The use of plasma actuators for flow control is not new, however, nanosecond pulsed plasmas is quiet recent in this domain [4], even more in a noise reduction strategy. The main advantage of the plasma actuators is their high degree of modularity in terms of driving signal, allowing a wide range of actuation frequencies (0 to 50 kHz). In the present study the actuator is a Dielectric Barrier Discharge (DBD) driven by a nanosecond high voltage pulsed generator. This plasma actuator is placed in the nozzle, few millimeters upstream the outlet of the jet (Fig.1(a)). Its geometry structure has been designed to actuate the azimuthal mode 0. The driving signal is built of bursts composed with 24 kV, 250 ns pulses at a fixed frequency of f_p=3500 Hz modulated by a low frequency f_b. Varying the number of pulses in each burst sequences results in varying the duty cycle of the signal. Typically the burst frequency f_b is set between S_t=0.2 and S_t=0.4. At each high voltage pulses, a pressure wave is produced.



(a)



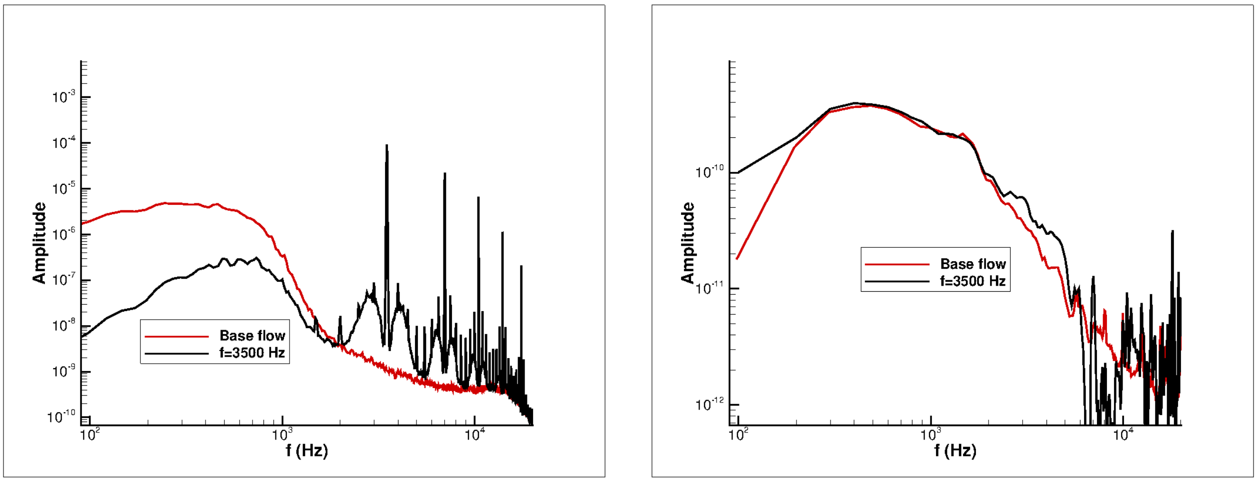
(b)

Figure 1. Sketch of the experimental setup : (a) nozzle and plasma actuator and (b) microphones distribution

Measurement are performed by a near field antenna composed of 24 microphones disposed on an 8° virtual cone. This antenna is divided into 4 rings of 6 equally spaced microphones. A far field azimuthal antenna composed of 3 microphones and a polar antenna with 5 microphones are also used (Fig.1(b)). All these signals are simultaneously sampled a 200 kHz. Signal post treatment is not discussed here, however the use of microphones with plasma actuators is not trivial. While nanosecond plasma actuators produced strong perturbations as well in term of acoustic pollution as in term of electromagnetic emission.

RESULTS

Figure 2 shows a typical power spectra in the near field and the far field area. Some preliminary results shows that this kind of actuator have an authority on the jet. For example,an actuation with duty cycle of 100% (f_b=0 Hz) results in a large reduction of the low frequency part (f<2 kHz) of the near field pressure. However a peak at the driving frequency and the harmonics for higher frequencies are observed. A "broadening" phenomenon is observed around these peaks. That may be the footprint of a distortion due to the crossing of the pressure wave, produced by the plasma actuator, in the mixing region of the jet. This phenomenon has already been observed by Tibbe [5].



(a) (b)

Figure 2. PSD of the base flow case and plasma controlled jet at f_p=3500 Hz, duty cycle 100%, for (a) the near field (x=2 Diameters) and (b) the far field (Polar angle = 20°). Mach number : 0.3 .

For this particular simple actuation, in the far field region, the power spectrum is unchanged in the range of 200 Hz < f < 2 kHz. In the range of 2 kHz < f < 6 kHz, the noise is increased.

CONCLUSION

We have demonstrated here that it is possible to manipulate the jet with a nanosecond dielectric barrier discharge actuator. Although an increase of the radiated acoustic field in the range of 2 kHz < f < 6kHz has been observed, only one control strategy has been investigated here. Some authors have demonstrated that a modification of the control strategy can lead to different results with the same actuator. In the final paper a parametric study involving actuation frequency,duty cycle and azimuthal modes will be performed to analyse the receptivity of the acoustic of the jet to the plasma actuator.

ACKNOWLEDGEMENT

The research leading to the results has received funding from the European Union Seventh Framework Program (FP7 2007e2013) under the grant agreement n° 266103 and the Ministry of Industryand Trade of Russian Federation (project ORINOCO).

References

[1] J. Laufer, R. Schlinker and R. E. Kaplan. Experiments on supersonic jet noise *AIAA Journal*,**14**:489–497,1976
[2] M. J. Fisher, M. Harper-Bourne and S. A. L. Glegg. Jet engine noise source location: the polar correlation technique *Journal of Sound and Vibration*,**51**:23–54,1977
[3] P. Jordan, T. Colonius. Wave Packets and Turbulent Jet Noise *Annual Review of Fluid Mechanics*,**45**:43–62,2013
[4] N. Benard, N. Zouzou, A. Claverie, J. Sotton and E. Moreau. Optical visualization and electrical characterization of fast-rising pulsed dielectric barrier discharge for airflow control applications *Journal of Applied Physics*,**111**:033303-1–033303-13,2012
[5] T. G. Tibbe. Effect of Open-Jet Shear Layers on Aeroacoustic Wind Tunnel Measurements *National Aerospace Laboratory report*,**138**:1–85,2010