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**To cite this version:**

Thomas Humbert, Joachim Golliard, Jean-Christophe Le Roux, Éric Portier, Yves Aurégan. MAINE Flow facility for the measurement of liner properties in multimodal acoustic field with grazing flow. e-Forum Acusticum 2020, Dec 2020, Lyon, France. pp.751-752, 10.48465/fa.2020.0408 . hal-03229439

**HAL Id: hal-03229439**

**https://hal.science/hal-03229439v1**

Submitted on 21 May 2021

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# MAINE Flow facility for the measurement of liner properties in multimodal acoustic field with grazing flow

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**This oral presentation tackles modal control in a flow rig with Mach number up to 0.6. The incident acoustic waves are produced either using a beamforming technique, or either by inverting the transfer function that links each source to each propagating mode. The performances of these techniques will be compared and the influence of the incident acoustic field on the transmission loss of a Single Degree of Freedom liner will be discussed.**

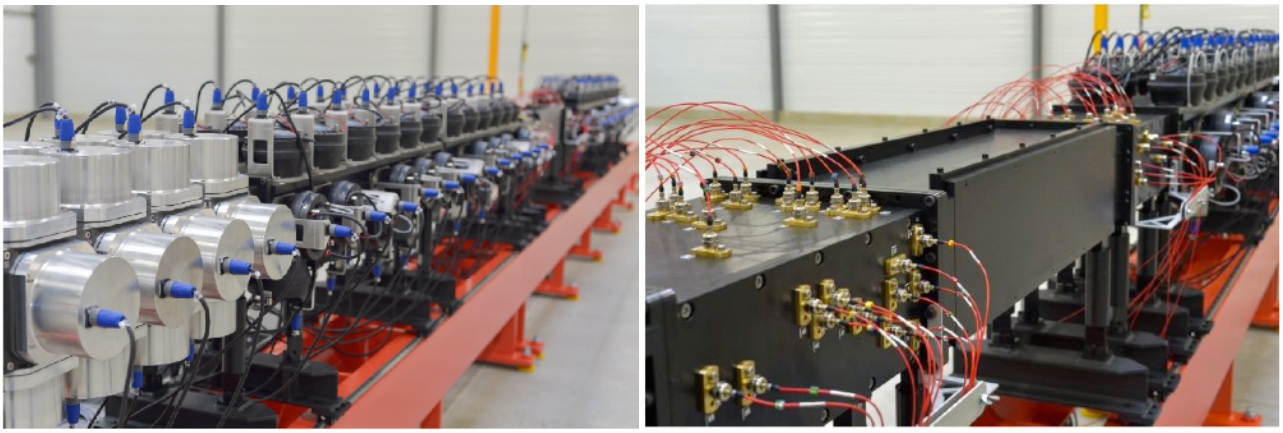

*Figure 1: Pictures of MAINE flow. (a) 24 loudspeakers and 66 compression chambers are located both upstream and downstream the test section. (b) 60 microphones are placed on each side of the test section.*

MAINE Flow (for Multimodal Acoustic ImpedaNce Eduction with Flow) is a new 150 x 280 mm$^2$ rectangular flow duct that allows studying the acoustic properties of liners in flow and acoustic conditions that are typically found in aircraft engines nacelles [1]. For instance, the duct height in the direction facing the liner (280 mm) is close to the free space that faces the liner when installed on the nacelle, especially in the annular by-pass duct. Moreover, the liner is subjected to a grazing flow up to M=0.6 and to an acoustic field up to 150 dB on the frequency range 300-5000 Hz. These sound pressure levels are achieved using 24 loudspeakers (dedicated to generate the low frequency plane wave) and 66 compression chambers mounted on each side of the test section.

One goal of this test-rig is to assess the aeroacoustic properties of liners for controlled complex incident acoustic fields. Both the generation and the modal decomposition of the sound field are not trivial. For the generation step, two methods have been compared :

- Beamforming : the phases of each acoustic channel is chosen so that the required duct mode is favoured.
- Pseudo-inversion of the transfer matrix that links the sources and the modes : given the dimensions of this matrix, a Tikhonov regularisation is required to contain the control amplitudes.

Once the waves are generated, the amplitude of each acoustic mode is calculated from the microphone signals. To that end, the propagation matrix that links the acoustic pressure at each microphone positions to the amplitudes of all propagating modes has been computed. This matrix identification has been verified by measuring the reflection coefficients of a rigid plate mounted perpendicular to the axis of the duct and closing it.

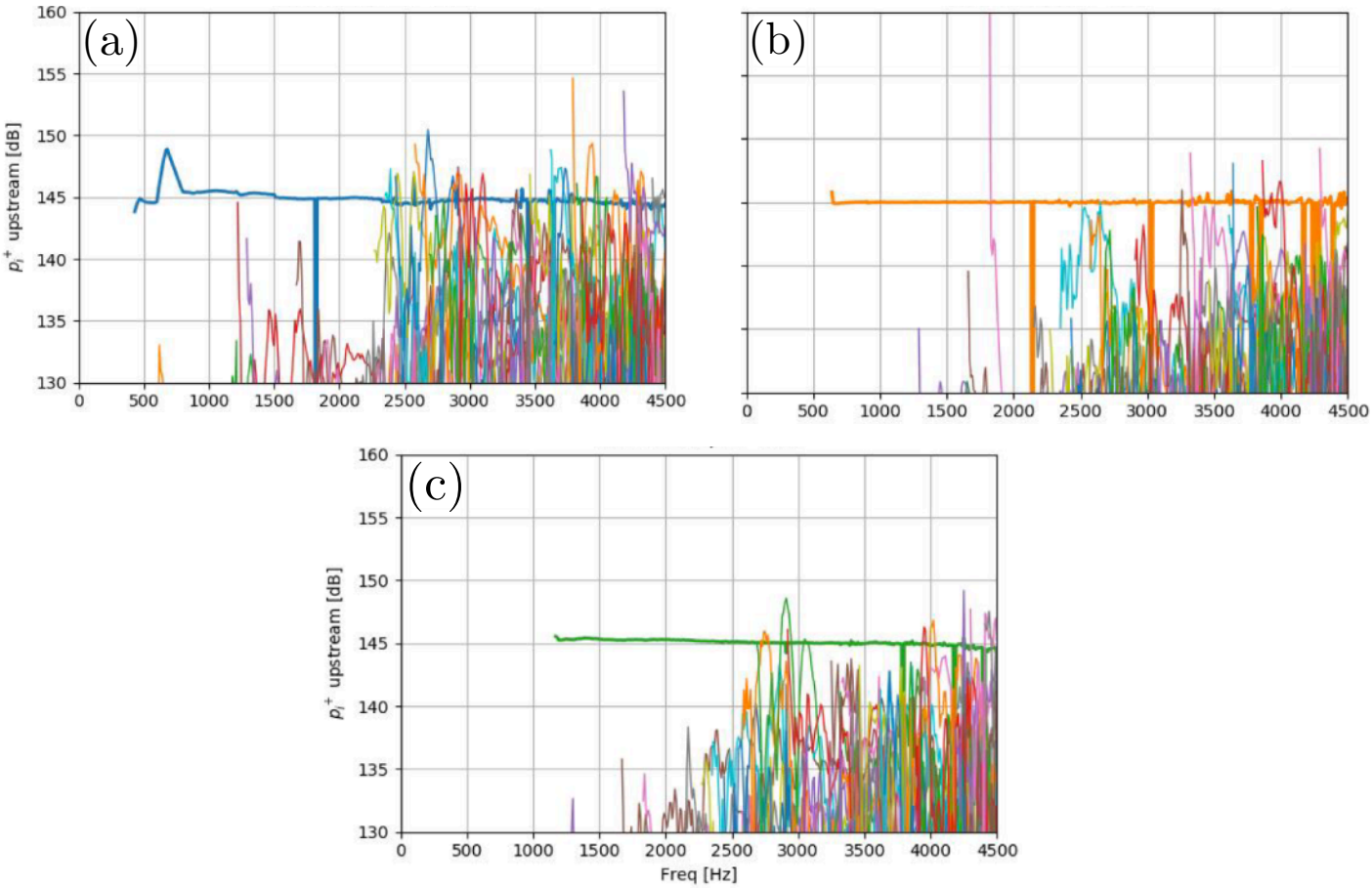


*Figure 2: Experimental parameters : 145 dB, M=0.2. Upstream modal amplitudes as a function of frequency when the plane wave (a), the first mode (b) and the second duct mode (c) are favoured by beamforming. The amplitude of the desired mode is drawn with a thicker line.*

Figure 2 displays the upstream incident modal amplitude obtained for three different acoustic excitation when the flow mach number is M=0.2 in presence of a Single Degree of Freedom Liner (SDOF). For the experiment described in the (a) panel, beamforming was used to favour the plane wave at 145 dB between 450 and 4500 Hz. The amplitude of the plane wave as calculated after modal decomposition is then drawn in blue and has to be compared to the amplitude of the other propagating modes. Up to 2500 Hz, the amplitude of the desired mode is at least 10 dB greater than for the other modes. This is not the case anymore for higher frequencies. The panels (b) and (c) describe the same experiment, but for the first and the second high-order modes, which are respectively drawn in orange and green. It appears that the emergence performances are better for these high-order modes, showing that beamforming is capable to provide a straightforward way to control the acoustic field in a duct with flow.

Several other points will be discussed in the oral presentation. In particular, we will show that pseudo-matrix inversion technique works much better than beamforming in order to generate one particular mode or a combination of modes. Then, this tool will be used to measure the transmission loss of a liner for several flow velocities and incident acoustic fields.

[1] Golliard, J., Leroux, J. C., Portier, E., Humbert, T., & Auregan, Y. (2019). MAINE Flow: Experimental facility for characterization of liners subjected to representative acoustical excitation and grazing flow. In *25th AIAA/CEAS Aeroacoustics Conference* (p. 2682).