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CORRELATION OF NEARFIELD PRESSURE WITH MIXING LAYER VELOCITY IN A SUPERSONIC JET

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INTRODUCTION

The pressure fluctuations generated by a rocket exhaust at lift-off can induce structural vibration capable of damaging the payload. Reduction of these effects requires that the nearfield phenomena be better understood. The said field comprises a complex superposition of hydrodynamic and acoustic fluctuations and the part played by each in terms of the upstream field is poorly understood. To this end experimental measurements have been performed on an isothermal jet with a Mach number of 1.4 and a nozzle diameter of 50mm. The objectives of these experiments are:

- generation of a database to facilitate physical analyses,
- reconstruction of the velocity field using a limited number of nearfield pressure measurements by means of Linear Stochastic Estimation (LSE, Adrian [1]),
- separation of acoustic and hydrodynamic fields with a view to developing phenomenological models capable of predicting the nearfield, farfield and upstream dynamic,
- identification of acoustic-hydrodynamic interactions in the nearfield.

Extensive nearfield pressure measurements have thus been performed, synchronously with two-component LDV measurements, and cartographies of pressure-pressure and pressure-velocity correlations obtained.

EXPERIMENTS

The near pressure field was sampled using a linear array of 39 pressure transducers, and the velocity field investigated using a two-component LDV system. Velocity measurements comprised radial profiles at 8 axial stations, from 1D to 8D, with 30 measurement points per profile. The simultaneous nearfield measurements were performed using a microphone array inclined at 9 deg to the jet axis (in order to follow the expansion of the flow) the upstream microphone being located 0.8D from the jet axis and 1 diameter downstream of the jet exit plane. Additional nearfield pressure measurements were also performed for 8 radial positions of the array (from 0.8D to 4D).

RESULTS AND DISCUSSION

A sample of some preliminary results are shown in figure 1 and 2. Figure 2-a shows the pressure-pressure correlation coefficient for a reference microphone at 5D, where the convection velocity is clearly identified by the slope of the maxima. It is interesting to note that even at this location there is evidence of propagative phenomena, manifest in a weak pattern comprising lines with slope of opposite sign (corresponding to propagation in the uptream direction). Figure 1 shows similar measurements for a radial array location of 1.5 diameter. The pressure field here contains a more significant contribution from the acoustic field, this being manifest in the more marked presence of the upstream propagation pattern. Figures 2-b show the velocity-pressure correlation coefficient for a velocity measurement 3 diameters downstream of the exit plane and 0.3 diameters from the jet axis - this corresponds to the high speed side of the mixing layer. Here again it appears that the convection of large structures is identified by the slope, however there is a slight change of slope implying an increase in convection velocity as we move downstream. This would appear to be related to the increased influence of propagative phenomena as we move in the downstream direction. In effect the microphones at the downstream end of the array are downstream of the main noise generating region of the jet (the end of the potential core). In addition, the criteria of $kr' = 2$ (where k is the wave number and r' is the radiale distance to the center line of the mixing layer) which defines the demarcation between zones where hydrodynamic and acoustic phenomena dominate (see Arndt et al. [2]), gives for these locations cut-off frequencies between 2.5 and 1.5 kHz, which means that the downstream microphones are in a region where the principal acoustic and hydrodynamic energies are of similar order. Thus the downstream microphones are increasingly subject to the acoustic field, hence the change in slope implying higher convection velocities - the slope manifest on the downstream microphones being in effect due to both convective and propagative phenomena.

CONCLUSION

The results presented here represent just a preliminary sample of the results obtained. The next step in the work will involve using the velocity-pressure correlations to generate instantaneous velocity fields using LSE, from which source terms can be generated, whence using an acoustic analogy the farfield noise can be predicted (see Picard and Delville [3], Ricaud [4]). In addition the capacity of a Proper Orthogonal Decomposition (Lumley [5]) to separate contributions from acoustic and hydrodynamic fields will be discussed. Finally these tools will be used to study and better understand the acoustic-hydrodynamic interactions manifest in the near field of the jet.

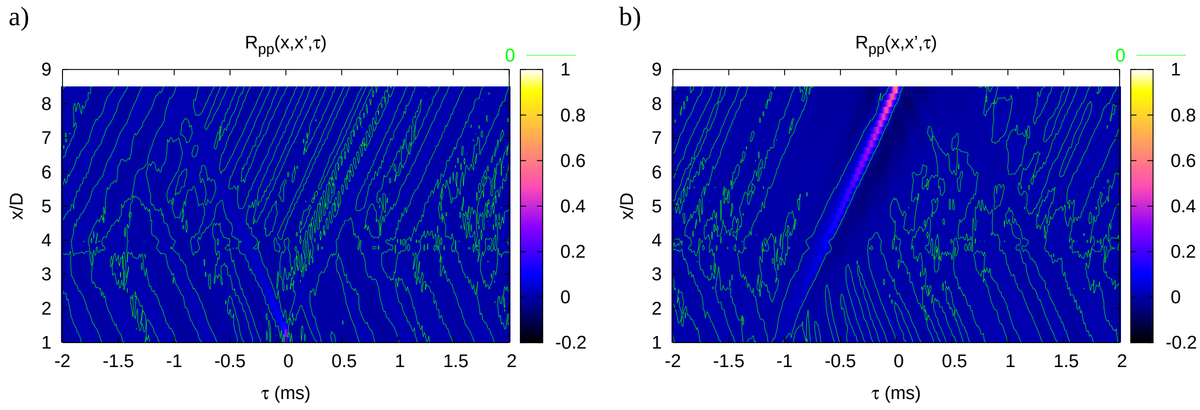

Figure 1. Pressure-Pressure correlation coefficient on a microphone array following the jet expansion, located at the radial position $r/D \in [2, 3.2]$ for a reference microphone at $x/D = 1$ (a), or $x/D = 8.5$ (b). The green lines correspond to a value of zero.

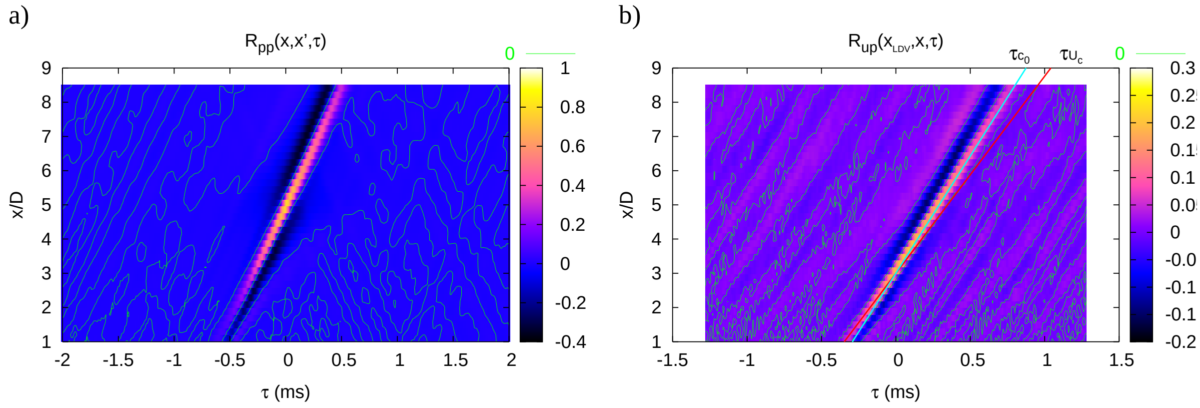

Figure 2. a)Pressure-Pressure correlation coefficient on a microphone array located at the radial position $r/D \in [0.8, 2]$ for a reference microphone at $x/D = 5$. b) Velocity-pressure correlation coefficient for a ldv measurement point located at the position $x/D = 3$ on the high speed side of the mixing layer. The green lines correspond to a value of zero, the cyan and red lines representing propagative and convection velocities respectively.

References

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