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EXPERIMENTAL IDENTIFICATION OF THE SINGLE SOURCE OF SCREECH IN SUPERSONIC ROUND JETS

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Near-field acoustic measurements and time-resolved schlieren visualisations are performed on ten round jets with the aim of analysing the different parts of the feedback loop related to the screech phenomenon in a systematic fashion. The two stages of the screech cycle that set the screech period are examined, namely the convection of the instability wave within the jet shear layer, and the acoustic feedback. The ideally expanded Mach number of the studied jets ranges from $M_j = 1.07$ to $M_j = 1.50$. The single source of screech acoustic waves is found at the fourth shock tip for A1 and A2 modes, and either at the third or the fourth shock tip for the B mode, depending on the Mach number. The phase of the screech cycle is measured throughout schlieren visualizations in the shear layer from the nozzle to the source. Estimates of the convective velocities are deduced for each case, and a trend for the convective velocity to grow with the axial distance is pointed out. These results are used together with source localization deduced from a two microphones survey to determine the number of screech periods contained in a screech loop. For the A1 and B modes, four periods are contained in a loop for cases in which the radiating shock is the fourth, and three periods when the radiating shock tip is the third, whereas the loop of the A2 mode contains five periods.

Keywords: screech noise, supersonic jets, feedback loop

1. Screech noise

Noise produced by imperfectly expanded supersonic jets differs from subsonic jet noise by the emergence of shock noise. Major knowledge about supersonic jet noise is available in comprehensive reviews, for example in Tam [1], Raman [2] or Bailly and Fuji [3]. The present study [4, 5] focuses on the screech, a resonant phenomenon producing a high amplitude acoustic tone from non-ideally expanded supersonic jets. As an illustration, the acoustic spectrum of an underexpanded round cold jet at Mach number $M_j = 1.15$ is shown in Fig. 1 for $\theta = 130^{\rm o}$, where M_j is the equivalent ideally expanded jet Mach number and θ the observer angle taken from the downstream jet axis. The Reynolds number based on the velocity $U_j = 356$ m.s^{-1} and the convergent-nozzle diameter $D = 38$ mm is $Re \simeq 1.3 \times 10^6$. Screech is a sharp tonal contribution of shock noise with a strong upstream directivity.

The staging behaviour of the screech frequencies produced by round jets is also, now, well established.

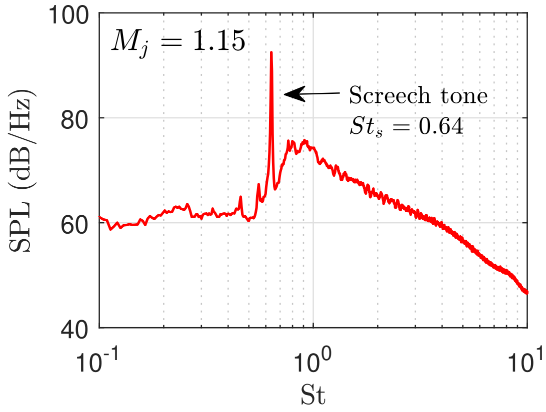

Figure 1: Acoustic spectrum for the $M_j = 1.15$ jet measured at a distance of $55D$ from the nozzle, for an observer angle $\theta = 130^{\circ}$, taken from [5].

Four main modes have been identified, the reader may refer to the reviews above for an historical perspective. The two modes A1 and A2 modes are axisymmetric, whereas the C mode is helical. The B and D modes are flapping in nature, and comprise two oppositely rotating helices, and the secondary mode b is also a flapping mode. In other words, all antisymmetric modes are flapping modes.

2. Experimental identification of screech source

The aim of the present study [5] is to localise in a systematic fashion the unique source of screech feedback with respect to different modes, and at various setting points within the range of a given mode. The knowledge of the source position permits the estimation of the time spent for an instability to be convected from the nozzle to the source, and for the feedback to reach back to the nozzle. From this, the convective velocity and the period of a screech loop are determined. This experimental investigation is based on measurements of near-field acoustic and schlieren visualisations at high frame rate [4, 6] that provide complementary insights into the features of the acoustic and hydrodynamic phenomena related to screech. An instantaneous schlieren view of the $M_j = 1.15$ jet is displayed in Fig. 2 as an illustration. Acoustic and hydrodynamic properties of screech have been extracted for 10 underexpanded supersonic jets of Mach number ranging from $M_j = 1.07$ to $M_j = 1.50$, to cover the A1, A2, B and b modes of screech.

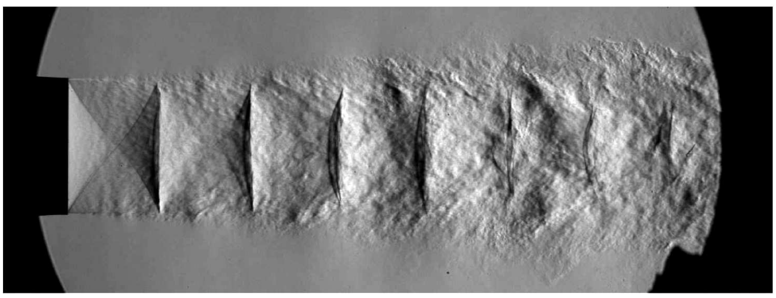

Figure 2: Instantaneous schlieren view of the $M_j = 1.15$ jet (screeching jet for mode A2).

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