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EXPERIMENTAL STUDY OF THE SOUND SOURCE OF THE EDGE TONE

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ABSTRACT
The characteristics of the edge-tone produced by a laminar jet are studied experimentally for the velocity range up to 62 m/s, using 10 mm x 100 mm jet and a wedge with pressure transducers embedded in the wedge surface. The coherence functions between the surface pressure fluctuations and the edge-tone are measured in order to identify the sound sources. Two coexisting sound sources corresponding to two peak frequencies, f_1 and f_2 in the edge-tone spectrum are found on the wedge surface. The spanwise distributions of both sources show strong two-dimensionality while the chordwise distributions show distinguished difference. The coherence function for the f_1 has one rather flat peak while it shows two separate peaks for the f_2. A double vortex structure seems to exist in the flow near the wedge surface resulting in two distinctive pure tones.

1 - INTRODUCTION
A laminar two-dimensional jet impinging on a wedge produces self-sustained oscillation which results in a pure tone flow noise, so called edge-tone [1]. The oscillation is sustained essentially by the feedback, or upstream propagation of the disturbance produced at the wedge to the sensitive area of the shear layer. Although this phenomenon has been studied widely and was reviewed by Rockwell and Naudascher [2], and by Blake and Powell [3] in depth, the precise details of its generation mechanism still remains as an open question. Powell [4] showed that the generation of the edge-tone would strongly depend on the surface dipole distributed over the wedge surface. In this study, the chordwise distributions of the surface pressure fluctuation on the wedge surface were measured in detail, simultaneously with the edge-tone, and the relation between the surface pressure fluctuation and the edge-tone was investigated in order to identify the source of the edge-tone.

2 - EXPERIMENTAL APPARATUS
The wind tunnel used has 10 mm x 100 mm nozzle exit which produces laminar jet with the velocity up to 75 m/s. A triangle wedge has the nose angle of 30°, 250 mm span and 100 mm chord length, with 11 pressure transducers (Kulite LQ-125) embedded in the wedge surface. Figure 1 shows the experimental apparatus. The coordinate system x, y, z has the origin at the center of the nozzle, while the x', taken to downstream along the wedge surface, y', normal to the surface, and z', spanwise have the origin at the center of the leading edge of the wedge. A condenser microphone is placed at x=z=0, y=1.2 m to measure the edge-tone.

3 - RESULTS AND DISCUSSIONS
At first, the optimum streamwise location of the leading edge was explored and it was fixed to be 66 mm down stream from the nozzle exit. Figure 2 shows the change of the edge-tone spectra in the far field with the jet velocity between 4 m/s and 62 m/s. Two distinctive peak frequencies, both increasing with

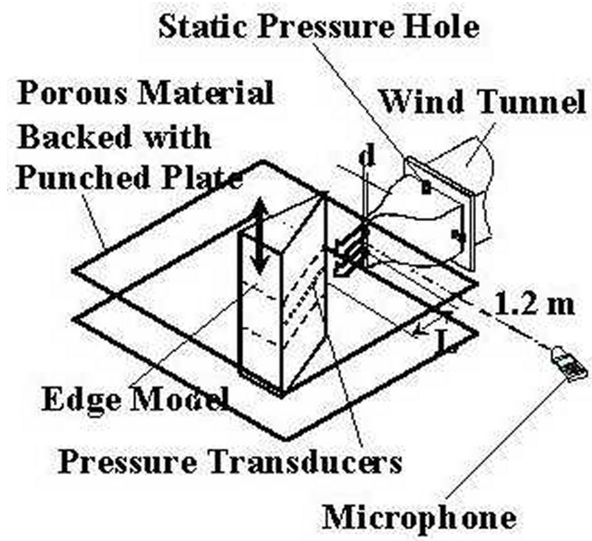

Figure 1: Experimental apparatus.

the velocity, are found in the spectra. The highest peak in the lower frequency is called here f_1 and the other with lesser peak is called f_2, and it was found that $f_2>2f_1$.
Distribution of the pressure fluctuations on the wedge surface and the coherence functions between the far field sound and the surface pressure fluctuations were measured in order to identify the source of the edge tone on the surface. The spectra of the pressure fluctuation at x'=6 mm are shown in Fig. 3. It is interesting to find that the pressure fluctuations do not show the peaks below 45 m/s and the peaks for f_2 are hardly noticeable in comparison to the edge-tone.
The chordwise distribution of the pressure fluctuation coefficient, Cp' normalized with the dynamic pressure of the mean velocity, for f_1 and f_2 are shown in Fig. 4, Fig. 5 respectively. The distributions are rather uniform at the front half of the surface and gradually decrease towards the trailing edge for f_1. The pressure coefficient is much lower for f_2 as expected from Fig. 3. The coefficient is highest near the leading edge and has a mild bump at the mid-chord. It does not depend as strong on the mean velocity as in the case of f_1. The pressure fluctuation at the leading edge, $x'/d=0$, is the stagnation pressure and it is quite large compared to other location. Therefore these data are not plotted in the figures.
The chordwise distribution of the coherence function between the edge-tone and the pressure fluctuation for f_1 and f_2 are shown in Fig. 6, Fig. 7 respectively. While the pressure fluctuation coefficient changes widely for changing the mean velocity as shown in Fig. 4, the coherence for f_1 is remarkably high for all velocities for the front half of the wedge surface as shown in Fig. 6. The coherence keeps high value towards the trailing edge ($x'/d=10$) for higher velocities but it goes down quickly after $x'/d=5$ for lower velocities. The pressure fluctuation contributing to the generation of the edge-tone is supposed to be caused by the vortex generated at the leading edge and conveyed downstream over the wedge surface. Figure 6 indicates that the streamwise length of the vortex is larger for higher velocity.
For f_2, although the pressure fluctuation is quite small, the coherence has two peaks, of which magnitude depend on the mean velocity. Smaller size vortex may be generated at the leading edge corresponding to f_2, and the length might have been stretched as it is conveyed downstream.
Spanwise distribution of the coherence function for f_1 and f_2 are shown in Fig. 8, Fig. 9 respectively. It is quite uniform spanwise (z' direction) for f_1. For f_2, the highest value is limited to the central part only but lower value contours are rather two-dimensional. From these experimental results, the generated vortices seem to have a double structure in streamwise direction but is nearly uniform spanwise.
Further investigation, particularly the distribution of the vorticity in the vicinity of the wedge surface will be necessary to understand the generation mechanism of the edge-tone more precisely.

4 - CONCLUSION

Experimental study of the edge-tone generation mechanism was performed for a laminar jet impinging onto a triangle wedge. Relation between the edge-tone and the surface pressure fluctuation was investigated in detail. The edge-tone has two distinctive peak frequencies, both increasing with the jet mean velocity. The coherence between the edge-tone and the surface pressure fluctuation indicates that there seems to be a double vortex structure which results in the two distinctive peaks in the edge-tone. Further

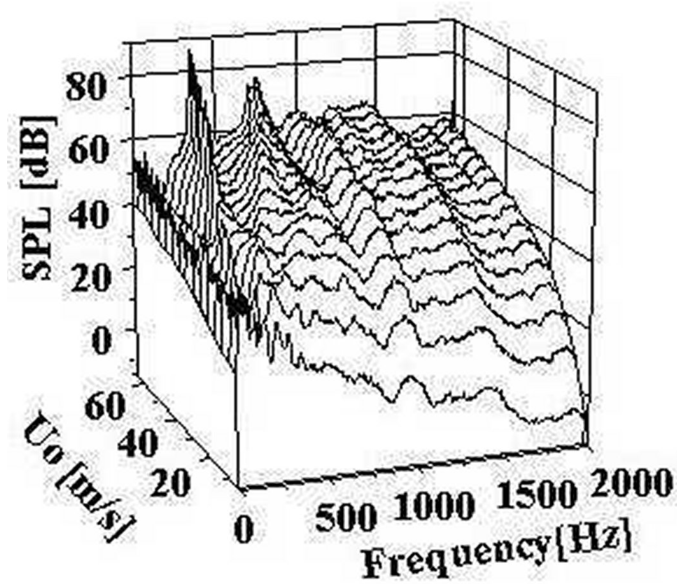

Figure 2: Spectra of the edge-tone.

investigation of the vorticity field is required to obtain clear understanding of the edge-tone generation mechanism.

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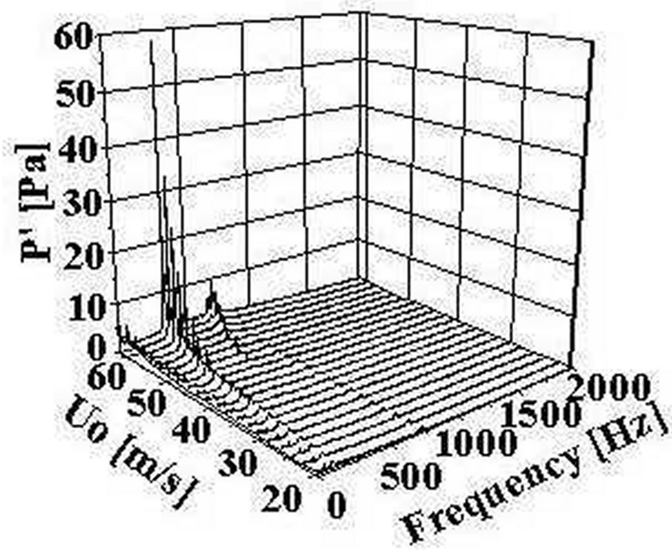

Figure 3: Spectra of the pressure fluctuation on the wedge surface at x'=6 mm.

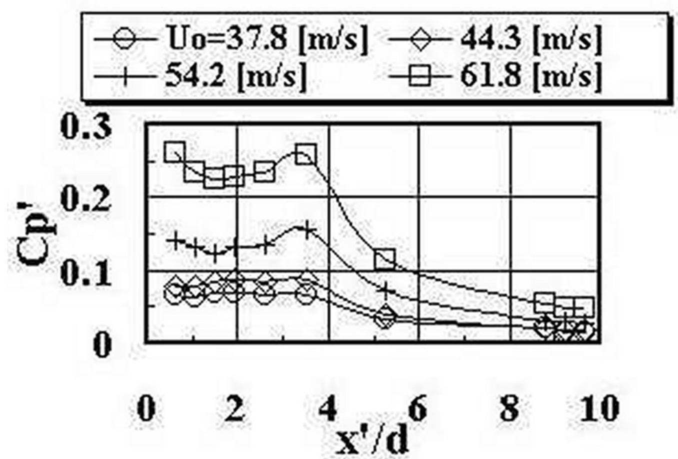

Figure 4: Chordwise distribution of the pressure fluctuation for f_1, d=10 mm.

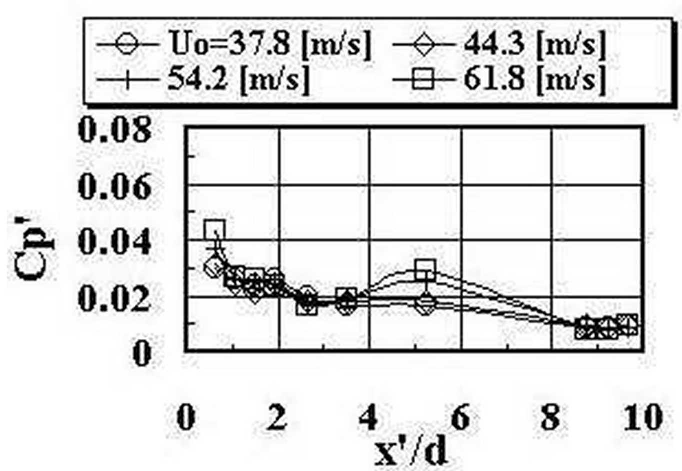

Figure 5: Chordwise distribution of the pressure fluctuation for f_2, d=10 mm.

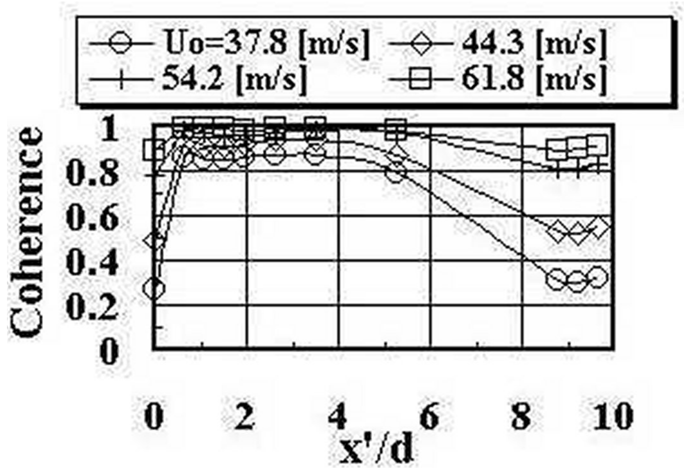

Figure 6: Chordwise coherence distribution for f_1, d=10 mm.

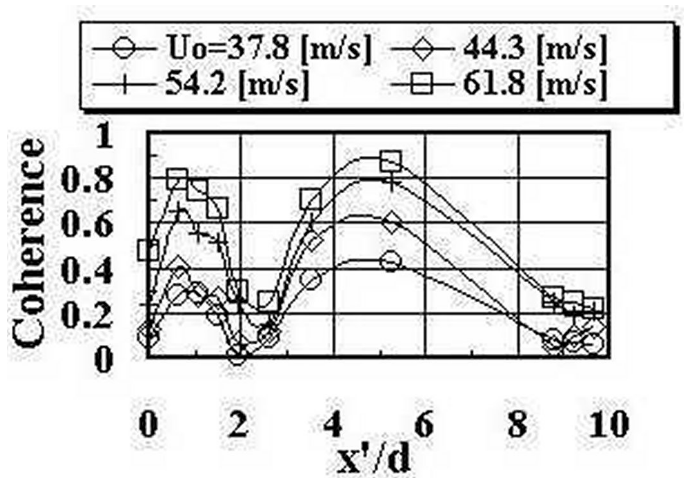

Figure 7: Chordwise coherence distribution for f_2, d=10 mm.

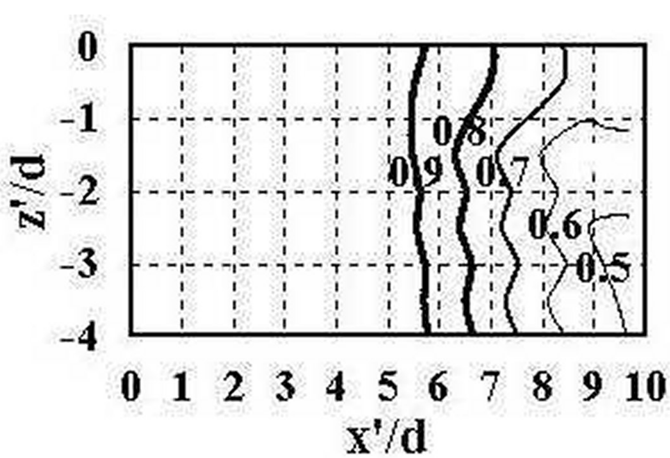

Figure 8: Two-dimensional coherence distribution for f_1, U_0=54.2 m/s, d=10 mm.

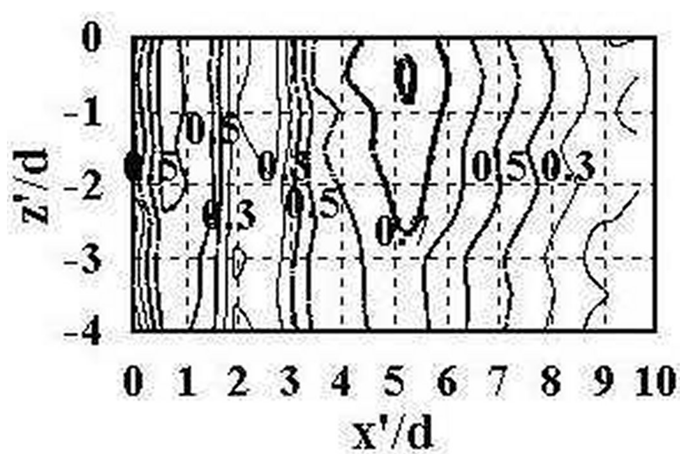

Figure 9: Two-dimensional coherence distribution for f_2, U_0=54.2 m/s, d=10 mm.