Control of Vortex Oscillations by External Sound Excitation at the Corner of a Cylinder

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1. Introduction

Suppression of wind-induced vibrations is frequently a key issue in designing very flexible structures such as long span steel bridges, tall buildings and towers as well as slender structural members. Application of active control concept has also attracted interests of structural engineers these days, and a variety of techniques are now put into practice.

Vortex excited oscillations appearing at rectangular sections are mainly caused by unsteady separated flow from the leading edges. If the separated flow from the leading edge is controlled, vortex oscillation may be suppressed. This experiment investigates the possibility of suppressing flow-induced vibration of structures by applying periodic excitation such as sound wave to the flow around the structures.

2. Experimental setup

Spring mounted model with upper and lower sound effect from the leading edge, as shown in Fig.1, is employed. The rectangular cylinder had span of 600mm. Sound excitation was generated with two speakers placed outside the test section.

Wind velocity will be changed from 2 to 7m/s. The sound frequency of two speakers will be controlled from 0 to 400Hz. During these measurements, the sound pressure was kept about 75dB for each operated sound frequency. The natural frequency of the model equals to 7.23Hz. The experiment was set up with 3 models of pipe section for sound source: vertical, oblique and horizontal.

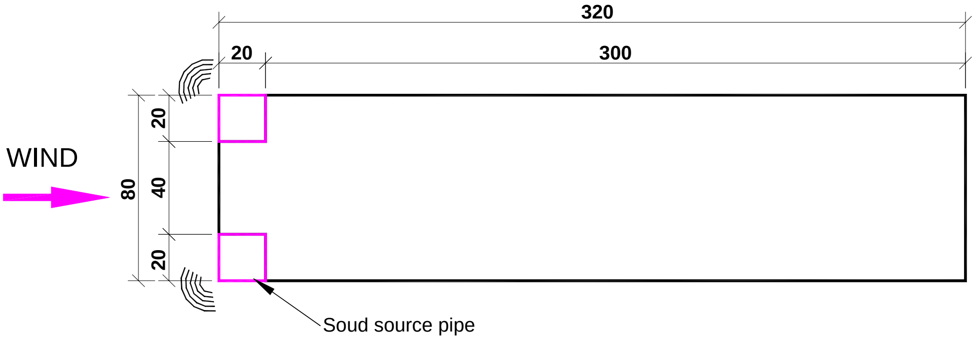

Fig. 1: Cylinder cross section with sound source pipes at the leading edges

From outside of wind tunnel, two speakers produce sound, whose frequency is controlled by an amplifier. Then the sound was transmitted through two steel tubes to the pipes at the lower and upper corner of the model leading edge. The pipe has a slit for emission of sound as shown in Fig. 2.

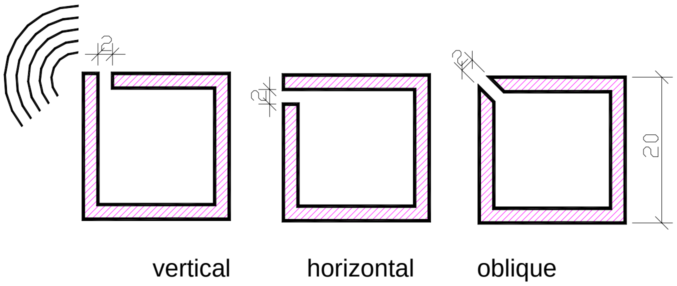

Fig. 2: Cross sections of sound source pipes

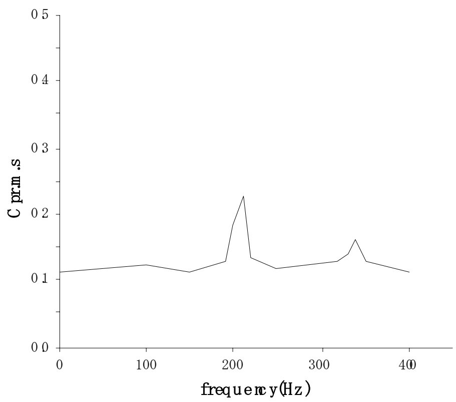

Fig. 3: RMS of pressure coefficient with sound frequency

Key words: vortex oscillation, rectangular cylinder, suppression, applied sound

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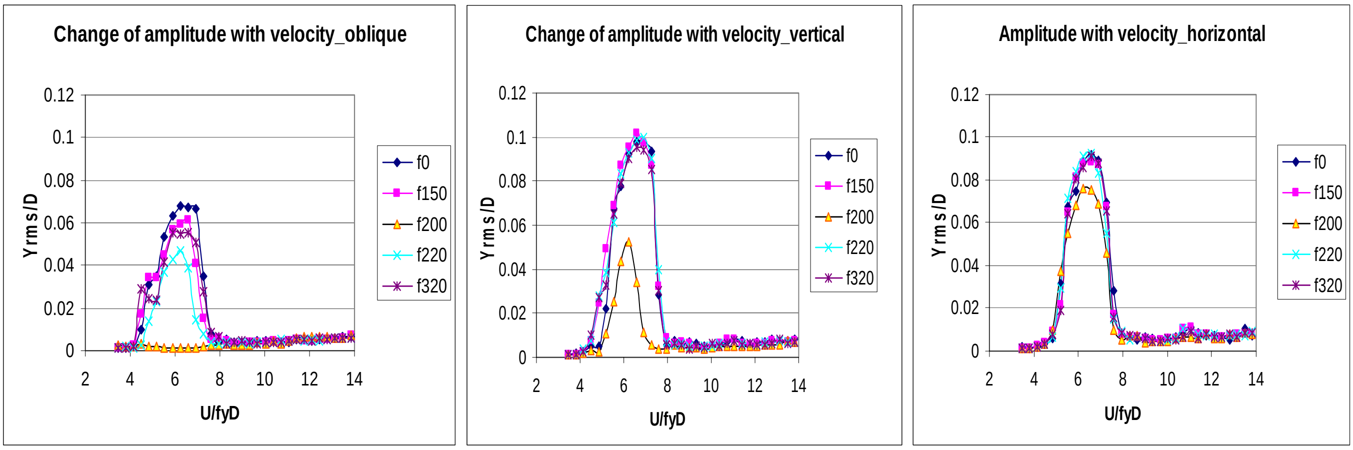
3. Experimental results

The effect of sound pressure on the surface pressure was checked. Fig. 3 shows the value of RMS of pressure coefficient, C_{prms}, at the corner location of leading edge, $C_{Prms} = 2p_{rms}/(\rho U^2)$. The flow velocity was 5 m/s and the cylinder was fixed. The RMS of pressure coefficient increases when sound excitation frequency is about 200Hz and 320Hz. It means that the pressure is more fluctuated at those frequencies.

Through these experiments, it shows that the sound excitation has only important effects on suppressing wind-induced vibration when frequency is about 200Hz and 320Hz.



(a) *(b)* *(c)*

Fig 4: Oscillation amplitude RMS with change of velocity and sound frequency

Y_{rms}, the RMS of oscillation amplitude *U, wind velocity*

f_y, natural frequency of spring model *D, width of the model cross section*

f0, f150..f320: sound frequency

The free oscillation test was conducted with sound pressure. As shown in the Fig. 4, the effect of applied sound on the vortex-induced vibration varies with the sound frequency. In the sound frequency range of 0Hz-400Hz, applied sound with a 200Hz frequency was the most effective to suppress the vortex-induced vibration.

Among three experimental models, the oblique one is effective in suppressing vortex induced oscillations. The sound excitation in case of horizontal model effect little to the separated flow at the leading edge of section.

4. Conclusions

Shear flows around a bluff body are sensitive to periodic excitation such as a sound wave with the specific frequency related to the convective instability of the shear layers.

We would like to set up numerical method for comparing the results. Numerical simulation may also serve as a useful tool to analyze the evolution of flow fields around structures, provides flow visualization and estimate the attendant loads.

Acknowledgement

The authors would like to express the appreciation to Mr. Otaki, a graduate student at Department of Civil Engineering, for his co-operation in these experiments.

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