Experimental Study of Fluctuating Lift Force and Correlation Length for Rectangular Cylinder

Seiji NAKATO

Kanto-gakuin University
Yokohama, JAPAN

nakato@kanto-gakuin.ac.jp

Seiji Nakato, born 1972, received his civil engineering degree from the University of Tokyo, Japan. He is Associate Professor at Kanto-gakuin University, Japan. His main area of research is related to wind engineering.

Summary

In this study, characteristics of spatial correlation of fluctuating wind velocity around rectangular cylinder were experimentally investigated by wind tunnel testing. Spanwise correlation length derived from a Gaussian function fitting to the coherence, simple evaluation using strain gage balance, and windward correlation length were presented. Reduction of fluctuating lift by inhomogeneous section was also proposed.

Keywords: fluctuating lift, correlation length; coherence, vortex shedding;

1. Introduction

In the wake of rectangular cylinder in a cross-flow, Strouhal components are dominant due to vortex shedding. However, the correlation length are scattered and inconclusive. The difference among experimental result indicates that spanwise properties are sensitive to experimental condition such as the detail of the end treatment, aspect ratio and blockage.

Correlation length is of relevance for practical applications of structures e.g. bridges, towers, offshore risers, cables, wires and handrails.

The purpose of the present study is to study fluctuating lift force and correlation length for rectangular cylinder and to investigate fluctuating lift suppression with appendages or openings by wind tunnel experiments.

rectangular cylinder with appendages *rectangular cylinder with opening*

Fig. 1: Model

2. Experimental setup

In this study, the experiments were conducted using the open-circuit wind tunnel with a 0.4m high by 0.4m wide nozzle section. Four types of model which were a circular cylinder , a rectangular cylinder and that with appendages or openings were used in this experiment shown in Fig. 1.

The measurements of drag and lift were conducted by strain gauge type 2-components balances. The measurements of fluctuating velocity were conducted by two hot-wire placed at in the wake in line with the model axis.

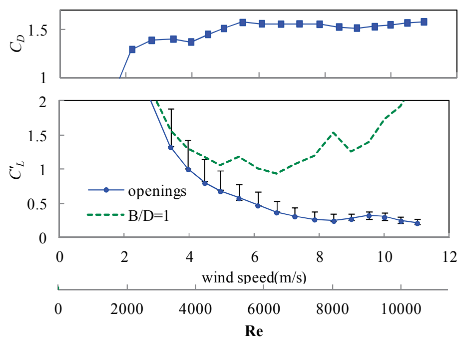

Fig. 2: Fluctuating lift coefficient versus wind speed, dotted line: rectangular cylinder, solid line: rectangular cylinder with openings

3. Results

3.1 Drag and Fluctuating Lift

Drag and lift coefficients for rectangular cylinder B/D=1 and rectangular cylinder with openings shown in Fig. 2. Drag coefficient of rectangular cylinder was almost constant C_D=2.4±0.1 in the range 5×10^3<Re, that agree well with previous experiment. Fluctuating lift significantly changed with wind speed.

Simplified evaluation method of spanwise correlation was employed using lift measured by 2-components balances. The root-mean-square values of the total lift F_L is between root sum square of $F_{L,1}$, $F_{L,2}$ (lift of both side) and linear sum $F_{L,1}$, $F_{L,2}$, which is shown as error bar. In higher wind speed region, the graph shows that fluctuating lift forces at support was fully correlated to each other (not shown here). For rectangular cylinder with openings, C_D of 1.5 is 30 % smaller than that of rectangular cylinder, which is correspond to decrease of projection area. Although *St* decreased a little (*St*=0.14), C_L' decreased significantly by 60% to 90%.

3.2 Spanwise correlation length

The spanwise coherence were represented well by Gauss function $Coh = \exp\left(-ky^2\right)$,where y is spanwise separation. Fig. 3, Fig. 4 show case of rectangular cylinder, that with openings respectively. Correlation length L_C was derived as integral scale;

$$L_c = \int_{-\infty}^{\infty} Coh(y)dy = \sqrt{\frac{\pi}{k}} \quad (1)$$

L_C =8.5 *D*, 8.3*D* respectively. Fig. 4 show a scatter and accuracy of approximation is not good.

3.3 Windward correlation length

Spectrum of fluctuating velocity is narrow-band random vibration with Strouhal peak f_s, so the time series of fluctuating velocities can be modelled as continuous time convolution with impulses. Duration time and windward correlation length defined as

$$T_c = \int_0^{\infty} e^{-h(2\pi f_s)t}dt = \frac{1}{h(2\pi f_s)}, \quad L_{c,x} = T_c \times 0.75U \quad (2)$$

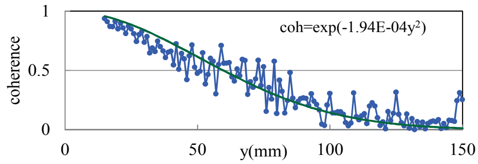

Fig. 3: coherence at f=61 Hz, rectangular cylinder, U=10.0 m/s, Re=9.5×10³

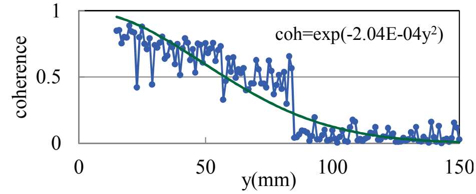

*Fig. 4: coherence at f_p=93 Hz, rectangular cylinder with openings, U=*10.0 m/s

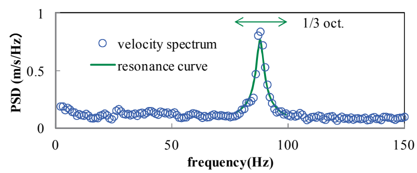

Fig. 5: Fluctuating velocity specrum, rectangular cylinder, y=0, U=10m/s

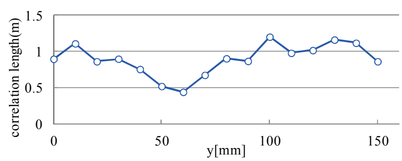

Fig. 6: Windward correlation length, rectangular cylinder, U=10m/s

where h is damping constant. Convection velocity is assumed 0.75*U*. Fluctuating velocity spectrum of rectangular cylinder with fitted resonance curve is shown in Fig. 5. Fitting was given within the 1/3 octave frequency range with center position was peak frequency. Windward correlation length $L_{c,x}$ is of order of 0.5m(33*D*) to 1.2m(80*D*) shown in Fig. 6.

4. Conclusions

The present investigation involves an experiment study of the characteristics of correlation length. Rectangular cylinder with appendages was not effective, but that with openings was effective for reduction of fluctuating lift.

References

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