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Comparison of the Side-Jets and Rear-Jet Effects on the Controllability of Flow-Induced Vibrations

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Abstract

The problem of a bluff body oscillating in a fluid flow has been receiving a great deal of attention. When a bluff body is placed in a flow, it experiences fluctuating hydraulic forces in both transverse and stream-wise directions. It is caused by the formation of vortices behind the body, which could cause large damages of structures. It is called the flow-induced vibrations.

In this article, it is investigated the effects of that side-jets and rear-jet, which is applied to control the vortex shedding. The rear-jet is available to control the flow-induced vibrations according as the body shapes and the velocity of fluid flow in which the galloping phenomena is not appeared.

Keyword: *vortex, flow-induced vibrations, control, side-jets, rear-jet*

1. Introduction

When a bluff body is placed in a flow, the body generates a separated shear layer and vortices in the large rear region of the body. The vortex formation behind the body could be the cause of the fluctuation of pressure field and the hydraulic or aerodynamic forces to the body in transverse direction and stream-wise direction. It can lead large damages of the body.

Therefore, if the vortex formation could be controlled, it would be very useful in engineering. Some methods have been offered to control the vortex shedding frequency or the generation of separated shear layer. Arai & Tani [1] have investigated the method of a using splitter plate, and Igarashi [2] have controlled the flow around a square section cylinder using a rod, which is set in upstream. These methods are shown the effect of alleviating the influence of the hydraulic forces on the structures. They, however, must construct a new other structure around a body in order to control the vortex shedding. In many actual cases, such that features can cause some problems.

There is a method in which jet flow is used in order to control the vortex shedding without mounting a new other structure. Arai & Hong [3] have investigated the effect of side-jets on the control of the flow-induced vibrations with a rigid square-section cylinder. They have found out some interesting characteristics that the inhalation side-jets strongly influence more than the injection side-jets.

In this article, the side-jets are inhaled and rear-jet is generated from the slit, which passed through the body from upstream to downstream. This is one of the simplest methods. There is not using any other new construction or instrument to generate the suppression power for the control of flow-induced vibrations.

2. Numerical Analysis

In this analysis, the 2-dimensional incompressible viscous unsteady flow is solved. The governing equations are the continuity equation and the Navier-Stokes equations. According to the MAC method, the Poisson equation of pressure is calculated. The convection term, which is in the Navier-Stokes equation, is discretized by using the third order upwind scheme and the diffusion term is discretized by using the second order central difference.

On the body surface except the slits of side-jets, the moving condition (which is considered the fluctuation of pressure from the acceleration of body) is applied. The velocity and pressure distribution of the side-jets are treated as the Poiseullie flow. The Sommerfeld radiation condition is applied in the far field.

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In all simulations zero damping is assumed since this would produce the maximum vibration amplitude. In other words, the system is a simple harmonic motion system. The square-section cylinder is allowed to vibrate only in transverse direction with an one-degree-of-freedom, where the cylinder is free to respond in transverse direction. The vibration equation can be rewritten in dimensionless form using the segment length of the square-section cylinder L and the free flow velocity U_∞ as follows;

$$Y_{\tau\tau} + \omega_n^2 Y = C_f / (2m), \tag{1}$$

Where

$$C_f = C_l - 2M^* a_y / (\rho L U_\infty^2). \tag{2}$$

Here m is the mass of cylinder and ω_n is an angular natural frequency of the cylinder. The force coefficient, C_f, is constructed by the lift coefficient, C_l, and the added force due to the virtual mass, M^*, where a_y denotes the acceleration of the cylinder vibration. Equation (1) can be solved easily using the Runge-Kutta method, once the force coefficient is known from the flow field calculation.

In this calculation, we set the segment length L to the length of one segment of square-section cylinder. The slit size is set with $0.03L$ for the side-jets and $0.2L$ for the rear-jet. (see Fig. 1)

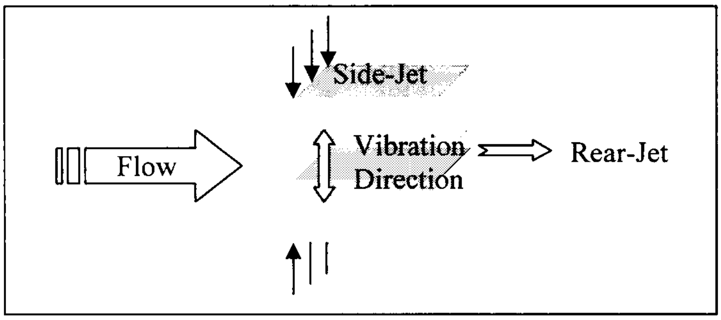

Fig. 1. Schematic of the body.

3. Results

With emphasis on the performance of side-jets and rear-jet on the control of flow-induced vibrations, the numerical simulations were carried out. The results are summarized as follows;

1. The vibration is suppressed by the inhalation side-jets, in which the RMS value of the amplitude is suppressed to about 35 % of the no side-jets case, while the case of rear-jet shows 81 % suppression in the same Reynolds number region. In this case, 100 % means zero effect.
2. The existence of the transition regime is pointed out, in which the galloping phenomena are suppressed perfectly. The key phenomena are the separation, the reattachment, and the secondary separation.
3. For the shape that the galloping phenomenon is usually appeared, the effect of the rear-jet for the suppression of body oscillating cannot be expected. When the entire body is buried in the wake such as square-section cylinder, the possibility that the galloping phenomenon appears is very high.

References

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