Title	On the Vibration of a Pillar Shape Moored in Uniform Flow
Author(s)	NASHIMOTO, Katsuaki
Citation	北海道大學水産學部研究彙報, 32(3), 234-241
Issue Date	1981-09
Doc URL	http://hdl.handle.net/2115/23763
Type	bulletin (article)
File Information	32(3)_P234-241.pdf

Bull. Fac. Fish. Hokkaido Univ.
32(3), 234–241. 1981.

On the Vibration of a Pillar Shape Moored in Uniform Flow

Katsuaki NASHIMOTO*

Abstract

This paper concerns the measurement of a lift force and a drag force of a pillar shape moored in the uniform flow. The lifting force of the pillar shape moored in the uniform flow vibrates regularly by the vortex of its wake. The auto corerogram and the power spectrum are calculated by the vibration of the lift force, the frequency of the vibration of one was analyzed, and the pattern of the eddy current of the wake of the pillar shape of which moored in the flow was estimated.

The frequency of the vibration of the lifting force (f) can be expressed as a function of the water velocity (V) and the length of the pillar shape (L) at Reynold's number of $1\text{–}5\times 10^4$ as follows,

$$f = KV/L$$

where K is the value of the coefficient that has the same physical meaning as the Strouhal number. The value of K changed with the form of the pillar shape and the moored attitude.

It is clear that a method of studying the pattern of the vibration of shape moored in the flow can be used effectively in order to know the surrounding of the sound of the artificial fishreef has a complicated form.

Introduction

Often we discuss that a flow pattern of the vortex by the flow on the wake of an artificial fishreef set up in the sea bed has direct effects upon the mechanism of the gathering fish[1,2]. It is difficult to measure quantitatively this flow pattern and to express it accurately, and moreover, this flow pattern is not clear at present time.

Generally, it is well known that the back position of the body which was set up in the flow generates the eddy current and is vibrated by this vortex[3]. Especially on the back position of a cylindrical body generated Karman's trail at the regular intervals in the region of a low Reynold's number. An appearance of the vibration of the cylindrical body is shown as a function of the water velocity and Strouhal number, but there are still many unclear points about the other bodies of the pillar shape and at the high Reynold's number of the cylindrical body. Recently, the hydraulic characteristics of the vibrating force on a circular pile due to waves have been investigated theoretically and experimentally[4,5]. As offshore structures rise the lift force and the in-line force due to waves, the structures are vibrated by these forces.

In this paper, the lift force and the drag force of the moored pillar shape were measured so that the flow pattern of the back position of an artificial fishereef was set up in the flow is examined. As the lift force of the moored pillar shape is

---

* *Laboratory of Fishing Gear Engineering, Faculty of Fisheries, Hokkaido University.*
(北海道大学水産学部漁具設計学講座)

vibrating violently with time, then, we are trying to analyze the frequency of the vibration of the lift force.

Materials and methods

A triangular pillar, a four-cornered pillar and cylindrical pillar were used as the experimental material. These pillar shapes were used in large quantities for making the artificial fishreef. The size of these pillar shapes used for the experiment have a total length of 75 cm, and a side length of 6 cm and 7.6 cm. Table 1 shows the size of the pillar shape used in the experiment, the weight in the water and mooring attitude in the flow.

A serious problem arises when trying to measure the pattern of the vortex made by the flow. In this experiment, a large-sized experimental water tank of twine symmetric elliptical circuits were used for the measurement. The flow is made by the paddle wheels (2.5 m diameter and 1.0 m width with 16 ridial blades) which are set on each side of the way. This large-size water tank is 25 m long, 9.2 m wide and 1.0 m deep. The central water way is 2 m width and the right and left water way is 1 m wide. The maximum speed of the flow is 2 m/sec.

Fig. 1 shows the schematic illustration of the experimental apparatus. The pillar shape was set up at a distance of 30 cm from the water surface, and was moored using 0.4 mm wire on the point of 200 cm from the upper stream and on the point 350 cm from the ceiling. On the mooring of the pillar shape a streamline body

Table 1. *Size, natural frequency, weight in water and moored attitude in flow on pillar shape which were used in the experiment.*

	Size of a side (cm)	Total length (cm)	Weight in water (kg)	Natural frequency (Hz)
Four-cornered Pillar	7.6	75	3.52	4.7
〃	6.0	75	3.24	2.5
Triangular Pillar	7.6	75	2.61	5.8
〃	6.0	75	2.02	4.7
Cylindrical Pillar	6.0	75	1.43	3.1

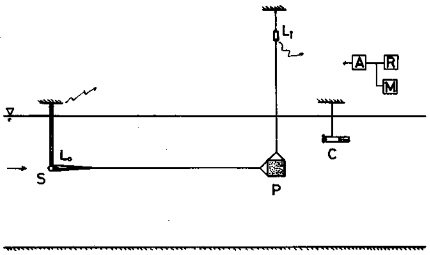

Fig. 1. Schematic illustration of experimental apparatus for measuring lift force and drag force.
C; Current meter, A; Strain meter amplitude, R; Data recorder, M; Voltage difference recorder, P; Pillar shape, S; Streamline body, L_0, L_1; Load cell.

was used which has a thickness of 32 mm and a width of 200 mm. The drag force and the lift force were measured by using a strain guage, recorded on a magnetic tape by data recorder, and monitored with a voltage difference recorder. The speed of the flow in the experiment changed from 20 cm/sec to 70 cm/sec, and was recorded for 60 seconds by data recorder. The water temperature during the experiment was about 17–18°C.

Results and discussion

The record of the drag force showed no change on a constant flow velocity. The small change of the drag force is considered to be an experimental error, but the vibration of the lift force was clearly observed. Fig. 2 shows an example of the measurement results of which the lift force was recorded contiously for 60 seconds. The frequency of the vibration on the lift force shows an increasing tendency with water velocity, and the amplitude of the vibration of the lift force also shows an

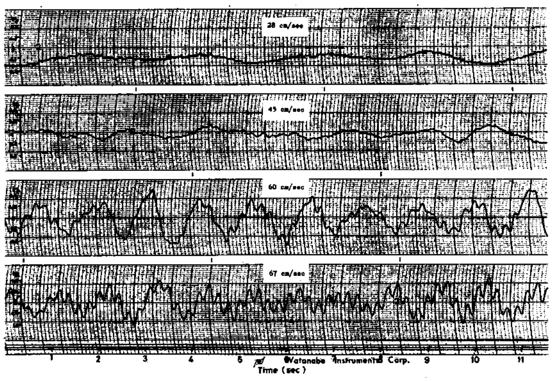

Fig. 2. Example of measuring results of lift force record by using a voltage difference meter.

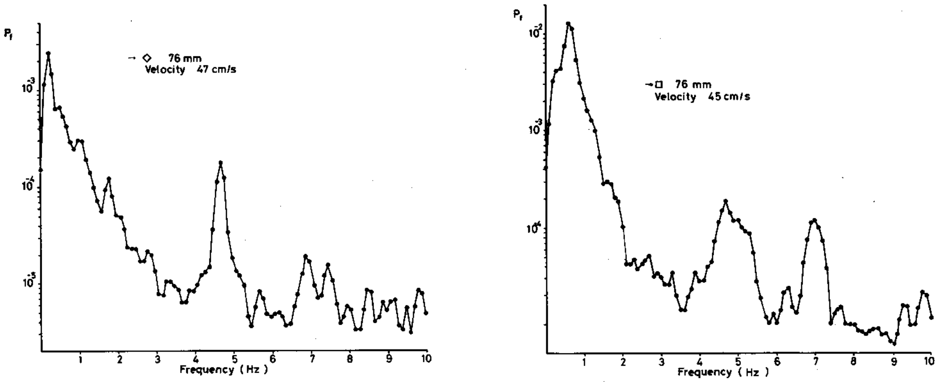

Fig. 3. Example of power spectrum of vibratile lift force for four-cornered pillar moored under conditions of two attitudes.

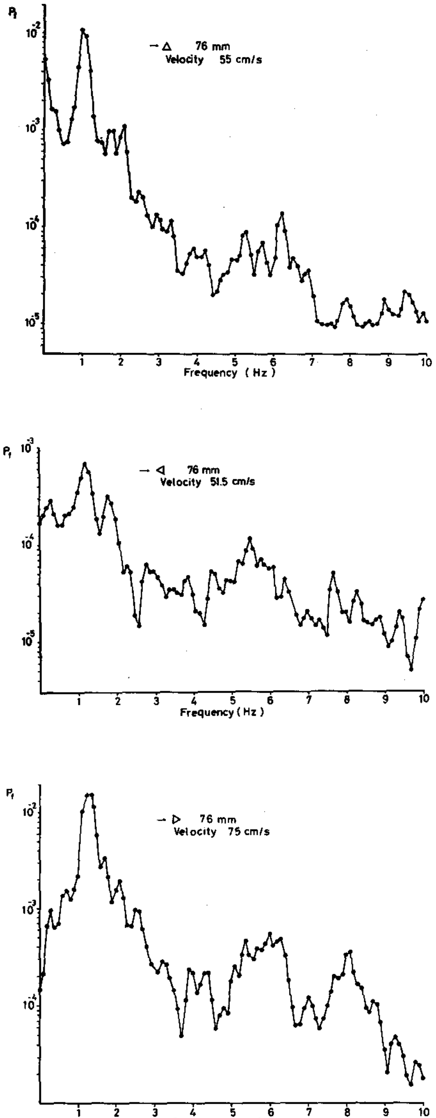

Fig. 4. Example of power spectrum of vibratile lift force for triangular pillar moored under conditions of three attitudes.

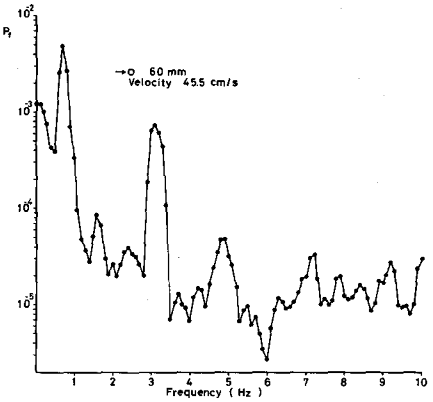

Fig. 5. Example of power spectrum of vibratile lift force for cylindrical pillar.

increasing tendency. To datect quantitatively the change of these vibrations here the auto corerogram and the power spectrum were calculated, and the frequency of the lift force was analyzed for various pillar shapes respectively. The calculation of the power spectrum was done by a treatment with a coefficient of Akaike's window No. 1[6]. The calculation of the power spectrum was done for 20 seconds. The record on a magnetic tape of a data recorder translated the numerical value at a time interval of 0.05 sec, and the samples of 400 were read automatically by a computer on one series.

Fig. 3 shows the example of the power spectrum of the four-cornered pillar under the various conditions of a moored attitude. The frequency of the vibration of the lift force generally has a high noise level, but apparently a conspicuous frequency can be observed from Fig. 3. It is considered that the power spectrum which has a high noise level is due to the vortex of the various sizes existing in the flow made by the paddle wheels. Fig. 4 shows an example of the power spectrum of triangular pillar under the conditions of the three attitudes. Regarding the triangular pillar, the pattern of frequency of the vibration of the lift

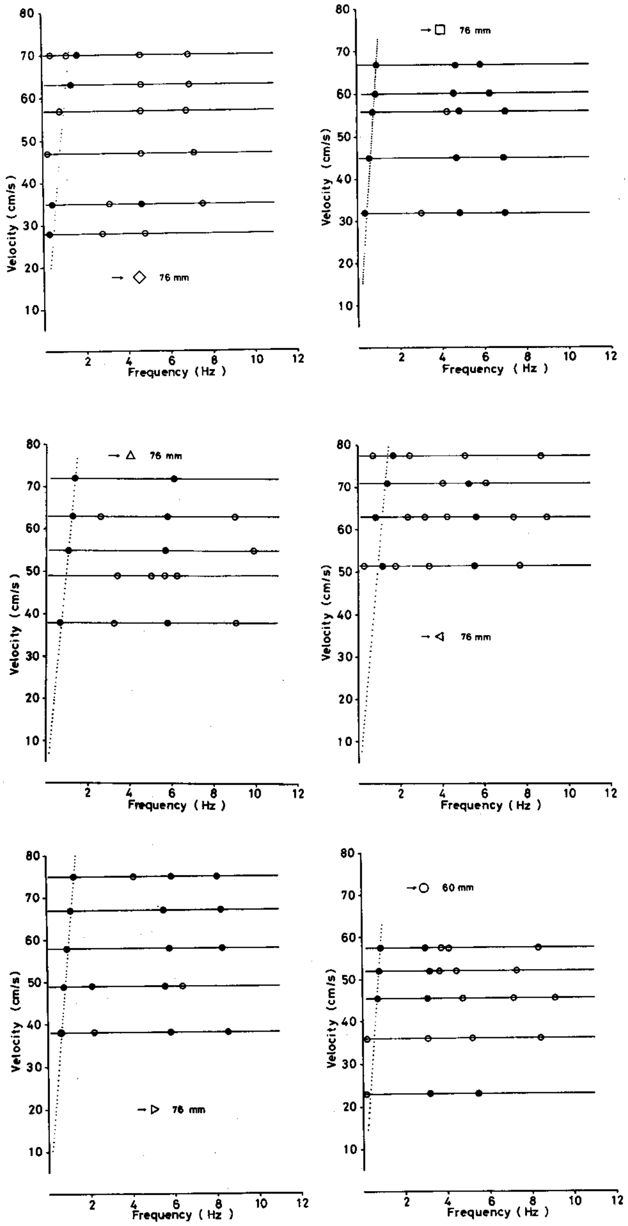

Fig. 6. Relation between dominate frequency of vibratile lift force and speed of flow for various pillar shapes.
●; Most dominante, ○; more dominante.

force shows a similar tendency to that of a four-cornered pillar. A predominant frequency shows a few changing tendencies by the attitude of the pillar shaped moored in the flow. Fig. 5 shows an example of the power spectrum of the cylindrical pillar.

In this paper, the most dominante frequencies and more dominante frequencies were arranged seperately by using the power spectrum and were calculated under the various attitudes with changing the water velocity for the pillar shapes respectively. Relations between these dominante frequencies and the water velocity are shown in Fig. 6. As is shown in Fig. 6, the low frequencies in the most dominante frequencies show on increasing tendency in proportion to the water velocity, but other frequencies do not show any correlation to the water velocity, which obviously has a constant frequency. The reason can be considered to be in connection with the system of the mechanical vibration of the apparatus for the measurement, which is caused by the revolution of the paddle wheels and the natural vibration of the moored pillar shape. The natural frequency of various moored pillar shapes measured are shown in Table 1, and the relation between the water velocity and the revolutions of the paddle wheels per second are shown in Fig. 7.

The wake of the cylindrical pillar moored in the flow can be widely noted to have formed a vortex street, and these vortex streets are fairly stable in Reynold's number of 50–200. Reynold's number of 200–4000 formed the vortex street at regular intervals. The pattern of the vibration of the cylindrical pillars is shown by Strohaul number. It is well known that this number *St* can be expressed as a function of Reynold's number *Re* as follows³⁾,

$$St = f\,d/V = 0.203\,(1-21/Re)$$

where f is a frequency of the vibration, d is the length of the pillar shape and V is the water velocity. On the plate moored in the flow, it becomes apparent that the Strohaul number does not relate to Reynold's number, and it has the value of about 0.15–0.18. Although Reynold's number has the value of about $1\text{–}5\times10^4$ in this experiment, here it is considered to have established a relationship between water velocity, length of the pillar shape and frequency of the vibration. As is evident from Fig. 6, the dominate frequency of the vibration f(1/sec) can be expressed as the function of the water velocity V(cm/sec); the frequency of the vibration

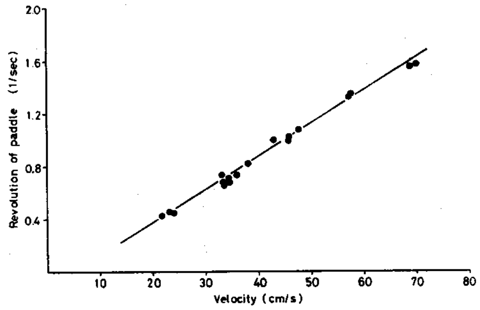

Fig. 7. Relation between speed of flow in water way and revolutions per second of paddle wheels.

Table 2. *Value of K calculated for pillar shapes moored under various attitudes.*

	Size (L) (cm)	Attitude	Coefficient (α) ($\times 10^2$)	$\alpha \cdot$L (=K)
Four-cornered Pillar	7.6	→□	1.4	0.11
〃	〃	→◇	2.0	0.15
〃	6.0	→□	0.9	0.06
〃	〃	→◇	1.7	0.10
Triangular Pillar	7.6	→△	1.9	0.14
〃	〃	→◁	2.2	0.17
〃	〃	→▷	1.6	0.12
〃	6.0	→△	1.3	0.08
〃	〃	→◁	1.4	0.08
〃	〃	→▷	1.0	0.06
Cylindrical Pillar	6.0	→○	1.5	0.09

approximates with an equation of $f = \alpha V$, where α is a coefficient. The value of the coefficient α is calculated for various pillar shapes (see Table 2). Here, let the product of the value of coefficient α and the length of the pillar shape L be replaced by K. The value of K has the same physical meaning as the Strouhal number. The results of the calculated values of K are shown in Table 2. The value of K for the various pillar shapes is smaller at all times than the Strouhal number, and this dynamical reason is not clear. On the four-cornered pillar, the value of K of an angular position which was set up in the upper stream is larger than a side position also set up in the upper stream. On the triangular pillar, the value of K changed by the moored attitude, and the value of K was the largest on the angular position set up in the upper stream in the three moored attitudes. The Strouhal number did not change with the length of the pillar shape, but the value of K for various pillar shapes was large with the long ones. The value of K changed by the moored attitude in the flow of the pillar shapes, and the relation between the vibration of the moored pillar shape and the water velocity were only slightly different, but these relations can be shown fundamentally as $f = KV/L$. It is known that the vibration of the moored pillar shape and the vortex pattern arises in the wake of the pillar shape can be estimated.

The sound around the artificial fishreef for gathering fish are very important. We need to consider the form of the pillar shape and the geometric arrangement for the designing of the artificial fishreef. In the future, we can measure the pattern of the vibration of the moored pillar shape and the pattern of vortex of the wake simultaneously, and will be able to analyze both relations. These experimental results may represent the base of studying the surrounding sound of the artifiical fishreef.

Acknowledgement

The author wishes to thank Dr. O. Sato (Faculty of Fisheries, Hokkaido University) for his helpful advice. The author is also grateful to Mr. S. Fujita for his help in computation.

References

1) Osaka, H., Yamada, H., Hirano, T., Arashi, Y., Okawa, N. and Yamada, S. (1978). Analysis of flow fields around the great-reef type model by wind tunnel testing. *Fisheries Engineering*, **15**, 19–26.
2) Kageyama, Y., Osaka, H. and Yamada, H. (1980). Flow visualization around the perforated cubic artificial fishreef-model by water tunnel testing. *Fisheries Engineering*, **17**, 1–10.
3) Ikemori, K. (1975). *Hydraulics*. 346p. Corona, Inc., Tokyo.
4) Sawaragi, T., Nakamura, T. and Kita, H. (1976). Characteristics of lift forces on a circular pile in waves. *Coastal Engineering in Japan*, **19**, 59–71.
5) Sawaragi, T., Nakamura, T. and Miki, H. (1977). Dynamic behavior of a circular pile due to eddy shedding in waves. *Coastal Engineering in Japan*, **20**, 109–120.
6) Akaike, K. (1973). Analysis of spectrum. p. 28–46. In Isobe, T. (ed.), *A function of correlation and spectrum*. 455p. Tokyo University public., Tokyo.