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◉ 論 文

Experimental Study of Flow Fields around Cylinder Arrays Using PIV

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PIV를 이용한 두 원주 주위의 유동장에 관한 실험적 연구

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Key Words : Particle Image Velocimetry(입자 영상 속도계), Laser Doppler Velocimetry(레이져 속도계), Flow Visualization(유동 가시화), Tandem Arrangement(흐름방향에 평행배열), Side by Side Arrangement(흐름방향에 직교배열), Image Processing(영상처리)

초 록

두 인접한 원주 유동장을 입자 영상 속도계를 이용하여 연구하였다.
실험은 회류수조에서 행하였다. 흐름방향에 평행하게 배치하는 방법과 직교배열의 두가지 방법으로 원주를 배열하였다. 연구 결과는 다른 연구자의 결과와 일치함을 보여주었다. 본 연구를 통하여 입자 영상 속도계를 이용한 유동장 해석이 대단히 효과적임을 알 수 있었다.

1. Introduction

Many researches were done on the flow field analysis around two adjacent cylinders. A lot of applications can be found in many fields, such as, mechanical engineering[1),2)], aerospace engineering[3),4)] and ocean engineering[5)~7)]. This research aims at the ocean engineering applications. Most of the ocean structures consist of cylindrical bodies. Thus the interaction between them are very important phenomenon to be analyzed.

Zdravkovich[8)] published a paper concerning the interaction effects between two adjacent cylinders, in side by side and tandem arrangements. His research was done in the wind

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tunnel. He presented the sketch of the classification of flow regimes. In this study the velocity vector fields were obtained by using the particle image velocimetry. The experiment was done in a circulating water channel. The flow fields were visualized by using laser beam sheet first. Then the video camera recorded the flow fields. The results were transferred to the computer through image board. Noise reduction was done on the input frames of images. After labelling of traces , the center of gravity were calculated. Then the particle identification was done by two frame method. Finally, the flow fields were obtained. Most of the results are in good agreements with those of Zdravkovich.

This research proved that PIV could be a very useful and efficient tool in the flow field analysis.

2. Motivation of the present study

As mentioned in the introduction, Zdravkovich published the paper concerning the interaction effects between two adjacent cylinders. He classified flow interference regimes which are linked to the observed vortex shedding responses for a wide range of arrangements. His results are shown in Fig. 1. In this figure, one can see the rough sketch of flow patterns. The flow characteristics are well described. This figure motivated the present research. That is, the authors wanted to prove the results. The authors wanted to get more detailed velocity vector fields. In this study investigations to get more detailed velocity vector fields were carried out by the application of PIV technique.

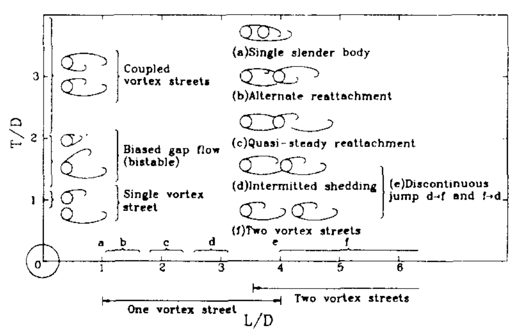

Fig. 1 Classification of Flow Regimes in Side-by-Side and Tandem Arrangements for Stationary Cylinders.
(M. M. Zdravkovich, 1985)

3. Experimental set up

The two cylinders positioned side by side to the approaching flow direction and one behind the other in tandem arrangement.

Table 1 schematically shows test cases. D represents the diameter of the cylinder. The cylinders were made of glass tubing of 54 mm outer diameter and 600 mm long. The experiment was done in a 1.8 m × 1.2 m circulating water channel(CWC) at a speed of 0.5 m/s(Re - 1.78 × 10^{4}). The turbulence intensity was observed to be 2.5%. The test cases were named as shown in Table 1.

Table 1 : Test Cases & Model Name

Uniform Velocity	Test Case	Proximity Interference	Test Case	Wake Interference
0.5 m/s	A	U 1.1D	D	U 1D
			E	U 1.3D
	B	U 1.3D	F	U 2.1D
			G	U 2.9D
	C	U 3D	H	U 5D

4. Visualization

The present study has used a 2-color 4 beam

F-LDV (4 watt, Argon-Ion laser) with back scattering type receiving optics. Flow visualization was done by generating laser sheet beam in the horizontal plane. The flow fields were recorded by video camera through the observation window located at the bottom of the CWC. Fig. 2 shows the experimental set up.

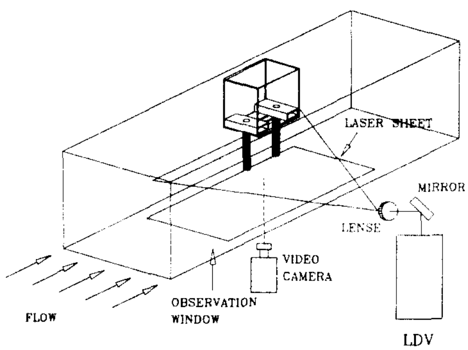

Fig. 2 Schematic Diagram of Test Setup

5. PIV Processing

The input images were obtained through DT-2853 image board at the distinct time intervals. Noise reduction was done on the input frames of image. To obtain velocity distributions from visualized images of flows binary correlation method was adopted. The data fields are binarized with respect to an appropriate threshold value. This process enables us to distinguish the background and particles. Then the individual particles were traced by the correlation functions. With the knowledge of the area of particles the centroids of the particles can be obtained at both frames. Then the flow fields can be represented in vector forms.

6. Experimental results

Flow field around a single cylinder was investigated in advance to figure out the flow characteristics before the flow field analysis around two cylinders was done. The input image of the flow field with the single cylinder is shown in Fig. 3. The velocity vector field is given in Fig. 4. The arrow at the outside of the

Fig. 3 Region of Flow Fields for Single Circular Cylinder

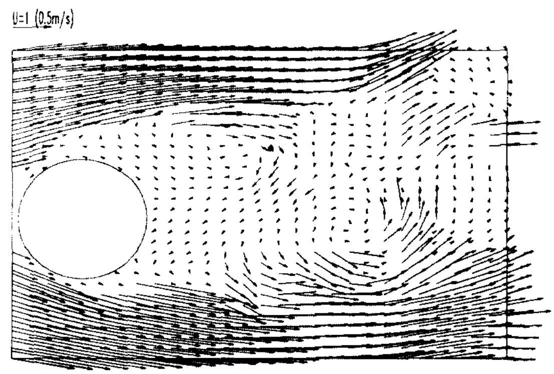

Fig. 4 Vector Fields for Single Circular Cylinder

upper part of the figure indicates the magnitude of 0.5 m/s velocity. This shows a typical flow field around single cylinder. The core of first generated vortex appeared in the upper part of wake region. The second vortex core is located in the lower part of the wake region in the down stream. Fig. 5 represents the result of the test case A. A large single Karman's vortex street is shown in the down stream of the adjacent two cylinders. When the distance between two cylinders increased up to 1.3D (case B), the so called biased gap flow is shown in Fig. 6. The wake region is divided into narrow region and wide region just like shown in Zdravkovich's result. The result of the test case C presents the coupled vortex streets as shown in Fig. 7. The flow regimes in tandem arrangements were

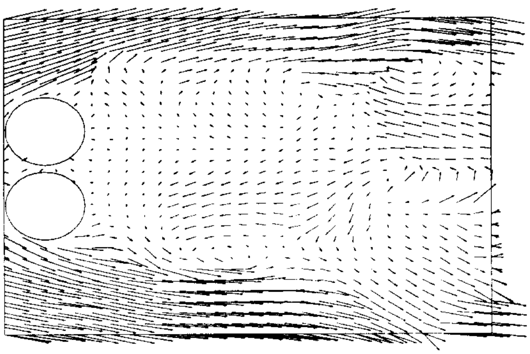

Fig. 5 Vector Fields for A

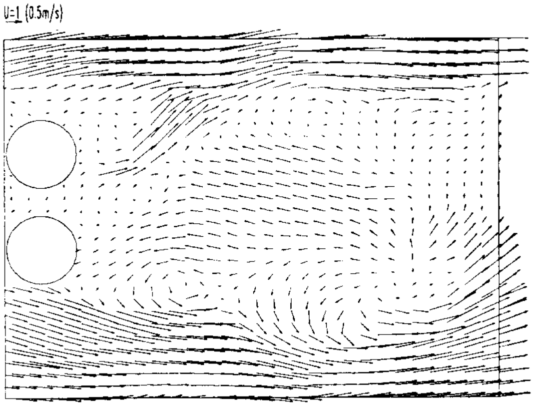

Fig. 6 Vector Fields for B

analyzed next. When the distance between two cylinders is 1D, the flow pattern generated by them depicts the flow field generated by a single slender body as shown in Fig. 8. When the gap reaches up to 1.3D, the flow generated by a cylinder positioned in upstream reattaches in the upper part of the cylinder in downstream. On the other hand, in the lower part of the second cylinder, there is no flow reattached to the second cylinder. In the downstream of the two

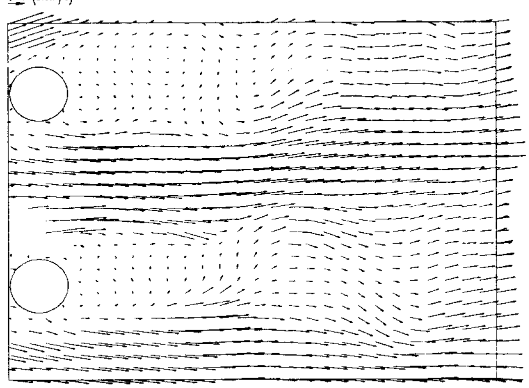

Fig. 7 Vector Fields for C

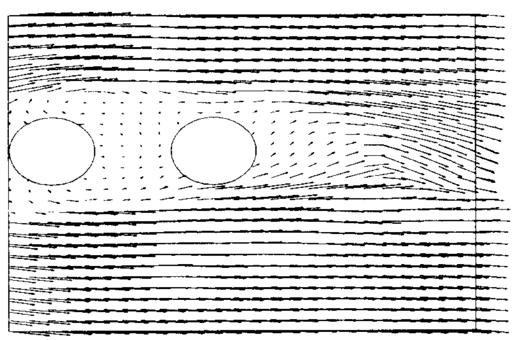

Fig. 8 Vector Fields for D

cylinders very typical vortex shedding can be seen in Fig. 9. Fig. 10 shows the case when the gap becomes 2.1D. The flow past the first cylinder attaches on both the upper and lower upstream side of the second cylinder. Concerning Fig. 11, present research was not able to explain Zdravkovich's result when the gap between the two cylinders become 2.9D. Zdravkovich's results was that occasionally one of the reattachments was disrupted but there was still no regular vortex shedding behind the front cylinder. Finally the gap reaches up to 5D, the flow field features two vortex streets as shown in Fig. 12. Most of the results are in good agreements with those of Zdravkovich. Before stating conclusions, the authors would like to mention about the sources of errors around the boundary regions. We only know the particle behavior in the boundary. Thus the velocity field around the boundary may not be as accurate as that of other regions. Because the analysis has to be done with insufficient information given at the boundary. Three dimensional effect of flow field may cause another error in the process of analysis. Zdravkovich carried out his experiment for Reynolds number ranging from 1×10^4 to 8×10^4. Considering the fact that the present experiment was done in 1.78×10^1, some discrepancies can be expected.

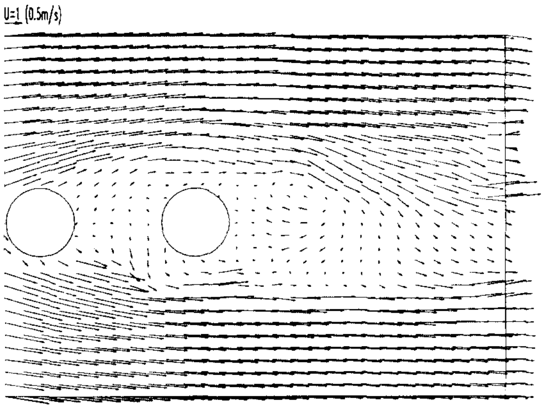

Fig. 9 Vector Fields for E

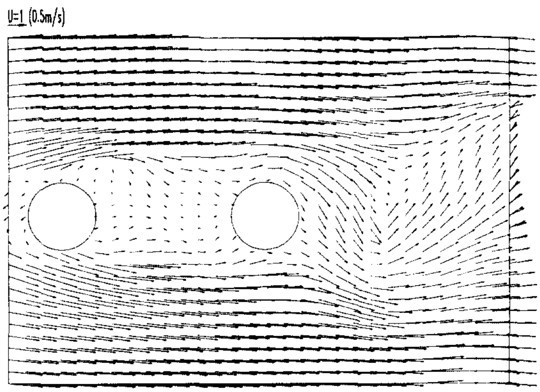

Fig. 10 Vector Fields for F

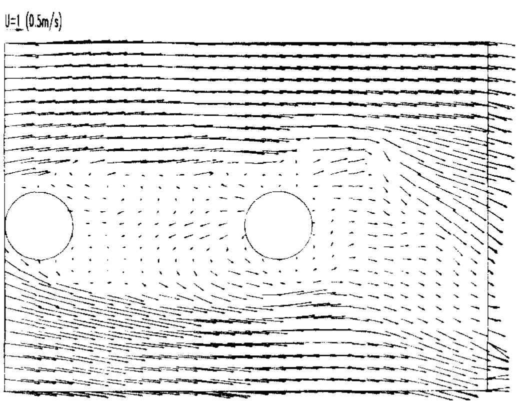

Fig. 11 Vector Fields for G

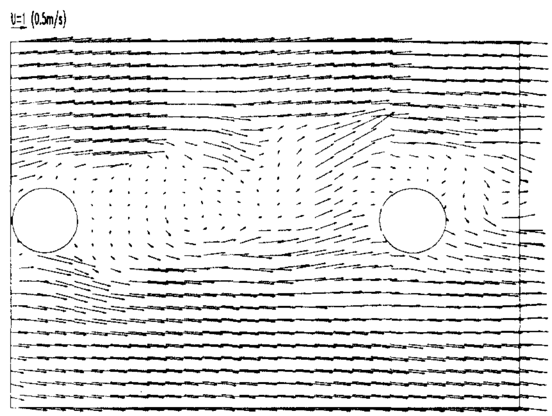

Fig. 12 Vector Fields for H

6. Conclusions

The authors were able to confirm the previous research done by Zdravkovich on the flow field analysis around two cylinders. Moreover, the authors succeeded in representing the detailed flow fields using PIV technique. Many informations about the flow field around two adjacent cylinders were obtained. This research demonstrated the usefulness and effectiveness of PIV technique in flow field analysis. Further applications of PIV technique on ocean engineering look quite promising.

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