Visualization Study of Flow Pattern around Two Obstacles near a Channel Wall with Hydrogen Bubble Technique

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Abstract

Experiments of the flow going past two obstacles near a channel wall were conducted by using the hydrogen bubble technique. In the experiments, two obstacles were located near the bottom wall of the channel at the different heights levels of an obstacle: Y_o = 5 and 10 mm (Y_o/H = 0.5, 1.0), and the three flow situations were corresponding to the pitch length of, P_i = 100, 150, and 200 mm respectively (or pitch ratio, P_i/D = 2.5, 3.75, and 5.0). The flow Reynolds number Re = 490 was studied in the visualization experiment. From the experimental results, it can be seen the situation of the flow-field going past the two obstacles at the different forms.

Keywords: visualization, hydrogen bubble technique, flow field, flow pattern, obstacle

1. Introduction

Flow visualization technique is one of the key technologies in the fluid dynamics. A hydrogen bubble technique, which is an extended technique of the flow visualization, is a strong tool for analyzing the flow field because it provides substantially instantaneous information on the flow and it is considerably used and significantly described by many researchers [1-4]. Recently, the basic knowledge on the characteristics of the flow fields and the heat transfer around the detached ribbed has been dramatically described. Channels with rib disturbed wall are often adopted in heat exchanger systems for enhancement of the heat transfer [5-8]. For works on the detached ribbed channel flows, a lot previous studies were concurred together with the fluid flow around a circular [9], a triangular [10] and a square cylinder near the wall [11-12]. Among the previous studies, the additional heat transfer measurements were made [13-14].

In the present study, a visualization test using the hydrogen bubble technique is reported. To conduct and an experimental study, the flow fields around two obstacles were selected because it has been one of the fundamental subjects in the fluid engineering [5-14]. In the experimental condition, two obstacles or rectangular cylinders were mounted near the bottom wall of a channel at various heights levels of an obstacle (Y_o/H = 0.5, 1.0) and pitch ratios (Pi/D = 2.5, 3.75, and 5.0). All of the experiments were carried out at the same inlet condition with the constant Reynolds number, Re=490.

2. Experimental work

The experimental setup is shown in figure 1. The main components are; rectangular water channels with the test section, the storage tank, the honeycomb and the screen, two the obstacles, PC computer, the visualizing device and the instrumentation.

2.1 Experimental apparatus: The experiments were performed on a horizontal water channel. A rectangular water channel was made of a transparent acrylic acid resin with 2000 mm in length, 40 mm in width and 40 mm in height. The walls of test section

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were made of acrylic plate so that they were transparent for black light and visualization techniques. The obstacle was made of acrylic with cross-section of 10x10 mm^2, it was mounted above the bottom wall of a channel with the two different heights levels of an obstacle are 5 and 10 mm, and placed 1200 mm downstream from the channel inlet, which corresponds to about 30 channel heights (30D). A schematic diagram on the setup of the test model is shown in figures 1 and 2. The coordinates systems are also shown in the figure.

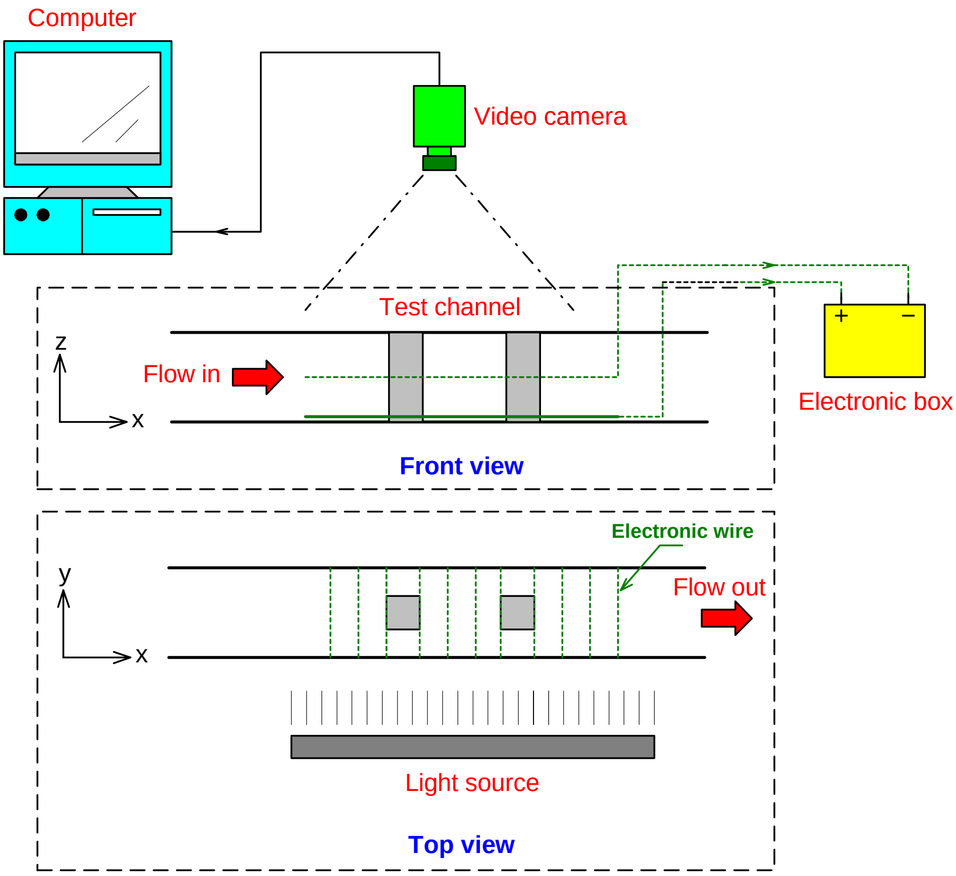


Fig. 1 The function scheme of the experimental set.

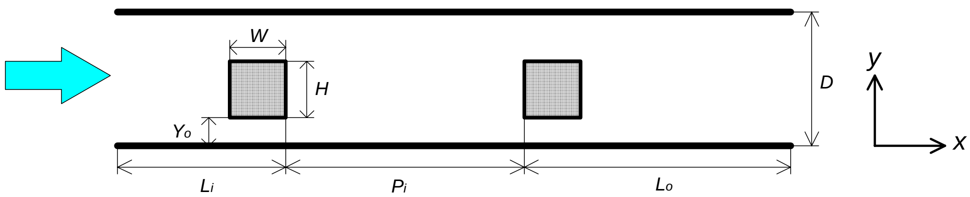


Fig. 2 Sketch of the square obstacle channel flow.

2.2 Flow visualization setup: Flow visualization by the hydrogen bubble technique was carried out under the isothermal condition and the characteristic of the flow from a rectangular channel was examined. Hydrogen bubble was generated by the electrical box and flow with the same water velocity in a channel. Two 50 black light lamps were used to illuminate the test section during imaging storing. A set of electronic wire with 40 mm in length were arranged in a water channel at equal interval lengths of 20 mm, which was controlled the bubble size by an electronic box and a light source was generated from the side wall of a channel. The images of flow patterns in a water channel were observed by a hydrogen bubble and recorded it through the top wall of a channel by using a video camera.

2.3 Operating procedure: The water at the room temperature flows from the reservoir tank to the main channel, and through the obstacle. After passing through the downstream channel, water returns to the reservoir tank. A globe valve to maintain the main flow controlled the water pump at the reservoir tank. The flow rate of the main channel can be set arbitrarily through a Rotameter. The experiments were conducted with fixed Reynolds number, the defined using the hydraulic diameter (D), the upstream velocity (U_o), and the kinematics viscosity of water (v), i.e., ($Re=U_oD/v$). Throughout the experiments, U_o was kept constant at 1.1 cm/s. This gives a Reynolds number, *Re*=490 in the experiments. With such a relatively low Reynolds number, the upstream flow characteristics are almost turbulence free.

Table 1. Details of test section geometry and inlet conditions.

Channel height (D)	40 mm
Channel width	40 mm
Channel length (L)	2000 mm
Obstacle height (H)	10 mm
Obstacle width (W)	10 mm
Height levels of an obstacle (Y_o)	5 and 10 mm
Entrance length (L_i)	1200 mm
Pitch length (P_i)	100, 150, 200 mm
Reynolds number, (Re)	490
Water means velocity, (U_o)	1.1 cm/s
Inlet temperature, (T)	25 ^{o}C

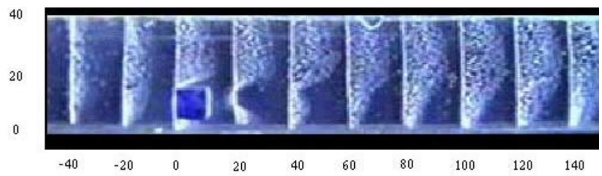
3. Experimental results

From the experimental results on hydrogen bubble technique, it is vividly observed the flow in the rectangular water channel with the placed obstacle. All of the experimental conditions are completely depicted in the figures 3-5.

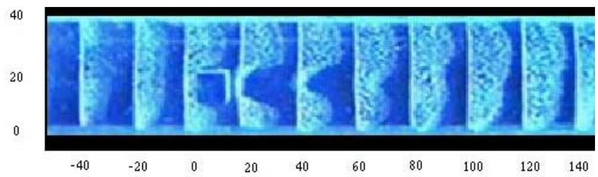
3.1 Flow through single obstacle: From visualization results in figure 3(a-b), it can be vividly observed the flow passing the single obstacle placed in the diversity of the heights levels from the bottom wall channel of 5 and 10 mm. The flow characteristics is presented in the velocity profile or velocity field at different positions of x = -40, -20, 0, 20, 40, 60, 80, 100, 120 and 140 mm, respectively. In the experiments we are assumed that the hydrogen bubble was flow with the same water velocity. It is obvious that at the distance before striking the obstacle happens at x = -40 and -20 mm with the flow characteristics adaptable at the fully developed flow and the wall rim gets the velocity nearing zero resulting from the shear layer, the velocity near the middle of the channel increasingly goes up.

As illustrated in figure 3(a) (Y_o/H = 0.5) when x = 0 mm flow pattern of the water flowing past the obstacle, it is found that the two-profile separation occurs. The first profile which can be seen above the obstacle, appears in the flow of higher velocity than it takes place at the entrance x = -40, -20 mm. It is worth noting that hydrogen bubble moves to longer distance. The facts are more clear that the second profile occurring below the obstacle gets the smaller size resulting from the wall friction or shear layer going higher caused by the surface during narrower flow which flowing past the obstacle to x = 20 mm. This phenomenon enhances 3-part flow pattern with the action of 2-re-circulation flow and backward flow at the middle area of the channel or at the back of the obstacle. This is because of the shear layer while flowing from both profiles. After flowing pass obstacle for a moment, the flow pattern much more increasingly enhances the combination. At x = 60 to 120 mm, the combination of two profiles is more noticeable but it is still not reach to the symmetry flow-field. The flow characteristics are going up to the developing state.

Figure 3(b): the obstacle is placed higher from the bottom wall of the channel than it used to be around 5 mm (Y_o/H = 1.0). It is indicated that the entrance characteristics are similar to the flow pattern as shown in figure 3(a) at x = -40 and -20 mm. It is obvious that the flow channel under the obstacle is wider, and consequently: this influences the flow pattern changing to the bigger size. In the meantime, at x = 20 mm it is found that the characteristics of re-circulation flow and backward flow still remain with extended bigger size. After this condition happens, the combination of the flow pattern of the above and the below obstacles much more increasingly goes up, however, in can be seen in 2 profiles. After x = 60 mm, the profile cannot meet the symmetry flow-field.



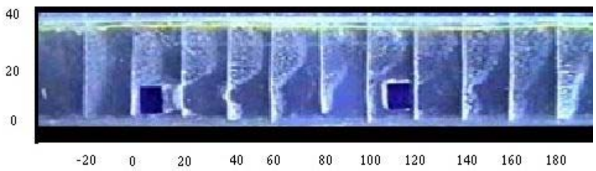
(a) Obstacle height level = 5 mm (Y_0 = 5 mm)



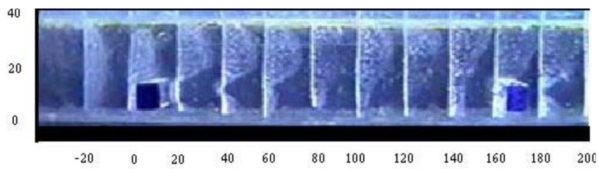
(b) Obstacle height level = 10 mm (Y_0 = 10 mm)

Fig. 3 A visualization of flow around single obstacle with various heights levels.

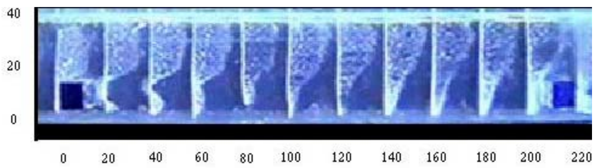
3.2 Flow through two obstacles: As shown in figures 4 and 5, it is depicted the flow passing the obstacle at the pitch length equal to (P_i) 50, 100, 200 mm with the flow pattern similar to the single obstacle. Meanwhile, in figure 4(a) the position of the flow passing the obstacle at x = 60 and 80 mm, it is worth observing that the flow pattern is still not in the combination which is different from figure 3(a) due to the induced from the second obstacle. Concerning the figure of the water flow after passing the second obstacle, it can not be clearly seen the re-circulation flow and backward flow caused by the loss of the potential in the first obstacle. This condition enhances the ring size of the re-circulation smaller as happened in figure 5(a) of which the flow field characteristics are similar. Consequently the difference is only that the flow under the obstacle has bigger size as shown in figure 3(a). While the pitch length is wider to 150 and 200 mm as shown in figure 4(b-c) and 5(b-c). It is concluded that the flow field characteristics after the first obstacle have the similar characteristics of the flow after passing the single obstacle. By the fact of the result of the substantially excessive distance of the pitch length, the results in no significant effects appear from the second obstacle.



(a) Pitch length = 100 mm (P_i/D = 2.5)

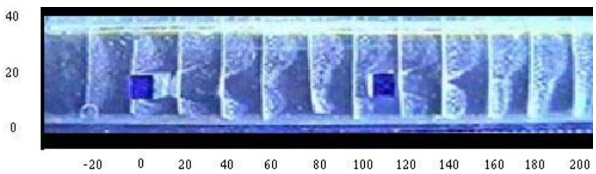


(b) Pitch length = 150 mm (P_i/D = 3.75)

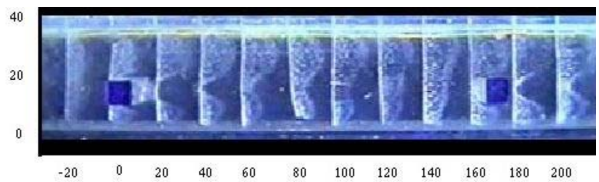


(c) Pitch length = 200 mm (P_i/D = 5.0)

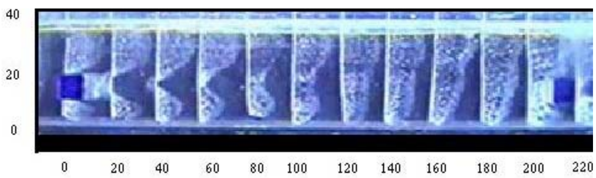
Fig. 4 A visualization of flow around two obstacles with various pitch lengths (Y_o/H = 0.5).



(a) Pitch length = 100 mm (P_i/D = 2.5)



(b) Pitch length = 150 mm (P_i/D = 3.75)



(c) Pitch length = 200 mm (P_i/D = 5.0)

Fig. 5 A visualization of flow around two obstacles with various pitch lengths (Y_o/H = 1.0).

4. Summary

The hydrogen bubble technique has been used to obtain detailed of the flow pattern in a water channel with an obstacle placed near a bottom channel wall with various obstacle heights levels which is Y_o = 5 and 10 mm and pitch length is 100, 150 and 200 mm. From the experimental results it can be summarized as follows:

- The more the pitch length increases in the amounts of structure, the lesser the flow between the two obstacles gets the significant effects.
- Concerning the obstacle of the heights levels near the middle channel, it is dramatically described the flow after passing the obstacle to the flow as the fully developed flow with a lot more and more increasingly faster.

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