

Control of Vortex Shedding around a Circular Cylinder by Using Meshy Wire

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Abstract
The PIV measurement results are presented in this study for the flow around a circular cylinder surrounded by meshy wire. The diameter of the cylinder, D was 50 mm and the tests were done for the Reynolds number of Re=5000. Wire meshes having different porosities (β=0.5, 0.6, 0.7, 0.8) with different wire thickness (b=1mm, 2mm, 3mm, 4mm) were used. The effects of porosity, β and wire thickness were investigated and the results were discussed to find out the optimum cases for effective flow control. Reynolds shear stress, $<u'v'/U_\infty^2>$ results show that the vortices formed by the cylinder are suppressed and the velocity fluctuations in the wake region were affected by the meshy wire that surrounds the cylinder. The optimum wire thickness is b=4mm for each porosity value to control the flow structure the best results are achieved by β=0.6 for all cases.

Keywords: PIV technique, meshy wire, vortex shedding, circular cylinder

1. Introduction

The shedding of vortices can induce unsteady forces with small amplitude to a resonant frequency which provokes structural failures [1]. The undesired strong structural vibrations, substantial increase in the average lift and drag fluctuations, enhanced mixing acoustic noise excess energy loses and other flow induced problems occur particularly.
Therefore suppression of vortex shedding has a significant importance in engineering applications like bridges, marine and offshore structures, oil and gas pipelines, tall buildings, chimneys and turbine blades, heat exchanger tubes, cooling systems for nuclear power plants, power transmission lines etc. [2]. As the environmental conditions can't be changed, an effective control technique should be used to reduce the vortex induced vibrations.
The flow control around a bluff body in a flow has been studied at various areas of engineering and science Most of the studies are on circular cylinders because of its importance and practical applications. The main aim of the flow control is destroying the occurrence of vortex shedding in the wake region where the flow separates from the surface and a turbulent region behind the cylinder is created if the pressure begins to increase in the rear half of cylinder.
Both active and passive control techniques have been carried out to control the flow around a bluff body. Passive control techniques are easier to apply and modify a flow without external energy expenditure.

Splitter plates were usually used as a passive control method [3-5]. Akilli et. al [6] investigated the effect of splitter on the suppression of vortex shedding in shallow water by using PIV technique. The study denoted that the splitter plate having different thickness had the same influence on the flow characteristics but a substantial effect on suppression of the vortex shedding for the gap ratio between 0 and 1.75D . They also studied the flow characteristics of the wakes behind the circular cylinder by attaching splitter plates. [7]. It was found that the frequency of vortex shedding decreased until the length of plate to gap ratio L/D=0.6

Setting up a small cylinder near main cylinder is another method that was used by [8-10]. Modification in the trailing edge geometry was also studied [11]. Sahin et al. [12] studied the flow structure around the base of the vertical cylinder mounted on a flat plate for the Reynolds number of Re=4000 by using high-image density particle image velocimetry. They observed that in the forward face of the cylinder base, three different stagnation points occur. Gozmen and Akilli [13] studied on the control of the flow around a circular cylinder surrounded by outer permeable cylinder in deep water. As a result of all of the experiments flow structures can be passively controlled by altering the surface configuration or attaching additive devices to a bluff body. The purpose of this study is to observe the effect of meshy wire that surrounds a circular cylinder on the control of wake structure downstream of the cylinder placed in deep water using the PIV technique. Four different wire thicknesses b=1mm, 2mm, 3mm, 4mm with different porosities β=0.5, 0.6, 0.7, 0.8 were used for this purpose.

2. Materials and Method

Experiments were carried out in a large-scale water channel located in the Fluid Mechanics Laboratory at Cukurova University. The model of water channel is shown in Fig.1. The water channel test section is constructed of transparent Plexiglas with the thickness of 15mm with upstream and downstream fiberglass reservoirs. And the channel has the dimensions of a length of 8000mm, width of 1000mm, and a depth of 750 mm. It also has honeycomb screen arrangement, which is located at the entrance of contraction. These reservoirs and honeycomb screen arrangements are used to maintain the turbulence intensity below 0.1 %. During all experiment, the water level was (h) maintained at the depth 550mm of and the water flow speed is controlled by an axial flow pump. Pump rotation speed was controlled by an ABB controller unit.

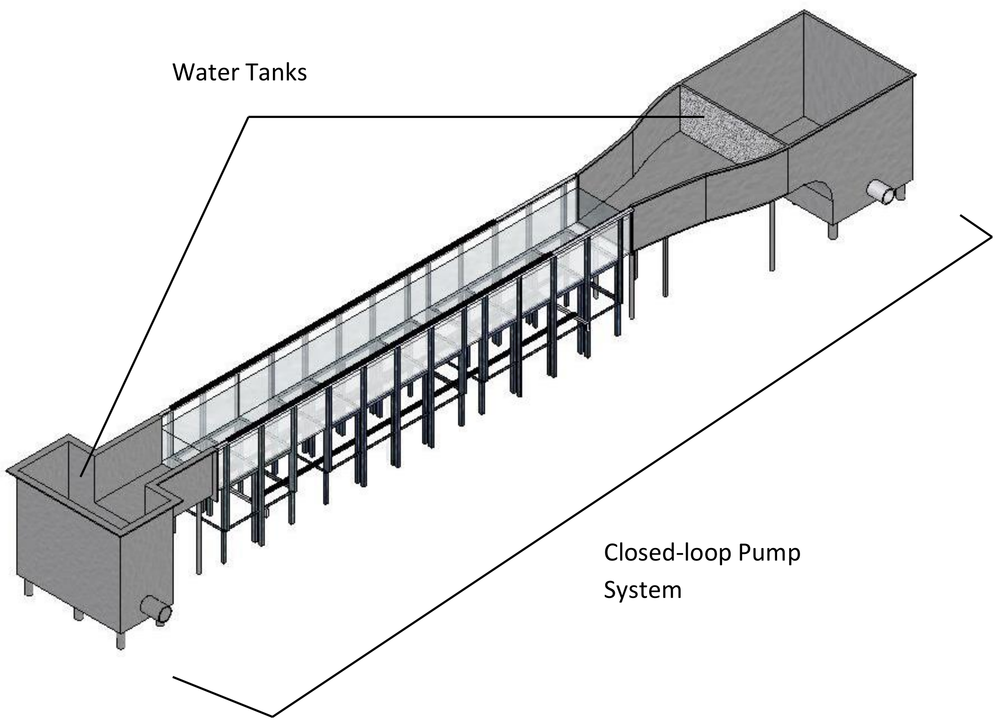


Fig. 1 Model of water channel

For the PIV stage, the flow was illuminated with two Nd: Yag pulsed lasers (532nm) mounted with a single casing and operating nominally at 120 mJ/pulse. The two orientations of the laser system use a combination of spherical and cylindrical lenses. The thickness of laser sheet was adjusted approximately to 2 mm. The water was seeded with 12µm, metallic-coated hollow plastic spheres. The movement of particles were recorded by a CCD camera with a resolution of 1600x1200 pixels equipped with a Nikon AF micro 60 f/2.8D lens captured the flow fields.. Dantec flow grabber digital PIV software employing frame to frame cross-correlation technique will be employed to calculate the raw displacement vector field from the particle image velocity data. In the image processing, 32x32 pixels rectangular interrogation windows will be used. During the interrogation process, an overlap of 50% is employed in order to satisfy Nyquist criterion. A total of 3844 (62x62) velocity vectors were obtained for an instantaneous velocity field at a rate of 15 frames per second. In each experiment, 350 instantaneous images were captured, recorded and stored [13].

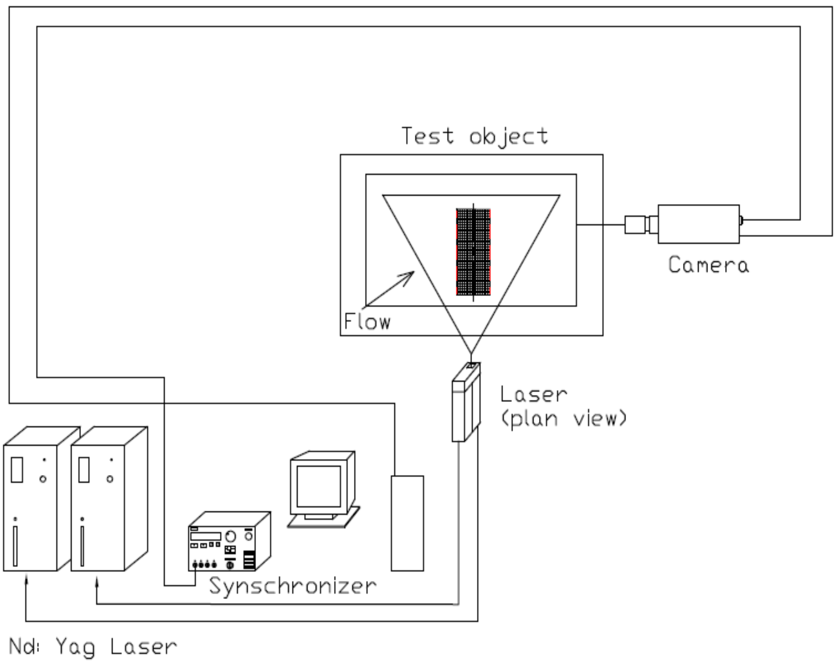
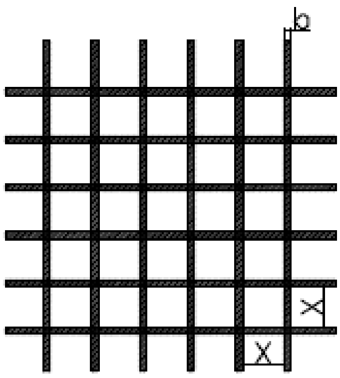


Fig. 2 Test section



$$\beta = \frac{x^2}{(x+b)^2}$$

Fig. 3 Mesh material and formula of porosity

All experiments were carried out in deep water of h=550mm. Test objects were consisted of a circular cylinder surrounded by meshy wire. The free-stream velocity was U∞= 100 mm/s, which corresponds to the Reynolds number of Re=5000 based on the bare cylinder diameter. Different wire meshes having different porosities (β= 0.5, 0.6, 0.7, 0.8) were used. Test section is shown in Fig. 2. Porosity is defined as the ratio of the gap area on the body to the whole body surface area. Porosity is calculated by using the following formula including wire diameter and distance between two wires (x) which is shown in Fig. 3.

For each value of porosity, one test object was having a diameter of 50 mm as shown in Fig. 4 was prepared. On the other hand, one parameter was the thickness of the wire. Thickness was changing as 1mm, 2mm, 3mm, and 4mm.

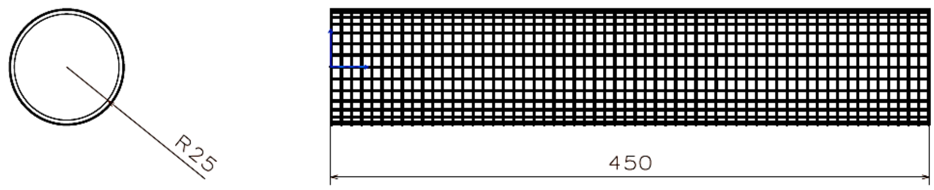


Fig.4. Model of test object

3. Results and Discussion

The aim of this work is to investigate the effect of meshy wire with different thickness and porosities that surrounds a bare cylinder with a diameter of D=50mm on the flow characteristics downstream of circular cylinder. Primarily the experiments were carried out with a cylinder which is called as 'bare cylinder' without any control of the flow structure case. The bare cylinder is a reference point to carry out comparison for determining the flow characteristics in the near wake region.

PIV experiments were performed for the Reynolds number of Re=5000 for four different wire thickness (b=1mm, 2mm, 3mm, 4mm) and four different values of porosity, β at a range of 0.5≤β≤0.8 with an increment ratio of 0.1 downstream of the cylinder surrounded by meshy wire arrangement at different time intervals. The results are the time-averaged values.

The time averaged velocity vector (<V>) is presented in the first column, second column represents time averaged vorticity, <ω> contours and the contours of normalized Reynolds shear stress, $<u'v'/U_\infty^2>$ are presented in third column are shown in Fig. 5, Fig. 6, Fig.7 and Fig. 8 evaluated by the PIV data. The first row of each figure represents the bare cylinder without any control of flow structure. The minimum and incremental values of Reynolds shear, stress, $<u'v'/U_\infty^2>$ contours were taken as ±0.005 and 0.005, respectively. The solid and dashed lines present negative and positive (counter-clockwise) Reynolds Stress, $<u'v'/U_\infty^2>$ contours respectively. The minimum and incremental values of time averaged vorticity, $<\omega>$ contours were taken as ±1 and 1, respectively.

Time averaged velocity vector (<V>) , time averaged vorticity, <ω> contours and the contours of normalized Reynolds shear stress, $<u'v'/U_\infty^2>$ results obtained from PIV experiments are presented in for β=0.5 and β=0.6 with all wire thickness are presented in Fig. 5 and Fig.6 for β=0.7 and β=0.8 in Fig. 7 and Fig.8..

As it can be seen from the figures that wire thickness b=1 mm and 2mm has adverse effect on the flow structure as increasing the maximum values.. With increasing wire thickness to b=4mm maximum value of Reynolds shear stress $<u'v'/U_\infty^2>$ decreases to 0.06 from 0.09 for β=0.6 case. Maximum decrease in Reynolds shear stress $<u'v'/U_\infty^2>$ again occurs in β=0.6 for all cases.

The shear layers elongate in the streamwise direction and later get closer to each other in β=0.5 and β=0.6. It is observed that the time averaged vorticity, <ω> contours in the near wake region of cylinder have a uniform and symmetrical flow structure for β=0.7 and β=0.8. The vorticity layer formed in the near wake of cylinder configuration shows that increasing the thickness of wire to 3mm and 4mm has an effect on the flow structure.

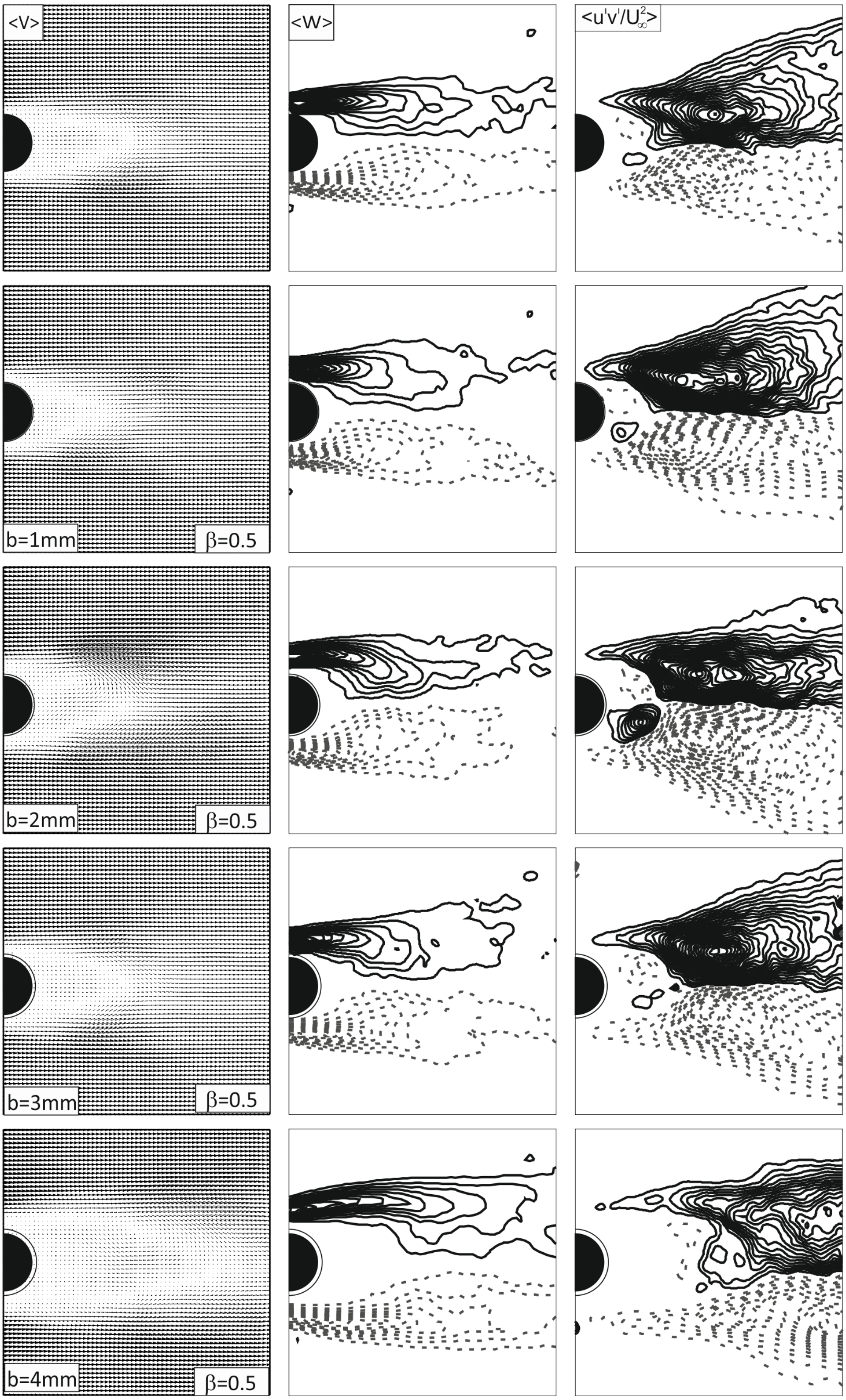


Fig. 5 Time averaged velocity vector (<V>) , time averaged vorticity, <ω> contours and the contours of normalized Reynolds shear stress, $<u'v'/U_\infty^2>$ for β=0.5

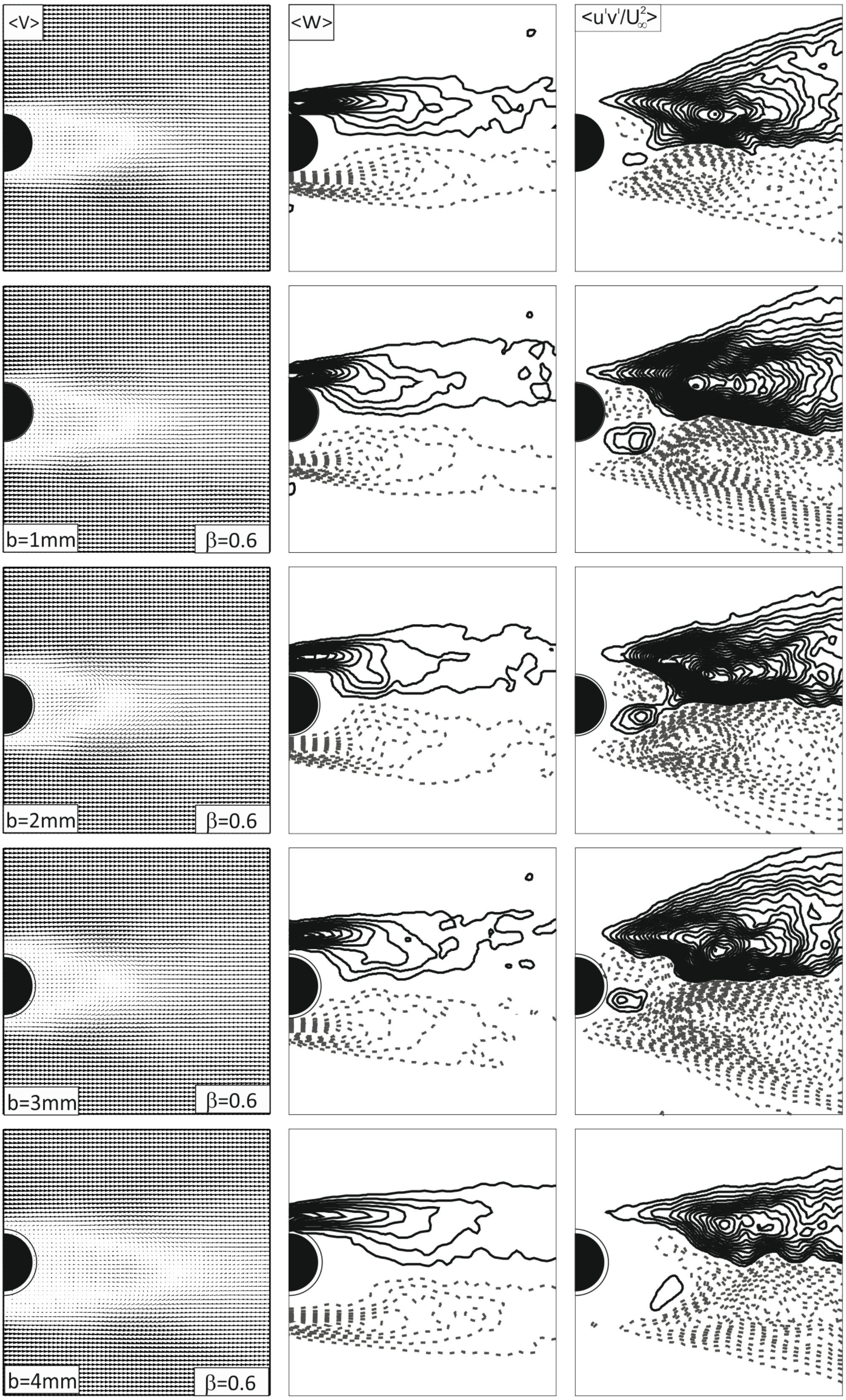


Fig.6. Time averaged velocity vector (<V>) , time averaged vorticity, <ω> contours and the contours of normalized Reynolds shear stress, <u′v′/U_∞^2> for β=0.6

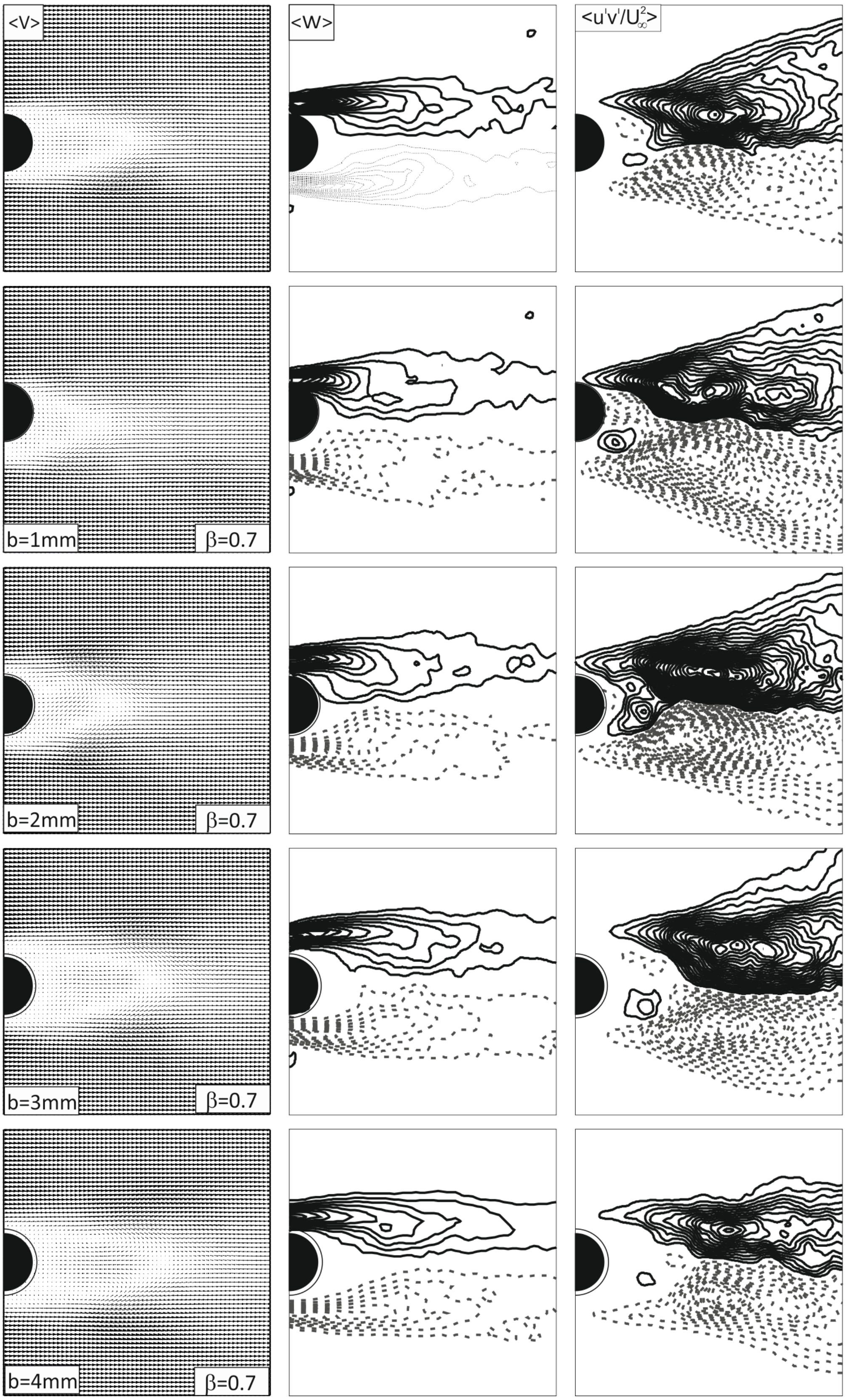


Fig. 7 Time averaged velocity vector (<V>) , time averaged vorticity, <ω> contours and the contours of normalized Reynolds shear stress, <u′v′/U_∞^2> for β=0.7

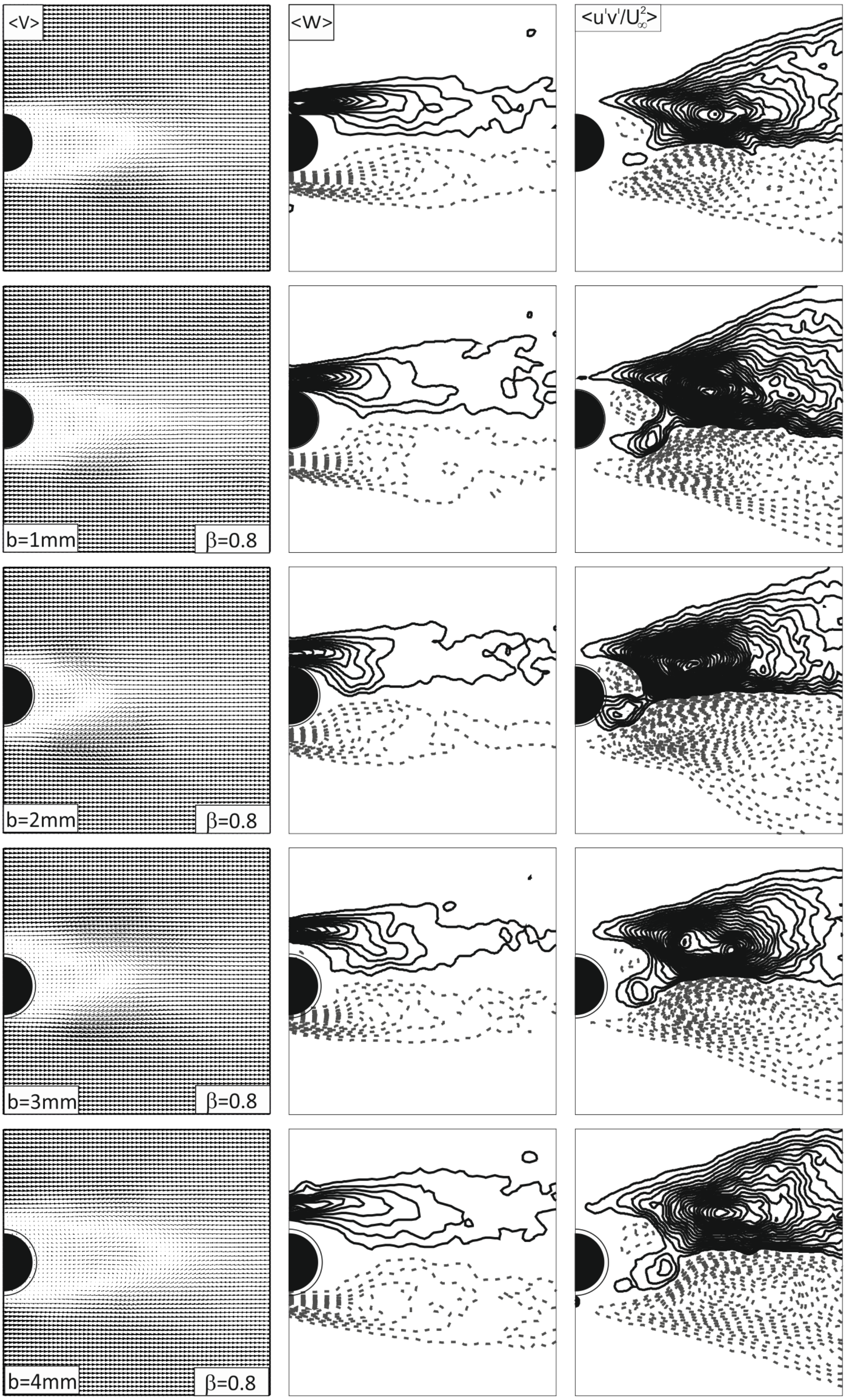


Fig. 8 Time averaged velocity vector (<V>) , time averaged vorticity, <ω> contours and the contours of normalized Reynolds shear stress, <u′v′/U_∞^2> for β=0.8

4. Conclusions

The effects of meshy wire with different porosities and different wire thicknesses that surrounds a bare cylinder on the flow structures in the wake region, were observed.

The peak value of Reynolds shear stress decreases as the wire thickness rises to 4mm. In addition for all porosities, the location of the minimum value of streamwise velocity, goes further downstream of the cylinder as the wire thickness is bigger than 2mm.

Gozmen and Akilli [13] observed that permeable cylinders placed around a solid cylinder are effective on the control of vortex shedding.

In addition to these studies is that presence of a meshy wire that surrounds the cylinder has an control effect on vortex shedding downstream of cylinder.

The experiments show that meshy wire with a thickness of 4mm is effective on the suppression of vortex shedding in the wake region for all porosities.It is clearly seen that wire thickness b and porosity of β have a significant effect on the flow structure.

5. References

[1] Williamson, CHK and Govardhan, R. (2004) Vortex-induced vibrations. *Annu. Rev. Fluid Mech*., vol.36, pp.413-455.

[2] Oruc, V. (2012) Passive control of flow structures around a circular cylinder by using screen. *Journal of Fluids and Structures*, vol.33, pp.220-242.

[3] Cruz, AS., David, L., Pécheux, J., Texier, A.(2005) Characterization by proper orthogonal-decomposition of the passive controlled wake flow downstream of a half cylinder. *Experiments in Fluid*, vol.39, pp.730-742.

[4] Farhadi, M., Sedigh, i K., Fattahi, E. (2010) Effect of a splitter plate on flow over a semi-circular cylinder. *Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering,* vol.224, pp.321-330**.**

[5] Gu, F., Wang, JS., Qiao, XO., Huang, Z. (2012) Pressure distribution fluctuating force and vortex shedding behavior of circular cylinder with rotatable splitter plates. Journal of Fluids and Structures, vol.28, pp.263-278.

[6] Akilli, H., Sahin, B., Tumen, NF. (2005) Suppression of vortex shedding of circular cylinder in shallow water by a splitter plate. *Flow Meas.Instrum.*, vol.16, pp.211–219.

[7] Akilli, H., Karakus, C., Akar, A., Sahin, B., Tumen, NF. (2008)Control of vortex shedding of circular cylinder in shallow water flow using an attached splitter plate. *Journal of Fluids Engineering* vol.130 no.4, pp.041401-041401-11

[8]Dalton, C., Xu, Y., Owen, JC. (2001)The suppression of lift on a circular cylinder due to vortex shedding at moderate Reynolds numbers, *Journal of Fluids and Structures*, vol. 15, pp. 617-628.

[9] Kuo, CH. and Chen, CC. (2009) Passive control of wake flow by two small control cylinders at Reynolds number 80. *Journal of Fluids and Structures*, vol.25, pp.1021–1028.

[10] Strykowski, PJ. and Sreenivasan, KR. (1990) On the formation and suppression of vortex 'shedding' at low Reynolds numbers. *Journal of Fluid Mechanics,* vol. 218 pp. 71- 107.

[11] Xu, CY., Chen, LW., Lu XY. (2010) Large-eddy simulation of the compressible flow past a wavy cylinder. *Journal of Fluid Mechanics* ,vol. 665 pp. 238- 273.

[12]Sahin, B., Ozturk, NA., Akilli, H. (2006) Horseshoe vortex system in the vicinity of the vertical cylinder mounted on a flat plate. *Flow Meas.Instrum*.vol.18, pp. 57-68.

[13]Gozmen, B. and Akilli, H. (2014) Flow control downstream of a circular cylinder by a permeable cylinder in deep water. *Wind and Structures*, vol. 19 no.4, pp.389-404.