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Experimental investigation of corner's form effect on the turbulence parameters sequence of square cylinder

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Abstract— ***In this study, the effects of corner's form on the turbulence parameters sequence of square cylinder in 0°, 15°, 30°, 45° angles of attack and Reynolds number 8800 has been investigated experimentally. The chosen models are made of plaxy glass, and include 15 mm side length and 400 mm length. To investigate the form influence of different corners on turbulence parameters sequence of square cylinder, three cylinders were used, having form of sharp, rounded and chamfered corners. The chamfering and rounding radius of the corners is selected as 2.5 mm. the results show that the angle of attack and the form of cylinder`s corners cause to important changes on the turbulence parameters sequence of square cylinder and the value of drag coefficient.***

Keywords— Hot-wire speedometer, aerodynamic, sequence of square cylinder, form of cylinder`s corners

I. Introduction

The flow having friction and compressible around cylinder is of the fluid mechanics classic problems. Despite the simple geometry of cylinder, the created flow in behind the cylinder would be so complicated, especially in high Reynolds which the momentum equations would not be simply attained of the numerical methods. In this case, the experimental investigation of the sequence behind the cylinder is an essential and dynamic issue in fluid mechanic discussion. Several factors affect the characteristics of square cylinder sequence including the effect of Reynolds number, blockage ratio, the ratio of vision, the surface roughness, dimensions of holder end plates of cylinder, the amount of inflow turbulence, the cylinder corners form and the angle of attack which in present research we tend to investigate the effect of square cylinder`s corners influence on its sequence turbulence parameters in 1 % input turbulence intensity.

Heretofore, several experimental and numerical studies are performed on flow around a cylinder with square cross section and it is of notable important issues for researchers. Sohankar and Colleagues [1], in 1995 performed the numerical investigation of flow around the square cylinder for 22000 Reynolds number and compared their results to the experimental values and found desirable results. Lee [2] investigated the rotation influences of square cylinder on frequent and average pressure field in 180000 Reynolds number. Hassan [3] studied flow around the square cylinder in different angles and the 6700 to 43000 Reynolds number.

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Sokhtanlu and Colleagues [4], performed experimental investigation of flow around the square cylinder in different angles of attack using hot-wire speedometer. Their results show that the angle of attack has notable influence on the value of drag coefficient of square cylinder. Tomura and Miagi [5], performed two and three dimensional laboratory investigation of flow around the square cylinder in different angles of attack and 30000 Reynolds number. They also performed the investigation of drag and Berea coefficients of cylinder in intensity of different turbulences of inflow on cylinder and varied forms of angles of square cylinder. They attained average acceleration profiles and turbulence intensity and also drag coefficient values in 0° angle of attack and 13200 Reynolds number around square cylinder with 15cm side length. Tomura and Miagi [6] performed the numerical investigation of the square cylinder`s corners form on pressure distribution. Their investigation results which consider the flow in three dimensional and compressible form show that changing the form of square cylinder corners cause to decrease of dragged and lifted coefficient along with increasing strouhal number. Kavaie [7] in 1998 performed the experimental investigation of the corners form influences in aero elastic instability values of high buildings with square cross section. He used wind tunnel system to perform his experiments and executed his experiments for three different corners form. His results show that a building with beveled corner form has better elastic stability than a building with rounded corner form.

II. Experimental conditions

In most cases, we need to determine drag of objects and devices. As performing theoretical and calculation methods are still far from practical engineering design, the experiments with wind tunnel is the only method to determine the accurate of drag forces. The wind tunnel system used in such experiments is of blower and open loop. The maximum nominal turbulences of free flow of the system are 1% which in this views it has high accuracy. The wind tunnel system in this research that is shown in Fig 1 has 168cm length and 40cm width and 40cm height. Using 7KW three phase motor used to produce air flow in wind tunnel system, we can reach the 0 to 30m/s speed range but in operation, according to the system`s characteristics, environmental conditions and calibration method in 5 to 28m/s speed range and there would be no acceptable accurate result which 10m/s speed is used in these experiments. Hot-wire speedometer system is one of the most important instantaneous speed measurement systems of fluid. According to the unique features of the system which its main and most important application is the performance of air or gas turbulence flows. The applied speedometer in the present research is of (CTA) fix temperature which is capable to measure the average speed, turbulence and outgoing vortex form the back of cylinder. Used one dimensional probe in the experiments has a sensor with 1.25mm length and 5µm diameter. To move probe in different points, an accurate mechanism is used with Freedom of third degree that is shown in Fig 2. The accuracy of the probe transmission mechanism is 0.01mm.

Figure 1. The wind tunnel system

Figure 2. The probe transmission mechanism

III. Physical models

The used cylinder in experiment is included 40cm length and 15mm side length. The material of these three models is of plaxy glass, so their surface roughness influence would not be appeared in results. model corner for is selected the same as Fig 3 which is of one of sharp corner models and into other models the cylinder corner are chamfer using milling operation and rounding the cylinder corners is done by turning operation.

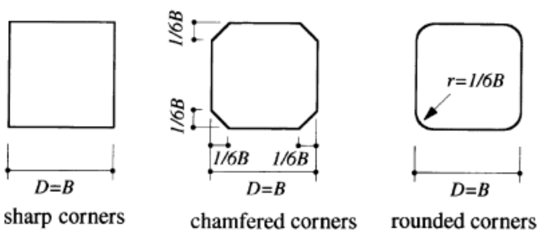

Figure 3. The cylinders with different corners

Blockage ratios defined as dividing side length of cylinder on tunnel channel height. This parameter is of influential cases in wind tunnel experiments and the parameter amount should not be less than a value.

$$(Blockage\ ratio)\ ß = D / H = 0.0375 \quad (1)$$

According to the features of wind tunnel and cylinder, the blockage ratio in above experiments is 0.0375 that has ignorable effect on the attained results. Also the parameter of aspect ratio which is defined as dividing cylinder length on cylinder diameter, according to the cylinder dimensions in experiments the value would be:

$$(Aspect\ ratio)\ L / D = 26.6 \quad (2)$$

Where D is the cylinder side and L is cylinder length.

According to the published researches in this field the aspect ratio in experiments usually is considered more than 20, which considering the aspect ratio in these experiments, this parameter is suitable and has ignorable effect on the results.

IV. Results

In this research, we tend to investigate the corner's form of square cylinder on its sequence turbulence parameters in 0°, 15°, 30°, 45° angles of attack and Reynolds number 8800. The measurement data is performed for 1% turbulence intensity and 0°, 15°, 30°, 45° angle of attack and in two situations of x/d= 1.5 and 2.5 from the back of cylinder which x is the distance from cylinder center and d is cylinder side length. Because rotational flow near cylinder, the first situation in location is selected as x/d=1.5, because from this location to the next the returning flows decrease and the stream pattern can be determined easily. The height of measurement data is also selected y/d= (-3.33, 3.33).

In Fig 4, the intensity value of free flow is shown in experiment case. As the diagram shows, the turbulence intensity of fluid flow in measurement site is less than 1% which shows the high accuracy of system.

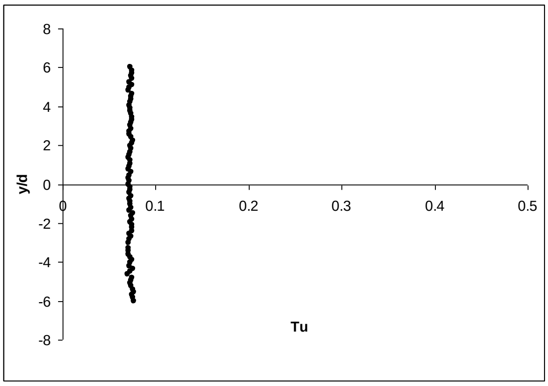

Figure 4. The turbulence intensity in cylinder installation site

In this part, we tend to study the effects of attack angle on the cylinder sequence characteristics including average speed profile, the turbulence intensity and drag coefficient. In Fig 5, the maximum turbulence intensity for the different attack angles is shown in different situations.

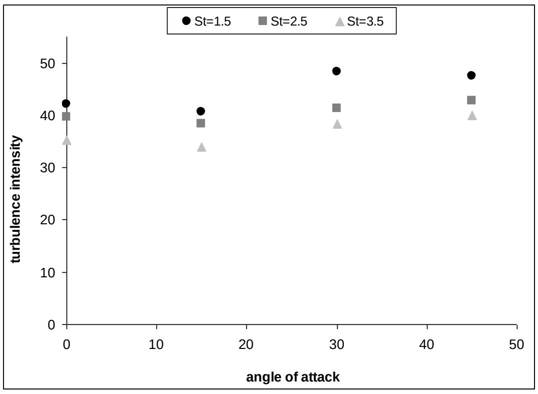

Figure 5. The maximum turbulence intensity in different attack angles for different situations

The results show that the value of the maximum intensity increases up to 15° attack angle and then increases up to 45° attack angle. We observe the reduction of turbulence intensity with increase of intervals because of the uniform flow. According to the attack angles and the chosen situations in these experiments, we observe the maximum turbulence intensity in 30° attack angle and x/d= 1.5 location and also the least turbulence intensity in 15° attack angle and x/d= 3.5. The average turbulence intensity in different angles of attack for different situations behind the cylinder is shown in Fig 6.

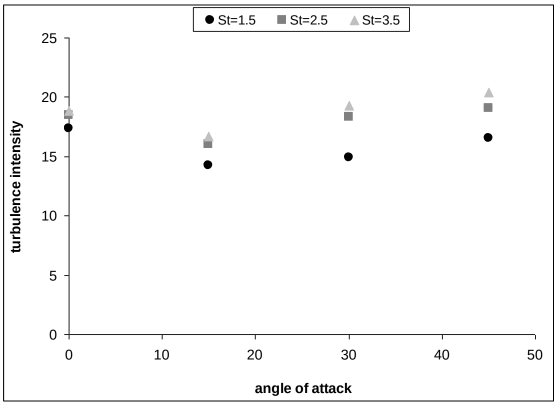

Figure 6. The average turbulence intensity in different attack angles for different situations

We can conclude that the average turbulence intensity will increase with the increase of distance from behind the cylinder which is because of the growing sequence range in behind the cylinder. Like the maximum turbulence diagram, in this situation also, the least turbulence intensity will occur in 15° attack angle and the maximum turbulence intensity occurs in 45° attack angle.

In this part, we tend to investigate the effects of corner`s form of square cylinder in its sequence parameters in 1% turbulence intensity value, to observe such effects, we consider three different corner form including sharp, chamfered and rounded. The maximum turbulence diagram, for different angles is shown in different situations including/d= 1.5 and 2.5 in Fig 7 and Fig 8.

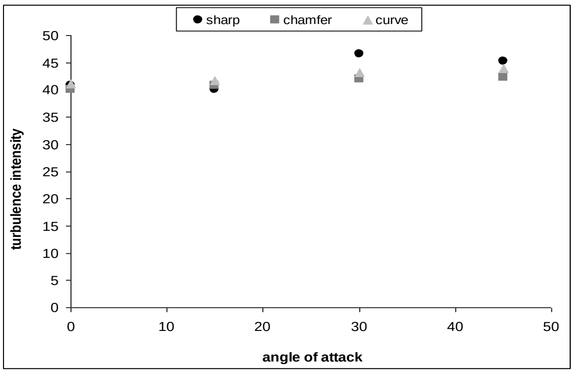

Figure 7. The maximum turbulence intensity in different corner's form for St= 1.5

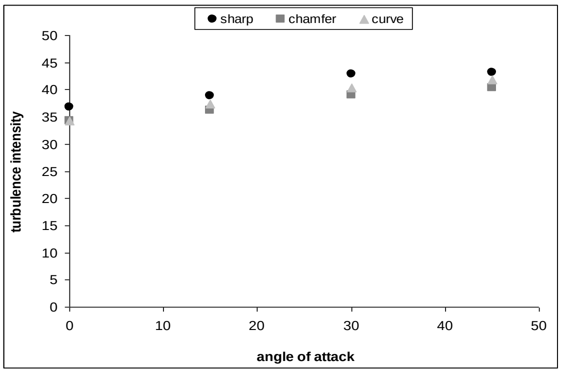

Figure 8. The maximum turbulence intensity in different corner's form for St= 2.5

The obtained results for these two situations show that the form of chamfered corner and the rounded one cause to decrease the maximum turbulence intensity than the sharp corner form, which in such situation, the cylinder with the chamfered corner has less turbulence intensity than the cylinder with sharp corners. The maximum variations in turbulence intensity value in maximum, occurs in two situations in 30° attack angle. The results show that in 30° attack angle, changing the corner's form from sharp to chamfered causes to 10% decrease in x/d= 1.5 and 7% decrease in x/d= 2.5.

In Fig 9 and Fig 10, the average turbulence intensity is shown for three different forms of cylinder corners.

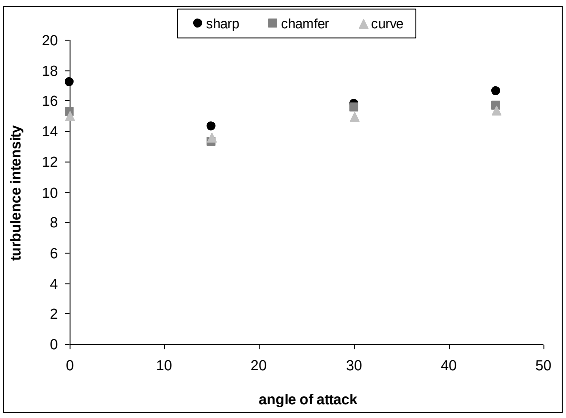

Figure 9. The average turbulence intensity in different corner's form for St= 1.5

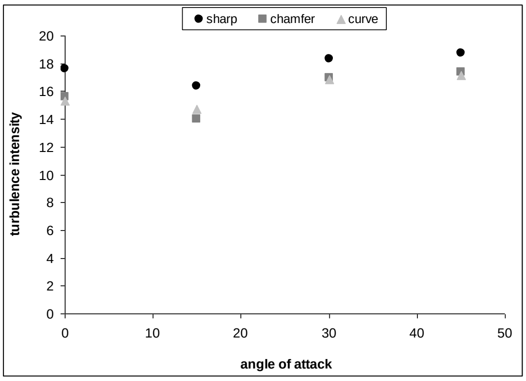

Figure 10. The average turbulence intensity in different corner's form for St= 1.5

The results show that with changing the corner's form from sharp to rounded or chamfered, the average turbulence intensity decreases in cylinder sequence. The cause would be the decrease in sequence range which finally leads to decrease of average turbulence intensity behind the cylinder. The maximum variation of the average turbulence intensity in x/d= 1.5 situation in 0° attack angle occurs because of variation in corner form from sharp to rounded which causes to 12% decrease in average turbulence intensity.

The drag coefficient diagram for different forms of cylinder corners is shown in Fig 11.

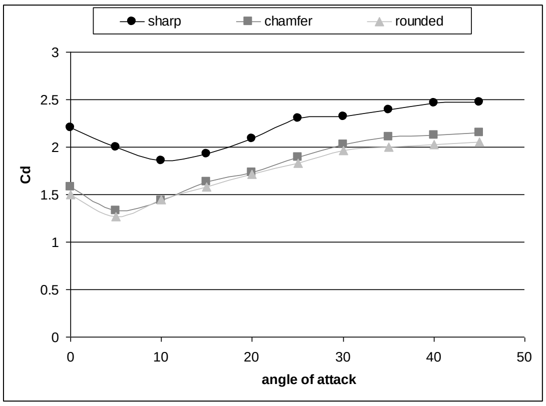

Figure 11. Drag coefficient in form of different angles

The results show that with changing the form of cylinder corners from sharp to rounded or chamfered, the least drag coefficient changes from 10° attack angles to 5° attack angles. Also, as it is obvious form Fig 11, drag coefficient decreases along with changing the corner's form of square cylinders which the value of this decrease is more for the smaller attack angles. The results show that the drag coefficient will decrease to 32% and 36% along with changing the cylinder corner from sharp to chamfered and rounded in 5° attack angles, respectively. The value of average decrease of drag coefficient is 18.6% in chamfered form and 21.3% in rounded form.

V. Conclusion

In this study, we tended to investigate the sequence of square cylinder in sharp, chamfered and rounded forms of corners in 0°, 15°, 30°, 45° angles of attack and the following results were gained:

- The value of mean and maximum turbulence intensity behind the square cylinder depends to the amount of distance from cylinder, attack angle and form of corners.
- The least turbulence value in cylinder sequence occurs in 15° attack angle.
- Chamfering and rounding the corners of square cylinder, generally, leads to decrease in maximum and mean turbulence intensity in cylinder sequence.
- Along with chamfering and rounding the corners form of square cylinder with sharp corner, drag coefficient will notably decrease.
- The value of drag coefficient with sharp corner cylinder occurs in 10° attack angle which chamfering and rounding cylinder corners causes that this minimum amount occurs in 5° attack angle.
- The maximum amount of drag coefficient for sharp corner cylinder occurs in 45° attack angle, which we can observe the maximum amount of drag coefficient in his attack angle with changing the form of cylinder corners.
- Drag coefficient can be decreased to 18/6% and 21/3% in average form with changing the form of cylinder corners from sharp to chamfered or rounded.

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