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Experimental Study of the Downstream Flow of a Cylinder with Three Different Cross Sections by Hot Wire Anemometry

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ABSTRACT

The detailed investigation of the flow behavior around the circular and square cylinders has important engineering applications. In the present work, the characteristics of flow in the downstream of three different models with the circle and square cross sections are investigated in the wind tunnel using the hot wire anemometry. For the model with a square cross section, the experiments were performed for both zero and 45-degree angle of attack. In this study, the effects of different Reynolds number and the cross-section of the cylinder are studied with the use of measured velocities and their fluctuation components. The Strouhal number and other flow characteristics in the downstream of the cylinder are compared to the published results in the literature. A good agreement is observed between the present results and the reported results. Comparing the results of three models showed that the reduced flow velocity behind 45 degrees orientated square cylinder in the interval X/D<4 are higher than two other models. In addition, the results reveal that the velocity fluctuations behind the square cylinder at zero incidence in the interval X/D<2 are higher than those for the other models.

KEYWORDS

Wind Tunnel, Hot Wire Anemometry, Wake Flow, Reynolds Number, Square and Circular Cylinders.

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1- INTRODUCTION

Drag and lift forces imposed on the various structures like circular and square cylinders employed in engineering applications are highly dependent on the nature and characteristics of flow field around these structures. In recent decades, a lot of research on the flow around a cylinder with various geometries have been performed. The most experimental studies have been conducted on two-dimensional cylinders using measuring techniques such hot-wire or hot-film anemometer and Laser Doppler Velocimetry (LDV) at different Reynolds numbers and geometries in the wind tunnel. These studies have been investigated to determine various properties such as the distribution of pressure, force coefficients, vortex shedding frequency, (Strouhal number) and flow patterns. Some of these these studies are mentioned as follows.

Saha et al. [1] measured two velocity components in the downstream of a square cylinder by using a hot-wire anemometer at Re = 8700 and 17625. The comparison of this result with the results from the other researchers in terms of average values of velocities was acceptable. It should be noted that the turbulence intensity in this study is less than other works.

Lin et al. [2] conducted the measurements in a water tunnel on a two-dimensional square cylinder at Re = 21400 by using a Laser Doppler velocimetry. They separated the periodic and random components of the velocity fluctuations around a square cylinder and presented the relationship between the flow condition and the distribution of turbulence.

Sohankar [3] studied the flow fluid over a square cylinder at different Reynolds numbers from 10^3 to 5×10^6 using large eddy simulation. It is found that the effect of Reynolds number on the global quantities, the mean and the large scale instantaneous flow-structures is not much at the higher Reynolds numbers, i.e. Re > 20000.

The purpose of this paper is to compare the experimental results of the flow field downstream of the two-dimensional cylinders with different cross sections (a square cylinder at zero and 45 degrees angle of attack and a circular cylinder) at various Reynolds numbers, see Table 1.

2- METHODOLOGY

Experimental measurements are conducted in the open circuit Yazd university wind tunnel. The test section dimensions are 457 × 457 mm^2 and 1200 mm length. The maximum speed of wind tunnel is 30 m/s and turbulence intensity is 0.4 %. The vortex shedding frequency, mean velocity and turbulence of the flow downstream of the cylinder are measured by using a hot wire anemometer with one-dimension probe. The hot wire sensor is calibrated statically and dynamically and the undesirable noise is eliminated using a low pass filter. The probe in different positions is moved by a traverse. Four Reynolds numbers, based on model diameter, are employed as listed in table 1.

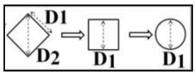
Reynolds number based on the size of D1 or D2 (proportional to geometry) 	13333	10000	6667	3333

Table 1: Reynolds numbers based on model diameter

3- RESULTS AND DISCUSSION

Dimensionless vortex shedding frequency is denoted as Struhal number that is a function of the Reynolds number. Vortex shedding frequency is measured in this study and it is found that they are in a good agreement with those reported by researchers.

The results of the mean velocity and turbulence of the flow downstream of the square cylinder at zero angle of attack in positions X/D = 1, 2 and 3.5 at Re = 10000 and 13333 are shown in figure (1). The present result are compared with the experimental results of Saha et al. [1] (Re=8700 and 17625) and Lyn et al. [2] (Re=21400) and the numerical results of Sohankar [3] (Re=5600) and Wang et al. [4] (Re=21400).

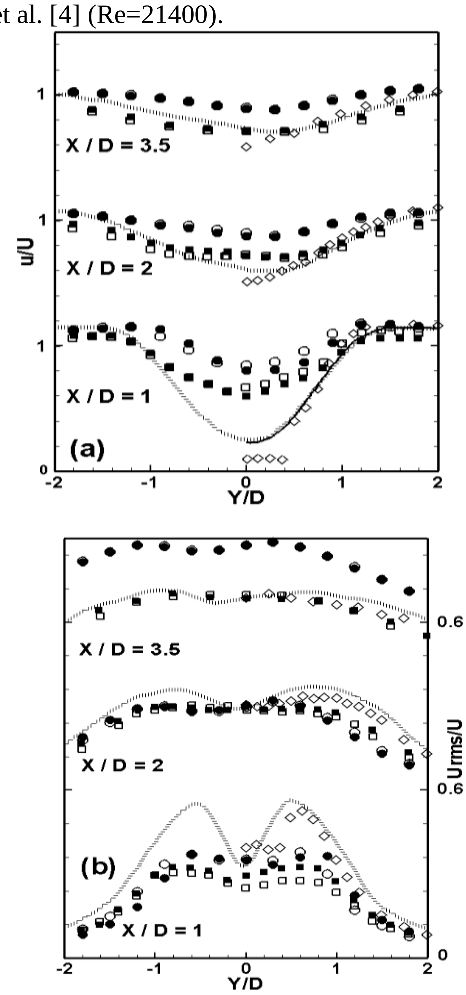


Figure 1: (a) Dimensionless velocity distribution and (b) turbulence at three positions (X/D=1, 2 and 3.5) downstream of the square cylinder at zero angle of attack for two Re = 10000 and 13333 (○ , ●) are compared with the previous works: (□ , ■) Re=8700 and 17625 Saha et al. [1]; (◊) Re=21400 Lyn et al. [2]; (——) Re=5600 Sohankar [3]; (- - - -) Re=21400 Wang et al. [4].

The comparisons show that in positions far from the model (X/D ≥ 2), the results are close to the reported ones. Some differences between the results of this work and the reported ones at position X/D = 1 were observed. This could be due to the use of different methods of the measurement and numerical methods. In addition, hot wire anemometer has a weak capability to measure accurately the velocity in the reversed flow near the model, i.e. X/D ≤ 1.

Figure (2) shows the dimensionless velocity distribution at positions X/D = 3, 5 and 10 for three-cylinder at Re=13333. The results depict that in positions near the three cylinders, the width of the wake is smaller than the positions far from the model. The reduced velocity in the wake position near the square cylinder at 45° angle of attack is higher than other cylinders, but the reduced velocity behind the square cylinder at zero angle of attack and the circular cylinder are almost identical.

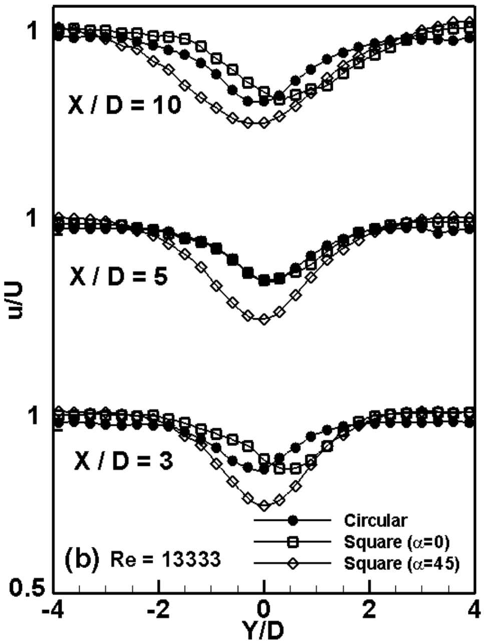


Figure 2: Dimensionless velocity distribution at three positions (X/D=3, 5 and 10) for three different models at Re=13000.

In our study, it is shown that the turbulence decreases with increasing the distance from the models employed. Likewise, it is observed that the turbulence components have a peak value near the model in the separated shear layer. This peak value for the circular cylinder is less than the one for square cylinder at all distances and Reynolds numbers employed.

4- CONCLUSIONS

Flow over square-section and circular-section bluff bodies are studied in the wind tunnel using the hot wire anemometry for different Reynolds numbers. From this experimental study, the following results are found.

1- Strohal numbers and other characteristics of the flow field downstream of two-dimensional cylinders in the present investigation are in a good agreement with the reported results from the other researchers.

2- The comparing results of three models reveal that the reduced flow velocity behind 45 degrees orientated square cylinder in the interval X/D<4 are higher than two other models. This difference decreases with increasing the distance from the cylinder.

3- The width of the wake increases by increasing the Reynolds number for all X/D positions and models employed.

4- The turbulence intensity downstream of the square cylinder with zero and 45 degrees angle of attack at Re=6666 at X/D=1 have a peak value but this peak occurs at position X/D=2 for the circular cylinder.

5- The results reveal that the velocity fluctuations behind the square cylinder in the interval X/D<2 are higher than the other models. At positions far from the model, the turbulence levels for three cylinders are closer together at all Reynolds numbers employed.

5- REFERENCES

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