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Experimental Investigation on Flow Downstream of a Triangular Bluff Body at Different Angles

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ABSTRACT: Study of vortex shedding and flow downstream of a triangular bluff body can be used to design a device for measuring the flow angle, a vortex flowmeter or to calibrate the hot-wire anemometer at low velocities. In this paper, flow velocity, turbulence intensity, and vortex shedding from a 10 mm triangular bluff body have been investigated experimentally using hot-wire anemometer. Results show that the flow angle has little effect on flow velocity distribution and turbulence intensity. However, variations of Strouhal number *(St)* with respect to the flow angle is large, so that Strouhal number at flow angle of 20 ° has the maximum value of 0.23 and at the angle of 62 °, it has the minimum value of 0.133. To calibrate the hot-wire anemometer, it is necessary to measure flow velocity in addition to the measurement of vortex shedding. Under this condition, if the probe is placed in the region**:** x/a=2.5 and 2.5<y/a<5.2, vortex intensity will be less than 6%, the velocity will be equal to the free stream velocity, and the vortices will be measurable.

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1. INTRODUCTION

The vortex shedding phenomenon of bluff bodies, such as triangular cylinder is important in fluid mechanics. This is the basis of vortex flowmeters [1]. Vortex flowmeters are linear flowmeters, which have the advantage of high accuracy. Strouhal number (*St*) and Reynolds number (*Re*) are commonly used to study the vortex shedding phenomenon. The Strouhal number is defined as $St = fa / U$, where a is the characteristic size of a bluff body, such as the length of a triangle, U the free stream velocity and f the vortex shedding frequency. The Reynolds number is defined as $Re = Ua / \nu$, where ν is the kinematic viscosity of fluid.

Some shapes such as triangles are not symmetrical about their axes. Therefore, their Strouhal number changes with the flow angle. This phenomenon can be used to measure the flow angle. Srikanth et al [2] studied numerically the vortex shedding at the downstream of equilateral triangle model for Reynolds numbers less than 80. They showed that the Strouhal number variations for Reynolds numbers 50 to 80, are from 0.18 to 0.192. They did not report vortex shedding results for Reynolds numbers less than 50. Johansson et al [3] studied the downstream flow of the equilateral triangle model at high Reynolds numbers numerically and compared their results with experimental results, showing the return flow in the wake region. Kumar & Dalal [4] studied the vortex shedding phenomenon at the downstream of an equilateral triangle at low Reynolds numbers numerically. They showed that when the angle of the triangle model is zero and the Reynolds number is 50, the Strouhal number is 0.15, with the Reynolds number increasing to 250, the Strouhal number decreases slightly.

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In this research, the downstream flow of the triangular model is investigated experimentally. The distribution of air flow velocity and its turbulence intensity as well as vortex shedding at different angles are studied and the results are used for applications flowmeters and hot wire calibration.

2. EXPERIMENTAL METHOD

All experiments were carried out using the wind tunnel located at Iranian Research Organization for Science and Technology (IROST). The test section of this wind tunnel is 60 cm×60 cm.

The hot-wire anemometer used in this work was made by Fara Sanjesh Saba (FFS) company. One dimensional probe of 5μm tungsten wire was used. In order to move the probe, a travers mechanism was used. This mechanism has a precision of 0.1 mm in three dimensions which can be controlled via a computer. Output of the hot-wire anemometer is transferred to computer via an A/D card, to be processed and analyzed.

Triangular cylinder of 10 mm side was used in this research. Fig. 1 shows coordinate axis and the model rotation angle. A stepper motor was used to change the model angle.

In this research, the vortex shedding, velocity and turbulence intensity distribution downstream of the model were measured.

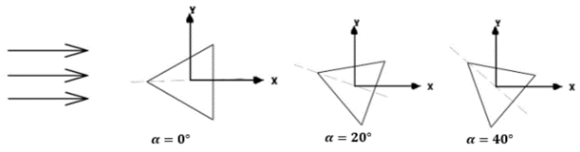

Fig. 1. Coordinate axis and model roll angle

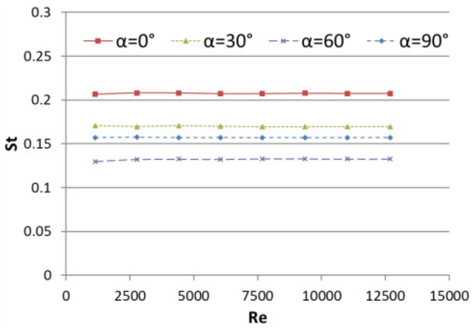

Fig. 2. Variation of Strouhal number in terms of Reynolds number for triangular cylinder at different model angles

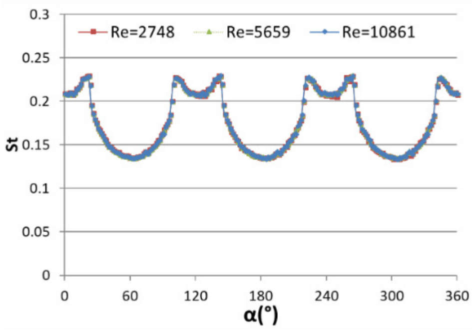

Fig. 3. Variation of Strouhal number in terms of roll angle for triangular cylinder at different Reynolds number

3. RESULTS AND DISCUSSION

First, the vortex shedding was investigated. Fig. 2 shows that the variation of Strouhal number in terms of Reynolds number for triangular cylinder at different model angles. Fig. 2 shows the Strouhal number is constant for different Reynolds numbers.

The Strouhal number changes with the flow angle but it is constant with the Reynolds number.

Fig. 3 shows the variation of Strouhal number in terms of rotation angle for triangular cylinder at different Reynolds numbers. The strouhal number variation with respect to the angle is nonlinear.

As shown in Fig. 3, the *St-α* curves are coincide with different Reynolds numbers. *St-α* variations are repeated for each 120° and are symmetric in each replicate. The lowest Strouhal number is 0.133 and occurs at 62°, 182° and 302°. The highest Strouhal number is 0.23 and occurs at angles of 20° and 100°, and these angles are repeated with periods of 120°. The curve also has a relative minimum value at an angle of 120° and this angle is repeated with a period of 120°.The strouhal number in the minimum area with the flow angle does not change very much, so it is appropriate to place the model at an angle of 62° for the flowmeter.

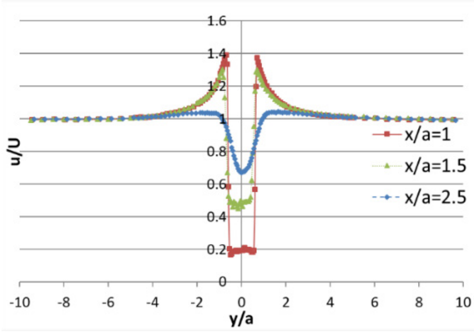

Fig. 4. The dimensionless mean velocity at downstream of the triangular cylinder at *Re*=10861, α=0°

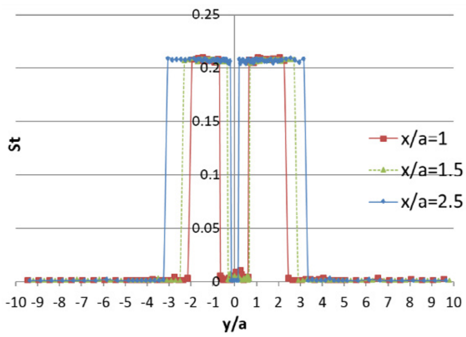

Fig. 6. The Strouhal number at downstream of the triangular cylinder at *Re*=10861, α=0°

In order to study the vortex shedding in more detail, the flow near and downstream of the model was studied. Fig. 4 shows the dimensionless velocity distribution of the airflow across the model at different distances at zero degree. The airflow was made dimensionless using the free stream velocity. According to Fig. 4 at distance *x/a*=1, the local velocity is greater than the freestream and is 1.38 times the freestream at *y/a*=±0.7. With increasing downstream distance, this value decreases and at *x/a* = 2.5 the local velocity equals the freestream velocity.

Also, as the distance downstream increases, the depth of the wake region becomes smaller but wider. At the distance *x/a*=1 the lowest velocity in the wake region is 0.19 and at the distance *x/a*=2.5 it is 0.67. Also, the width of the wake region is 1.25*a* at *x/a*=1 and at *x/a*=2.5 equals to 1.8*a*.

Ardekani [5] showed that in order to detect suitable positions for hot-wire calibration using vortex shedding, probe is needed to be placed in the dimensionless mean velocity region with $0.99 < u/U < 1.01$.

Fig. 6 shows the Strouhal number as a function of *y/a* at *x/a*=1, 1.5, and 2.5 for *Re*=10861 and *α*=0° downstream of the triangular cylinder. When it is *x/a*=1 region of 0.8≤*y/a*≤2.1 and -2.1≤*y/a*≤-0.8, the Strouhal number is 0.21. In other words, the frequency of vortex shedding can be measured. When it is *x/a*=2.5 region of 0.2≤*y/a*≤3 and -3≤*y/a*≤-0.2, frequency is measurable and this region gets bigger.

4. CONCLUSION

- The Strouhal number is dependent on flow angle of the model. At 20°, the Strouhal number has its highest value (0.23) and its lowest value (0.133) at 62°. When the model angle is 62° relative to the airflow, the strouhal number variations are small relative to the model angle, so this model angle is suitable for use a vortex flowmeter.
- The velocity profiles downstream of the model at different angles are approximately similar in proximity of the model the local velocity is greater than the freestream except in the wake region.
- As it has been already mentioned, for calibrating the hot wire anemometer in addition to measuring the vortex shedding frequency, it is necessary to maintain the turbulence intensity of the flow less than 6% and the velocity of the flow should be equal to the free stream velocity. This condition occurs when the probe is in the region area of x/a=2.5 and 2.5 ≤y/a≤5.2.

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