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FLOW VISUALIZATION STUDIES ON TRAPEZOIDAL BLUFF BODY FOR VORTEX FLOWMETER APPICATION

***A. Venugopal*, Amit Agrawal and S.V. Prabhu**

Department of Mechanical Engineering
Indian Institute of Technology Bombay, Powai, Mumbai 400076, India, *svprabhu@iitb.ac.in*

Abstract: In the present study, turbulent flow visualization is carried out to understand the vortex formation mechanism behind a trapezoidal bluff body, for vortex flowmeter application. The dye used for flow visualization is shear-thickening and high extension viscosity fluid, which can sustain turbulent separated flows. With the quantitative assessment of the images, the vortex frequency is computed which is in close match with the results obtained from Piezo-electric sensor based measurement. The study enhances the understanding of the complex vortex formation mechanism in the design of vortex flowmeter.

Keywords: Bluff body, Strouhal Number, Image processing, Piezo-electric sensor.

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1. INTRODUCTION

Flow visualization has always played a vital role in fluid dynamic research assisted with qualitative and quantitative results. The first foot print of the existence of vortex shedding was also documented in the form of historical painting of Leonardo da Vinci. The pivotal role of flow visualization in the development of vortex flowmeter deserves appreciation. Miau *et al.* [1] employed dye visualization techniques to understand the vortex shedding mechanism with ring shaped bluff bodies. Flow visualization images revealed that the presence of the pipe wall affects the vortex shedding mechanism and for blockage ratio above certain values, vortex shedding was completely inhibited. Miau *et al.* [2**Error! Bookmark not defined.**] studied the performance of T-shaped bluff body using dye visualization in water. The optimum ratio of width of the vortex shedder and length of the extended plate was explained with this study. Turner *et al.* [3] suggested improved vortex generator as a cylinder with slit and concave rear face with dye visualization based experiments. Popiel *et al.* [**Error! Bookmark not defined.**] investigated circular cylinder with slit and concave rear face using dye visualization and found that the geometry is very sensitive to end wall effect leading to horse shoe vortex. Pankanin *et al.* [5] based on flow visualization and image processing techniques, highlighted very important aspect of convection velocity and stagnation region in the formation of cylinder wake. However, most of the reported studies are restricted to qualitative and low Reynolds number.

In the present study, flow visualization experiments are extended for Reynolds number up to Re_D = 30000, which is seldom reported in the literature. The quantitative assessment of the images has provided a platform to directly compare the results obtained from piezo-electric sensor. The bluff body employed is trapezoidal in shape with a blockage ratio of 0.27, which is reported as the optimum shape [6, 7]. The dye used for flow visualization is shear-thickening and high extension viscosity fluid. The dye is most suitable for highly turbulent separated flows [8]. The composition of the critical compounds in the dye are varied to cover wide range of Reynolds number (Re_D = 2500 – 30000).

2 EXPERIMENTAL SETUP

A closed loop constant head tank is used in the present study to conduct flow visualization experiments in 52.5 *mm* bore diameter transparent circular pipe. Sufficient upstream length is provided to ensure fully developed flow conditions. Laws vane flow conditioner is used 10*D* upstream to the bluff body to reduce turbulent intensities. The dye is injected upstream to the bluff body with 1 *mm* hypodermic needles. He-Ne laser of 20 *mW* power is used for planner illumination of the flow field. The videos are recorded with Cannon DSLR 550D camera in movie mode at 60 frames per second.

3 DATA REDUCTION AND RESULTS

The flow visualization video is segmented in to frames for further analysis. The images are analyzed to compute the dominant frequency with the help of commercial software MATLAB. The intensity at a particular pixel location is saved for all the images to get the intensity power spectrum. The vortex shedding frequency is obtained from the dominant peak in the power spectrum. The sequence of vortex formation for Re_D = 10000 is shown in Fig. 1. The dye is injected only from one probe to obtain good quality images. The Strouhal number variation with Reynolds number is presented in Fig. 2. The results obtained with flow visualization are within ± 3.5% compared to piezo-electric sensor.

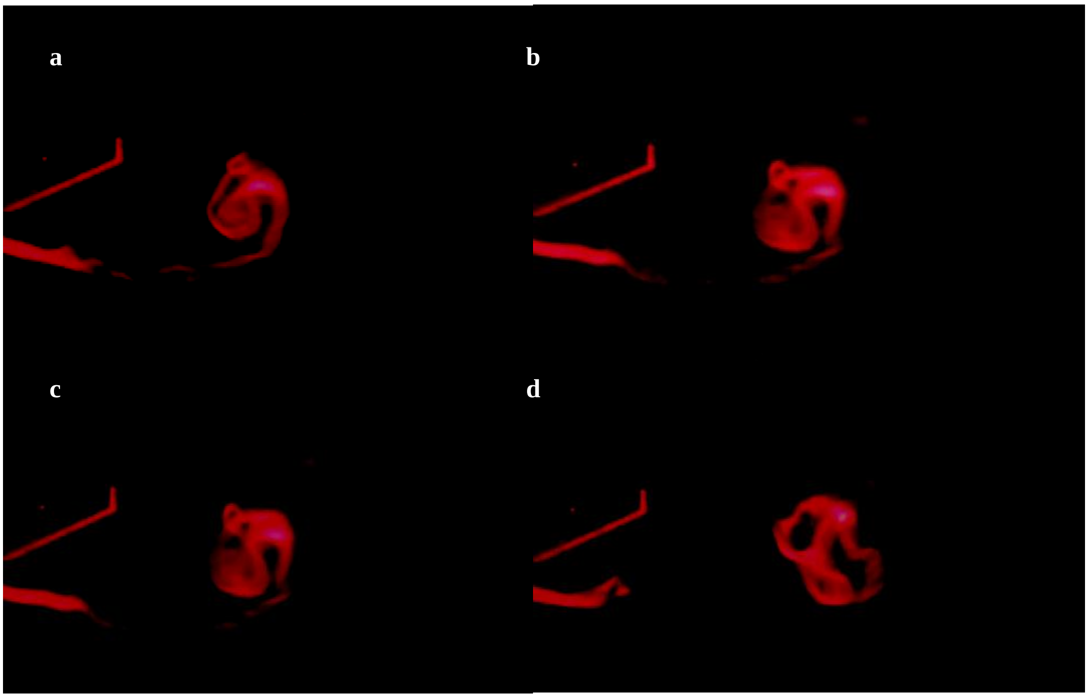

Figure 1: Sequence of vortex formation at Re_D = 10000

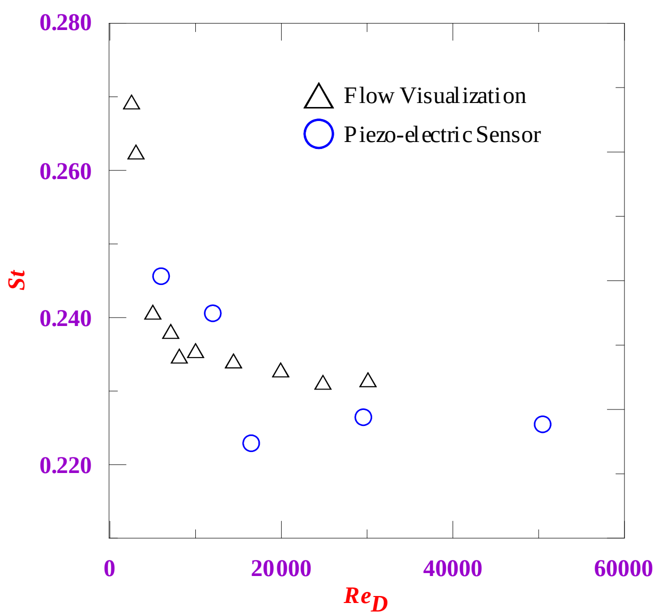

Figure 2: Variation of Strouhal number with Reynolds number

4 CONCLUSIONS

The flow visualization experiments conducted under turbulent flow conditions are in good agreement with those obtained with piezo-electric sensor. Non-linearities in Strouhal number variation with Reynolds number is observed below Re_D = 10000. This study has improved the basic understanding of vortex formation mechanism under turbulent flow conditions. The vortex convection velocity, the formation length, end wall effects and the optimum location of the piezo-electric sensor have been determined from such experiments; these will be presented in the final manuscript.

5. REFERENCES

[1] Miau, J. J., Hus, M. T., "Axisymmetric-Type Vortex Shedders for Vortex Flowmeters." *Flow Measurement and Instrumentation,* Vol. 3, pp. 73 – 79, 1992.

[2] Miau, J. J., Yang. C. C., Hou. J. H., Lee. K. R., "A T- Shaped Vortex Shedder for Vortex Flowmeter." *Flow Measurement and Instrumentation,* Vol. 4, pp. 259 – 267, 1993.

[3] Turner, J. T., Popiel, C. O., Robinson, D. I., "Evolution of an Improved Vortex Generator." *Flow Measurement and Instrumentation,* Vol. 4, pp. 249 – 258, 1993.

[4] Popiel, C, O., Robinson, D. I., Turner, J. T., "Vortex Shedding From a Circular Cylinder with a Slit and Concave Rear Face." *Applied Scientific Research,* Vol. 51, pp. 209 – 215, 1993.

[5] Pankanin. G. L., Kulinczak. A., Berlinski. J., "Investigations of Karman Vortex Street Using Flow Visualization and Image Processing." *Sensors and Actuators A*, Vol. 138, pp. 366 – 375, 2007.
[6] Venugopal, A., Agrawal, A., Prabhu, S. V., "Influence of Blockage and Upstream Disturbances on the Performance of a Vortex Flowmeter with a Trapezoidal Bluff Body." *Measurement*, Vol. 43, pp. 603 - 616, 2010.
[7] Venugopal, A., Agrawal, A., Prabhu, S. V., "Influence of Blockage and Shape of a Bluff Body on the Performance of Vortex Flowmeter with Wall Pressure Measurement." *Measurement*, Vol. 44, pp. 954 - 964, 2011.
[8] Hoty, J. W., Sellin, R. H. J., "A Turbulent Flow Dye Streak Technique" *Experiments in Fluids*, Vol. 20, pp. 38 - 41, 1995.