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PREDICTION OF WAKE STRUCTURE BY GROOVES

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Abstract

An investigation has been carried out to predict the wake formation behind the circular models in a transparent water flow channel. Nine models with circular base diameter of 50 mm were fabricated from Aluminium. Surface of each model were grooved triangular, semi-circular and rectangular. The depth of grooves was varied from 1.25mm, 2.5mm and 5mm. The flow visualisation was performed to examine wake structure behind the models for Reynolds Number of 80, 160 and 200. It was observed that the size of vortices was reduced drastically for model with semi-circular groove of depth 2.5mm at velocity of 0.5m/s compared to other models with groove depth of 1.25 mm and 5mm tested.

Keywords—Circular, groove, Reynolds Number, vortices

1. Introduction

In fluid dynamics, flows are visualized by various techniques such as surface flow visualisation, water flow channel, particle tracer method and optical methods. The techniques of flow visualization in water assessed for possibility of obtaining quantitative information. Stationary scheme demonstrate transition and separation of the boundary layer owing to velocity gradient at the surface of a solid boundary. Numerous kinetic methods engage either solid or bubbles of another fluid to trace particles of flow as reported in flow visualisation techniques (Slavica Ristic, 2007) in hydrodynamic and optical problems. To specify three-dimensional flow some of these methods may be adapted. Techniques using stream birefringence were investigated particulate flow in a channel published in open chemical engineering journal by the researchers (Azimian.M *et al*, 2014) for qualitative approaches still quantitative approaches are yet to represent. Infecting the human skin is one of the prone drawbacks of chemical methods. However an electrolytic method that uses hydrogen bubbles is versatile and often used technique.

To visualize flow past a model has become a dynamic research area due to its enormous engineering application such as designing of airfoils, pipelines, submarine cables, stacks and bridge piers. The study on flow visualisation in water was carried out by (Clayton & Massey, 1967) and published. Several previous analysis on the vortex shape behind an isolated notched cylinder have been reported with Reynolds numbers, Re (=ρ.D.U_0

/ν, where ν is the kinematic viscosity of water and U_o is the free-stream velocity of water) in the range of Re = 400 ~ 12000 is also investigated (Lin and Hsieh, 2009) on flow characteristics around a circular cylinder above a plane boundary on Journal paper published. For the notched cylinder near a surface of the water flow channel, it is expected that the wake formation was influenced by Reynolds number (Re), the thickness of plane boundary (δ), and the gap ratio (G/D) and their relations were explained (Anderson J.D, 1984) in the book of Fundamentals of Aerodynamics.

Almost all previous studies are concentrated on the relationship between vortex formation frequency and gap ratio, indicating that the vortex formation was influenced by the boundary layer of the plane and suppressed at the critical gap ratios. The study about the differences of flow characteristics around a circular cylinder was illustrated in vol 1. Fundamentals (Zdravkovich MM, 1997) and vol.2 Applications (Zdravkovich MM, 1997) near the plane boundary and flow over transverse aerodynamic roughness transitions by (Willingham & David, 2014). Also, a systematic study for the mean or instantaneous full-field velocity maps and the flow characteristics around the notched cylinder corresponding to different gap ratios still needs to be made clear in order to achieve a better understanding of such a flow. This flow characteristic can also be achieved by Laser Doppler Anemometry and demonstrated (Ristic S *et al*, 2007). The purpose of the present study is to provide detailed insight of the flow around a notched cylinder near a surface at low Reynolds number incompressible flow using SPH and the study carried (Mooris J et al, 1997). By flow visualization technique, the different flow phenomena on the net gap between cylinder and plane under the conditions with and without boundary layer are observed as shown in Figure1. As involved with the FLDV and PIV systems, the instantaneous velocity fields, the formation lengths, and the characteristics of the deflected gap flow in the wake of notched cylinder for different gap ratios will be addressed in detail to highlight the flow characteristics in partially premixed mode on Water channel Laser induced and PIV was demonstrated by (Sangl J *et al*, 2014).

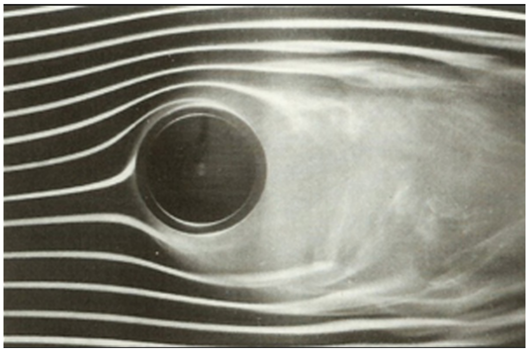

Figure 1. Flow visualisation over a cylinder

Flow visualization of the notched cylinder is observed using the water flow channel as shown in Figure 2.

Figure 2. Flow past a cylinder

2. Experimental setup

The experiments were conducted in the Aeronautical Department of Tagore Engineering College using water flow channel made up of acrylic sheet so that visualising the flow around notched cylindrical models with the support of Introduction to fluid mechanics (R.K.Bansal, 1983)

2.1. Water flow channel

The water flow channel was fabricated from acrylic sheet which consists of right angled triangle wedge to settle the flow. Meshes are used to make the flow streamlined as shown in Figure 3. The design parameters of water flow channel are as follows:

Tank Volume	0.3x0.15x0.1 m
Wedge distance from tank	0.08 m
Wedge angle	38.7 deg
No of meshes	2
Test section dimensions	0.3x0.3 m
Coloured solution used	Potassium Permanganate($KMnO_4$)

Table 1: Specifications of water flow channel

An adjustable stand (1.24m x 0.3m x 0.1m) was built to place the setup. Adjustable provision makes stand to level for any uneven surface. Water supply with sock arrangement to avoid turbulence was connected to tank. The wake region was measured with the help of the scale placed at the side walls and the flow was recorded with the help of camera and report on Computational analysis of flow over slotted cylinder was done previously by Saravana Kumar and Nirmal (2013).

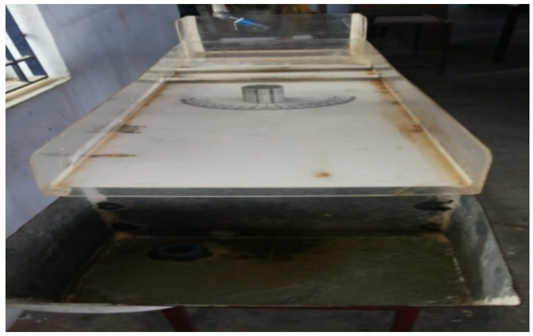

Figure 3. Artistic view of acrylic water flow channel

3. Notched cylindrical models

The spreading of vortex behind the model is taken as the wake region. Three different shapes of notches were studied viz. rectangular, semi-circular and triangular by varying the depth of notch from 1.25 mm, 2.5 mm and 5 mm.

3.1. Rectangular notch

The model of rectangular notch is depicted in Figure 4. When the flow approaches at the edge of a notch, there is a contraction because the edge is not normal to the plane of the notch. Due to the sharp corners in the rectangle, the vortex formed at the edge which disturbs the flow. The values are observed and tabulated.

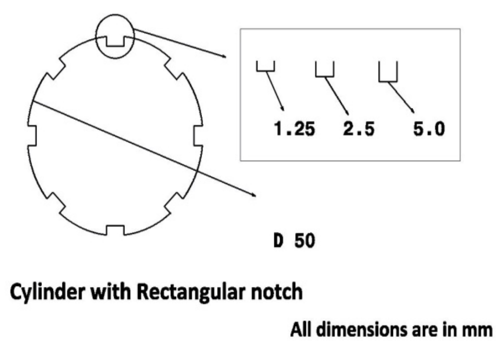

Figure 4. Rectangular notch model

3.2. Semi-circular Notch

The semi-circular notch model is presented in Figure 5. When the flow passes over the object, it creates wake. Due to the smooth edge surfaces, the reattachment point of the wake become smaller when compared to the rectangular notch.

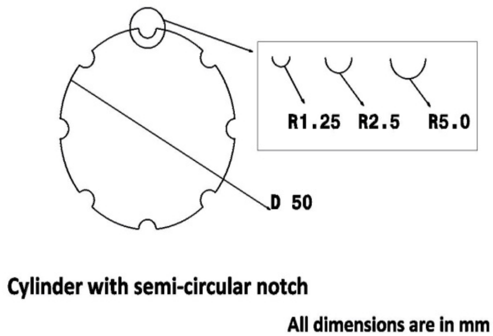

Figure 5. Semi-circle notch model

3.3. Triangular notch

The model with triangular notches is represented in Figure 6. The reattachment point and the wake region are measured and values are tabulated.

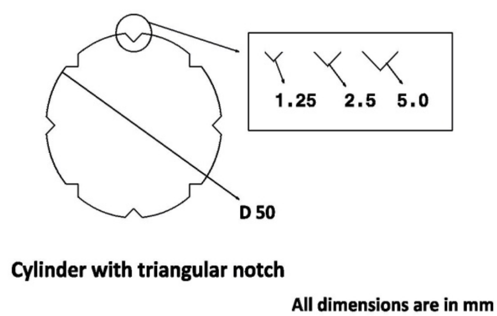

Figure 6. Triangular notch model

4. Experimental procedure

Models were placed in test section of water flow channel (WFC) and tested for flow velocities 0.15m/s, 0.25m/s,0.35m/s and 0.5m/s. The coloured solution of potassium permanganate crystals was ejected through the needle to visualise the wake region behind the models as shown in Figure 7. Wake region is non-dimensionalized with diameter of the model and flow velocity is converted to Reynolds Number. The distance between flow separation and reattachment is considered as wake region. Measuring scale fixed to the vertical wall of WFC is used to measure the wake region. The wake region behind the model has been observed and compared with the different shapes of notches. The flow pattern was visualised and vortex formation was captured by the camera. It is well established fact that wake regions are responsible for drag formation. Farthest the reattachment point, more the drag penalty as illustrated in comparative analysis of experimental and numerical flow visualisation (Ristic S *et al*, 2006). Also it was found that reattachment point keeps changing with change in shape and size of notch. A provision of measuring angle of inclination of wakes region is

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provided in the form of protractor, placed at the bottom of WFC and the method is incorporated in this study with Flow visualisation water tunnel, operating maintenance and instructions (ELD, 1984). The effectiveness of model is defined as smaller region of wake behind the model.

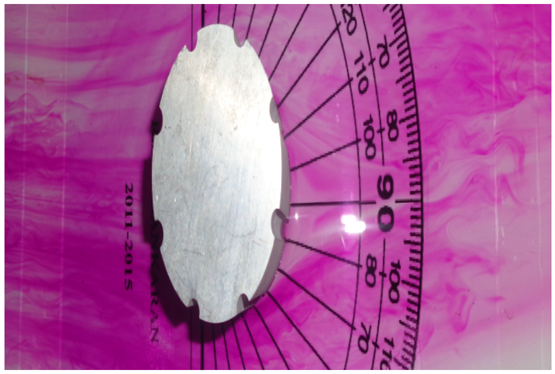

Figure 7. View of flow patterns in water channel

The results have been illustrated by plotting the graph Reynolds Number (Re) versus normalised reattachment distance (X/D) as illustrated in flow visualisation in a water channel report (Professor J.M.Cimbala, 2012).

5. Results and discussions

5.1. Wake formation

Figure 8 depicts wake formation around cylindrical model with triangular, semi- circular and rectangular notches of depth 1.25 mm. from plot it is clear that, at Re = 80, semi – circular notch exhibits smaller wake. The fact can be authenticated by value of X/D = 0.05 at the same time X/D = 0.1 and X/D = 0.12 for rectangular and triangular notches respectively. Also it is noticed that wake region drastically increases beyond Re = 160 in case of semi – circular and rectangular notches. However there is gradual decrement in case of triangular notch. This may be due to the shorter base length of notch which may be responsible for manipulating size and nature of vortices. This process may be attributed to diminishing of vortices and carried away flow field.

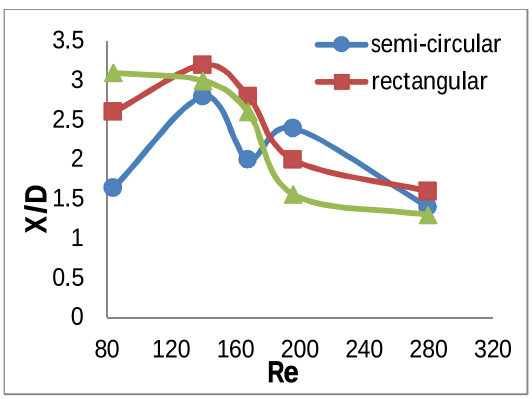

Figure 8.Wake formation for 1.25 mm depth

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Figure 9 illustrates wake structure around cylindrical model with triangular, semi- circular and rectangular notches of depth 2.5 mm. From diagram it is evident that, in case of semi – circular notch at Re = 80, initially vortices are smaller in size and capture minimal region compared to rectangular and triangular notches. The value of $(X/D)_{Re\ =\ 80}$ for semi–circular tend to be almost 0.08, while corresponding values approaches to 0.1 & 0.11 for rectangular & triangular notches respectively. It is clear that, depth of notches plays vital role in manoeuvring wake region for notches other than circular. In case of circular shape flow is re-energized eddies possessed in the flow field. During this process vortices travel longer distance till whole energy is exhausted. However trend remains to be identical for all the notches tested beyond Re = 160.

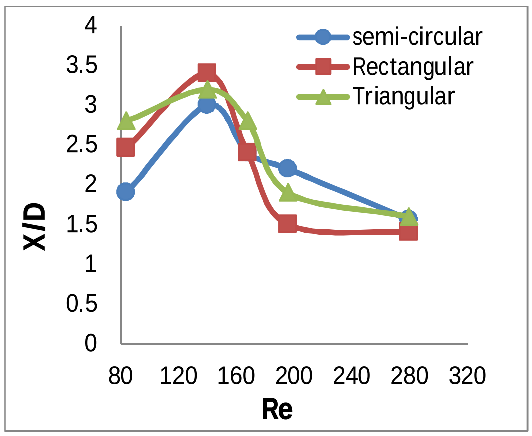

Figure 9. Wake formation for 2.5 mm depth

Figure 10 demonstrates wake region in the vicinity of cylindrical model with triangular, semi- circular and rectangular notches of depth 5.0 mm. It can be seen that, all the notch shapes fallows almost similar pattern for shedding vortices. It can be stated that, depth of notch becomes insignificant irrespective of notch shape, also sheds equal amount of vortices near the cylinder base. Re = 200 may be regarded as transition zone where vortices start breaking owing to high energy flow. Although vortices are smaller in size in this zone in case of rectangular notch compared to triangular and semi – circular notches. This may be attributed to effect of more corners possessed by rectangular notches. Also it is well established fact that, sharp corner bodies kept in high energy flow exhibits smaller vortices of varying size.

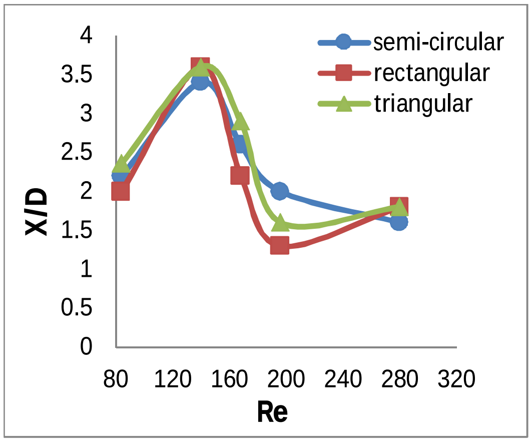

Figure 10. Wake formation for 5mm depth

6. Conclusion

An experimental study has been carried out to investigate effectiveness of notches for circular cylinders. The results of the above study demonstrate that the size of vortices behind the semi-circular notch model reduces significantly. It can be predicted that more edges and corners attributes towards large size of vortices. The maximum size of vortex (X/D) is 0.15 for rectangular and triangular notches at Re = 160 and minimal size of vortex is 0.05 which is achieved by semi-circular notch at Re = 280.

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Appendix

Notation:

Re = Reynolds Number
V = Flow Velocity
X = Reattachment Distance
D = Diameter of the model
WFC = Water Flow Channel

Author Biography

[1]***Rajesh Kumar B* –** Completed B.E. Aeronautical Engineering and working as a Research Assistant in the college where conducting research on Design and development of UAV and its application. The research work on Tandem wing UAV was carried out successfully under the supervision of Larsen & Toubro Limited, Chennai. Enthusiastic Engineer who seeking an opportunity to develop in the field of Aeronautics. Also teaching Aeromodelling to the students and conducting workshop on R/C planes. Also, completed Masters Diploma in Aerospace Design course and working on design tools like CATIA, ANSYS, CFD.

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