Experimental investigation of vortex flow visualization using various fluids

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Abstract:

Surface flow visualization around 2D objects is used to determine qualitatively the extent of resistance offered by the flow to the motion of the body. Surface visualization can be achieved either by moving the flow around the body or by moving the body in a static fluid. In this paper, we explore a range of techniques for creating images of fluid flows. The work is motivated not just by the utility and importance of fluid flows, but also by their inherent beauty. Vortex flows is very predominant in determining the resistance offered during the motion of a body in a medium. These flows have a characteristics which is independent of the media of the flow and its velocity, but depends only upon a parameter called Reynolds number which is a non dimensional number formed by the velocity, geometrical parameter and kinematic viscosity of the fluid.

Surface streaks accurately map out the skin friction pattern except the separation line. Surface flow visualization is generally considered to be qualitative. Perhaps topological aspects in identifying surface singularities may be considered to be quantitative. Nevertheless, the technique has been used effectively for quantifying features such as the upstream influence, separation and attachment of two and three-dimensional shock wave/boundary-layer interactions.

Model testing has an advantage to assess the performance of a moving body in a scaled down configuration, which is less expensive and has a scope of covering variety of parameters connected with the flow. In this paper, by using a towing tank surface visualization of vortex

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flows around simple geometrical bodies have been investigated to understand the basic nature of resistance offered by the flows to the moving body.

1. INTRODUCTION

A new method for the visualization of two-dimensional fluid flow is presented. The surface pattern in the presence of three-dimensional separation has been the subject of much analysis over the past five decades. Surface flow patterns obtained experimentally and numerically have also been used in combination to further the understanding of complex flows. It is now generally accepted that the surface streaks accurately map out the skin friction pattern except the separation line. Surface flow visualization is generally considered to be qualitative. Perhaps topological aspects in identifying surface singularities may be considered to be quantitative. Nevertheless, the technique has been used effectively for quantifying features such as the upstream influence, separation and attachment of two and three-dimensional shock wave/boundary-layer interactions.

The method is based on the advection and decay of dye. These processes are simulated by defining each frame of a flow animation as a blend between a warped version of the previous image and a number of background images. For the latter a sequence of filtered white noise images is used: filtered in time and space to remove high frequency components. Because all steps are done using images, the method is named Image Based Flow Visualization (IBFV). With IBFV a wide variety of visualization techniques can be emulated. Flow can be visualized as moving textures with line integral convolution and spot noise. Arrow plots, streamlines, particles, and topological images can be generated by adding extra dye to the image. Unsteady flows, defined on arbitrary meshes, can be handled. IBFV achieves a high performance by using standard features of graphics hardware. Typically fifty frames per second are generated using standard graphics cards on PCs. Finally, IBFV is easy to understand, analyze, and implement.

A vortex (*plural:* vortices) is a spinning, often turbulent, flow of fluid. Any spiral motion with closed streamlines is vortex flow. The motion of the fluid swirling rapidly around a centre is called a *vortex*. The speed and rate of rotation of the fluid in a free (irrotational) vortex are greatest at the centre, and decrease progressively with distance from the centre, whereas the speed of a forced (rotational) vortex is zero at the centre and increases proportional to the distance from the centre. Both types of vortices exhibit a pressure minimum at the centre, though the pressure minimum in a free vortex is much lower.

2. Experimental Details

Flow visualization is the process of making the physics of fluid flows (gases, liquids) visible. In this paper, we have explored a range of techniques for creating images of fluid flows. The work is motivated not just by the utility and importance of fluid flows, but also by their inherent beauty. The Flow Visualization course is designed for mixed teams of engineering and fine arts photography and video, but anybody who has paid attention to the patterns while stirring milk into coffee or stared at the curl of a rising tendril of smoke has participated in flow visualization, and will understand the purpose of this paper. In Most fluids (air, water, etc.) are transparent, thus their flow patterns are

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invisible to us without some special methods to make them visible.

On another level, we know the governing equations of fluid motion (the Navier-Stokes equations), but they are nonlinear partial differential equations with very few general solutions of practical utility[3]. We can solve them numerically with modern computer methods, but these solutions may not correspond to nature unless verified by experimental results.

On still another level the Navier-Stokes equations are pattern generators, and natural fluid flow display corresponding patterns that can recur on scales differing by many orders of magnitude. Such fluid patterns are familiar to almost everyone: the bathtub vortex and the tornado, the smoke ring and the mushroom cloud, the swinging of wires in the wind and the collapse of a historic bridge due to forced oscillations from vortex shedding.

2.1 Methods of visualization

In experimental fluid dynamics, flows are visualized by three methods:

Surface flow visualization: This reveals the flow streamlines in the limit as a solid surface is approached. Colored oil applied to the surface of a wind tunnel model provides one example (the oil responds to the surface shear stress and forms a pattern).

Particle tracer methods: Particles, such as smoke, can be added to a flow to trace the fluid motion. We can illuminate the particles with a sheet of laser light in order to visualize a slice of a complicated fluid flow pattern. Assuming that the particles faithfully follow the streamlines of the flow, we can not only visualize the flow but also measure its velocity using the particle image velocimetry or particle tracking velocimetry methods.

Optical methods: Some flows reveal their patterns by way of changes in their optical refractive index. These are visualized by optical methods known as the shadowgraph, schlieren photography, and interferometry. More directly, dyes can be added to (usually liquid) flows to measure concentrations; typically employing the light attenuation or laser-induced fluorescence techniques[1] [2].

2.2 Experimental Set-up

Typical qualitative analysis vortex wave forms of the kind discussed here are made in long, narrow wave tanks where plane waves can be generated mechanically with relative ease. Because a key goal of this work is to concurrently study the effects of vortex flows on surface properties on the dynamics of both capillary (gravity waves and vortex rings, such a tank arrangement was not conceivable. An experimental set-up that allows for the generation of capillary gravity waves in the same tank that is used for vortex ring study was therefore developed. This marks an improvement over previous workers who have used separate tanks for characterizing free-surface properties. The glass-walled tank used in these experiments has dimensions of 122 cm 182.8cm and 14cm deep and has a 1.2 cm thickness [4].

Radial capillary (gravity) waves are studied experimentally in the present work to illuminate the characteristics of the free surface. Radial waves were selected for measurement because of their desirable axial symmetry.

Because of the tank dimensions, a long, exceptionally straight wave maker, positioned along one wall, would have been necessary to

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ensure perfectly plane waves. Aluminum powder is being used to identify the proper vortex formation in the tank with the movement of the bodies of different geometrical shapes. A carrier is being used to move the geometrical shapes. The carrier is placed on a channel to move the geometrical shapes from one end of the tank to other end. The height of the carrier is placed in such a way that the body floats on the surface of the medium.

Fig: 1. Experimental Setup of surface visualization of vortex flows

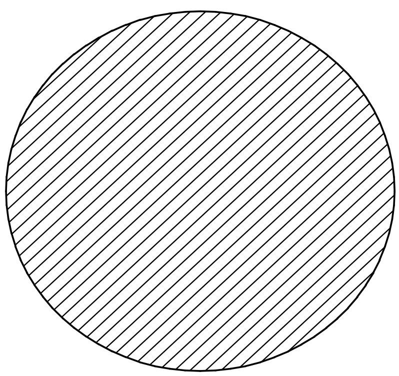

Fig: 2. Circle

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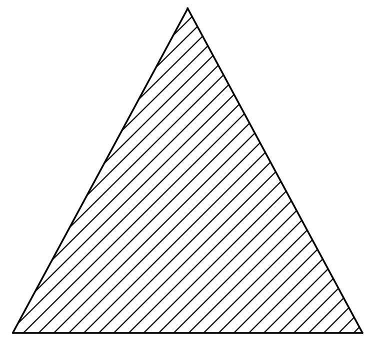

Fig: 4. Triangle

Fig: 5. Triangular Model

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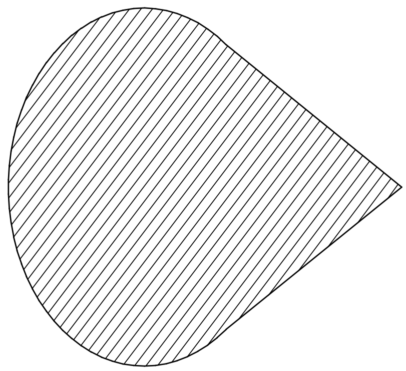

Fig: 6. Drop Structure

Fig: 7. Drop like Model

2.3 Experimental Procedure

The glass tank is placed on a uniform surface floor. The half of tank is filled with water. Aluminum powder is uniformly distributed over the surface of water. Aluminum metal powder (atomized) AT wt 26.98(Atomization is accomplished by forcing a molten metal stream through an orifice at moderate pressures) is used and due to its property it floats on the surface of water, it helps for the better visualization. The channel is placed over the glass tank to carry the trolley over the whole length of tank. The trolley is connected with model in such a way that model floats over the surface of water. Then the trolley is run with the help of battery which moves across the channel and the model floats over the surface producing the vortex [5][6].

Different geometrical shapes are used as models and depending upon the shapes different vortex formation is observed and this vortex formation is captured.

3. Results & Discussion

The objective of the work presented in this paper was to establish surface techniques in the visualization of Analytical method, with a strong emphasis on vortices. Stream surface computation was improved to the point where complicated flows can be treated. [7][8] We discussed a vortex core region definition that is physically justified and introduced an extraction scheme that can visualize the shape of vortices. Furthermore, we pointed out some applications of stream surfaces going beyond pure visualization, namely visual verification of presumed vortices and phenomenological extraction of vortex core line features. The results and observations are summarized below, together with some ideas for future work.

The experiment is done and the following results were observed for the water as a fluid

Fig: 8. Resistance offered by a body

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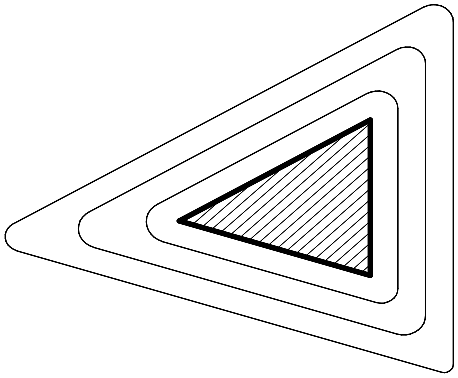

Fig: 9. Two dimensional Triangular body

Fig: 10. Resistance offered by a circular body

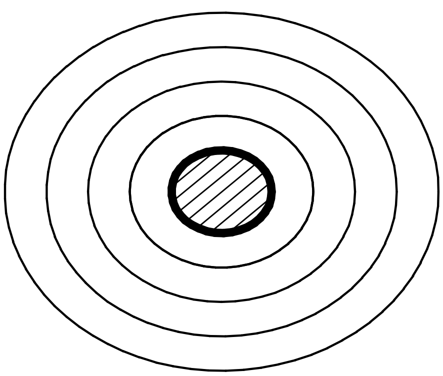

Fig: 11. Two dimensional circular bodies

Fig: 12. Resistance offered by a Drop like structure

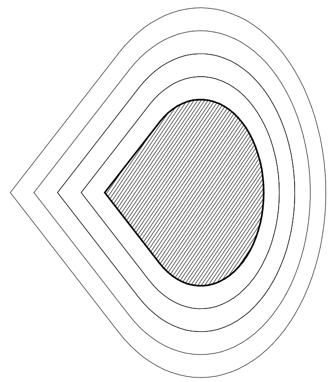

Fig: 13. Two dimensional Drop like structure

The experiment is done and the following results were observed for the Diesel as a fluid

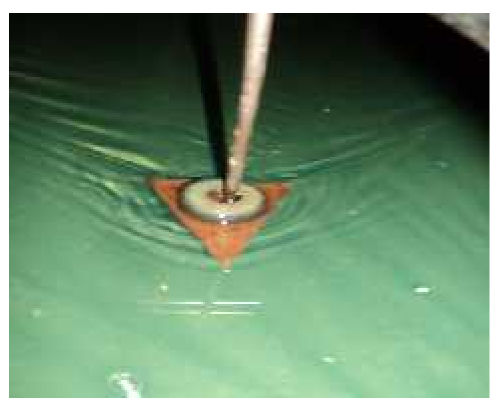

Fig: 14. Resistance offered by a Triangular body

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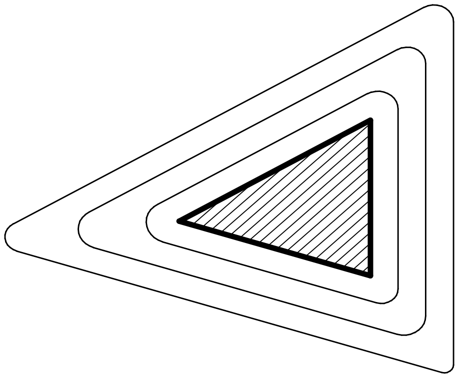

Fig: 15. Two dimensional Triangular bodies

Fig: 16. Resistance offered by a Circular body

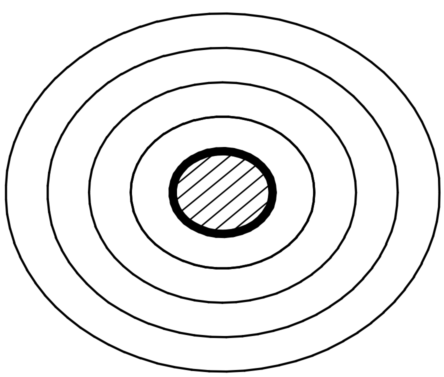

Fig: 17. Two dimensional circular bodies

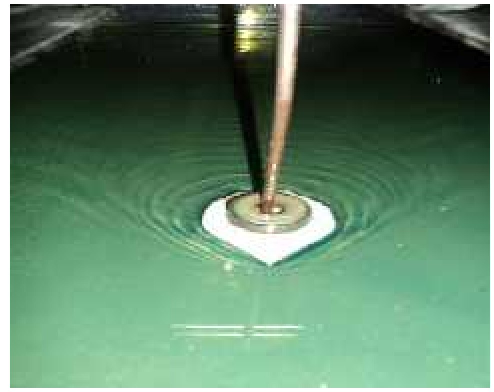

Fig: 18. Resistance offered by a Drop like structure

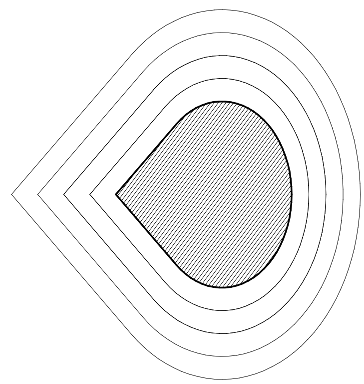

Fig: 19. Two dimensional Drop like structure

4. Conclusion

- The qualitative analyses of vortex formations were carried out. Different vortex formations are determined on the surface of water and diesel in a towing tank based upon the resistance offered by the geometrical bodies at different dimensions.

- Different vortex of different geometrical models such as triangle, circle, and drop like structure have been found, visualized and photographed. Different geometrical bodies show different vortex which depends on the

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resistance offered by the drag medium or fluid.

- In water the density is high than compare to the diesel and but the viscosity is less than the diesel, so that the visualization effect play an important role due to the variation of viscosity. Hence the surface visualization of vortex can be achieve qualitatively using water and diesel, in that water give better performance that diesel.

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