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STUDY ON VORTEX FLOW VISUALIZATION USING TWO DIFFERENT FLUIDS BY TOWING TANK METHOD

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Abstract: This paper presents a powerful surface-based techniques for experimental work of complex flow fields resulting from towing tank method, these flows have a characteristic which is independent of the medium and its velocity, but depends only upon a parameter called Reynolds numbers which is a non-dimensional number formed by the velocity, geometrical parameter and kinematic viscosity of fluid. There are many situations where one needs to compare with two or more data sets. it may be experimental results, physical parameter, flow visualization through photographs and so on. 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, , by using a towing tanksurface visualization of vortex flows around simple geometrical bodies will be investigated to understand the basic nature of resistance offered by the flows to the moving body. This paperfocuses on the comparative flow visualization (Streamline) of vortex flow between two different fluids like water and diesel by identifying the physical parameter using towing tank based experimental setup.

Key words: Vortices, vortex, streamline, towing tank.

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 obtainedexperimentally and numerically have also been used in combination to further theunderstanding 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 quantitative. Nevertheless, the technique has been used effectively for quantifying features suchas the upstream influence, separation, and attachment of two and three-dimensionalshock 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 warpedversion of the previous image and several 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 dyeto 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 spiralmotion with closed streamlines is vortex flow. The motion of the fluid swirling rapidly around a center is called a vortex. The speed and rate of rotation of the fluidin a free (irrotational) vortex are greatest at the center, and decrease progressivelywith distance from the center, whereas the speed of a forced (rotational) vortex is zero at the center and increases proportional to the distance from the center. Both types of vortices exhibit a pressure minimum at the center, though the pressure minimum in a free vortex is much lower.

2. LITERATURE REVIEW

I. The study of Taylor Couette flow began as early as the year 1890 and continues today due to its importance to various areas of research. Many researchers had made significant contributions to the understanding of the flow phenomenon and interested readers can refer to Chandrasekhar [1961], Diorama and Swinney [1985],Kataoka [1986], Chossat and Iooss [1992] and Koschmieder [1993] for an extensive review of the subject, and to Loureiro et al. [2006] and Douet al. [2006] for more recent studies of Taylor Couette flow. The literature reviewpresented in this chapter is confined to the study of Taylor Couetteflow between eccentric cylinders. Eccentric Taylor Couette flow draws the research community's attention in the mid-1900s. They were keen to investigate how the introduction of eccentricity might modify the conventional Taylor Couette flow problem. J. A. Cole conducted the first series of experiments in this area in 1967. Since then, a substantial amount of theoretical and experimental work had been devoted to Taylor Couette flow between eccentric cylinders. In this chapter, a comprehensive review of the previous studies on eccentric Taylor Couette flow will be presented. For the ease of reference, the review will be divided into two main sections. The first section summarizes the findings obtained from experimental studies under five distinctive areas of investigation unique to eccentric Taylor Couette flow. The second section describes the development of theoretical studies in these areas over the years and compares with the experimentalresults. An extensive review of this subject can also be found in Koschmieder [1993].

II. Historically, the very first investigations of fluid instability between rotating cylinders were done by Couette [1890] and Mallock [1896]. The aim of their experiments was to rather determine the viscosity of water by measuring the drag exerted by a rotating cylinder on another concentric cylinder at rest, than to study fluid instabilities. Nevertheless, the authors were first to notice the onset of flow instabilities due to an increase in the speed of rotation of either the inner or outer cylinders. Lord Rayleigh [1916], derived the first simple condition for the appearance of instability by neglecting the viscous forces in the fluid and introducing rotationally symmetric disturbances. He concluded that the in viscid flow remains stable only if the square of the circulation expression increases withthe increasing radius and proposed the first stability criterion for the case when both cylinders are rotating. The work done by G. I. Taylor in 1923 represents the first methodological approach to experimental and analytical explanation of the appearance and development of flow instabilities between rotating concentric cylinders. Taylor aimed his experiments towards obtaining a stability threshold bymeasuring the torque and comparing his results with Rayleigh's work.

III. Only few researchers combined the flow visualization and torque measurements toget added insight into the physics of the flow, and the exact transition points between different modes of instability. The second group is considering certain special aspects of instability modes, such as the Taylor wavy vortex or flow at larger Taylor (Reynolds) numbers (transition to turbulent flow). Finally, a small third group considers the flow between eccentric cylinders.

4. PURPOSE OF PRESENT STUDY

The objective of this work is to analyze the use of vorticity in the field line approach and to study the numerical visualization of the incompressible flows. Field line visualization techniques are used to analyze the particle trace and the seeding strategy of the flow field. Drag force is also a parameter to predict the flowof fluid and streamline over geometrical bodies.

According to theory of physics, fluid dynamics is a sub discipline of fluid mechanics that deals with fluid flow of the natural science. In the fluid field of mechanics there are several sub disciplines including aerodynamics and hydrodynamics.

Fluid dynamics has wide range of applications, such as calculating forces, moments, and displacement on an aircraft, which depends on the physical parameter like temperature, pressure, speed, velocity, and time.

The goal of this work is to understand and quantify the vortex visualization of thesurface films using different geometric models. The salient feature of surface properties, free surface interactions is to analyze the beauty of the natural visualization in presence of density and viscosity parameter. The dynamics of a vortex ring formation with a free surface are like those of wave motion. Both processes involve local area of the surface covered by the model and displacement,results in viscous elastic behavior of the interface.

In this approach, techniques such as flow visualization tunnel and towing tank method are used. The techniques are inspired by the traditional flow illustration drawn by Dalman and Abraham and Shaw in early 1980's, this work investigates the surface visualization of vortex by varying physical parameters.

5. **Experimental Setup**

Typical qualitative analysis vortex wave forms of the kind discussed here are madein long, narrow wave tanks where plane waves can be generated mechanically withrelative 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 plausible. 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 122 cm x 182.8cm and 14cm deep and has a 1.2 cm thickness.

Radial capillary (gravity) waves are studied experimentally in the present work toelucidate 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 ensure perfectly plane waves. Aluminum powder is being used to identify the proper vortex formation inthe tank with the movement of the bodies of different geometrical shapes. A carrieris being used to move the geometrical shapes. The carrier is placed on a channel tomove the geometrical shapes from one end of the tank to another end. The heightof the carrier is placed in such a way that the body floats on the surface of the medium.

In case of water and diesel- Case i)

Triangular model:

Fig 4.1: Triangular model with vortex
medium

Fig 4.2: Triangular model with formation in water
vortex formation in diesel
medium

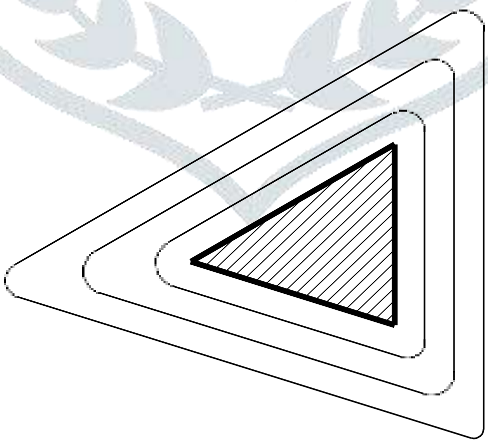


Fig 4.3: Triangular model in 2 Dimensional

Fig 4.1 & 4.2: In case of triangular model the vortex formation can be photographed in both the medium so the resistance offered by the diesel medium to the model is more, because the density is less than compare to the water medium.Hence the vortex formation or the streamline can be archived in the water mediumand this model is very near to the aero foil application.

Case ii) circular model:

Fig 4.4: Circular Model with vortex medium

Fig 4.5: Circular Model withformation in water vortex formation in diesel medium

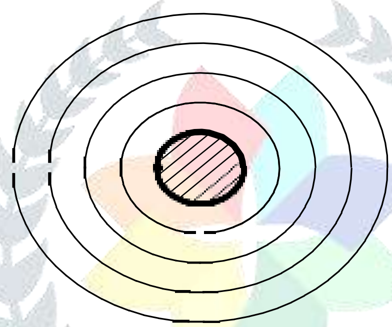


Fig 4.6: Circular model in 2 Dimensional

Fig 4.4 & 4.5: In case of the circular model the area covered over the surface of theof the medium is less so that the velocity is more resistance offered by both the medium is less. In this case the surface visualization by vortex flows can be achievednormally than compared to the triangular model.

Fig 4.7: Drop like structure with vortex *with water*

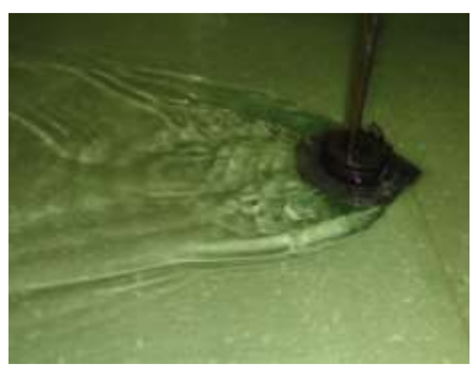


Fig 4.8: Drop like structure with Diesel

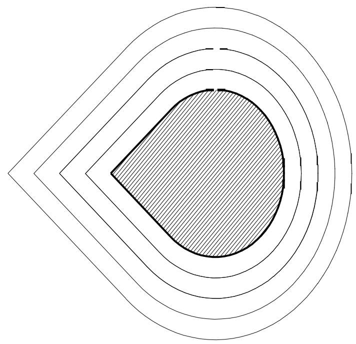


Fig 4.9: Drop like structure in 2 Dimensional

Fig 4.7 &4.8: In case of the drop like structure, normally the aero foil application will work with respect to this model, so this model gives a better performance of vortex formation in water medium than compare to the diesel medium. Because at the rare end of the model gives the very spinning vortex formation due to the less area covered by the mode over the surface.

Finally concluded that in the drop like structure the vortex formation is more in thewater medium than compared to the diesel. Taking this phenomenon and compare to the physical parameter like speed. Velocity and time shown in the next cases.

RESULTS & DISCUSSIONS:

Case i) Triangular model

Table 6.1: Velocity and Displacement results for triangular profile:

Sl/no	Speed (rpm)	Speed (m/sec)	Displacem ent (cm)	Time(sec)	Veloci ty (m/sec)	Drag Force(N)
1	280.23	0.527	124	2	0.62	0.1420
2	274.45	0.516	111.8	4	0.27	0.0538
3	252.67	0.475	99.6	6	0.16	0.0189
4	232.33	0.437	89.5	8	0.11	0.0089
5	195.81	0.368	80	10	0.08	0.0047

Case ii) Circular model

Table 6.2: Velocity and Displacement results for circular profile:

Sl/no	Speed (rpm)	Speed (m/sec)	Displacement (cm)	Time(sec)	Velocity (m/sec)	Drag Force(N)
1	215.78	0.406	110	2	0.55	0.2587
2	150.85	0.225	101.4	4	0.276	0.0651
3	94.60	0.178	85.2	6	0.142	0.0172
4	87.32	0.164	78	8	0.097	0.0080
5	66.42	0.104	67	10	0.067	0.0038

Case iii) Drop like structure:

Table 6.3: Velocity and Displacement results for drop like structure profile:

Sl/No	Speed (rpm)	Speed (m/sec)	Displacement (cm)	Time(sec)	Velocity (m/sec)	Drag Force(N)
1	225.2	0.424	120.7	2	0.603	0.226
2	177.56	0.334	110.5	4	0.276	0.047
3	168.2	0.316	102.3	6	0.170	0.018
4	122.34	0.230	86.2	8	0.107	0.007
5	95	0.178	77.7	10	0.077	0.003

Experimental Results for Diesel:

Case i) Triangular model

Table 6.4: Velocity and Displacement results for triangular profile:

Sl/no	Speed (rpm)	Speed (m/sec)	Displacement (cm)	Time(sec)	Velocity (m/sec)	Drag Force(N)
1	140.2	0.264	119.7	2	0.598	0.219
2	111.8	0.210	111.2	4	0.278	0.047
3	82.3	0.155	87	6	0.145	0.012
4	74.6	0.140	81	8	0.101	0.006
5	63.4	0.119	65	10	0.065	0.002

Case ii) Circular model

Table 6.5: Velocity and Displacement results for circular profile:

Sl/No	Speed (rpm)	Speed (m/sec)	Displacement (cm)	Time(sec)	Velocity (m/sec)	Drag Force(N)
1	95.6	0.180	110.3	2	0.351	0.0874
2	80.8	0.152	95.2	4	0.238	0.0040
3	75.8	0.142	80	6	0.133	0.0125

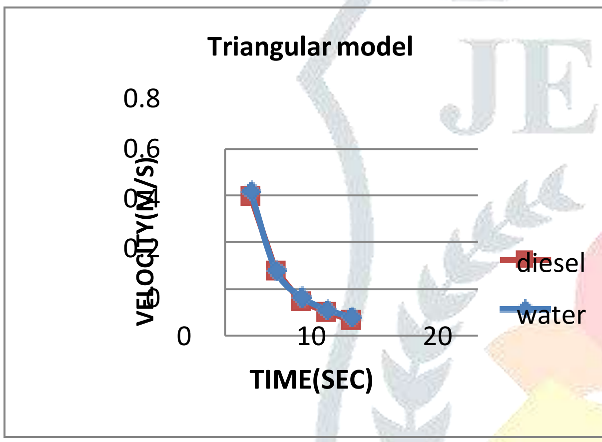
Case iii) Drop like structure:

Table 6.6: Velocity and Displacement results for drop like structure profile:

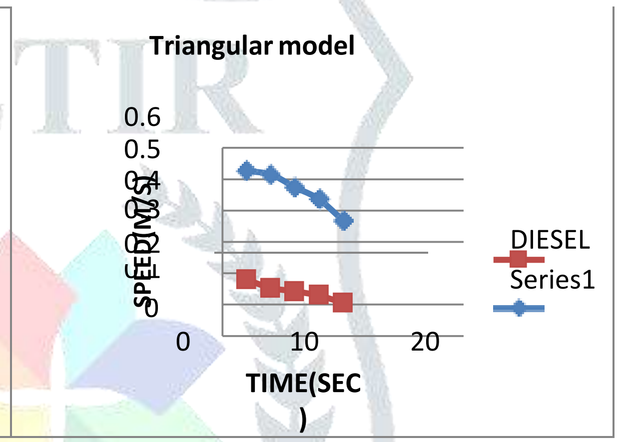
Sl/No	Speed (rpm)	Speed (m/sec)	Displacement (cm)	Time(sec)	Velocit y (m/sec)	Drag Force(N)
1	142.3	0.268	114.3	2	0.571	0.168
2	126.1	0.237	103	4	0.257	0.034
3	111	0.209	90	6	0.152	0.011
4	73	0.137	81.3	8	0.101	0.005
5	55.4	0.104	71.4	10	0.071	0.002

Comparison for Water and Diesel: Case i)

Triangular model:



Graph 6.1: velocity vs. time comparison graph between water anddiesel for triangular profile.

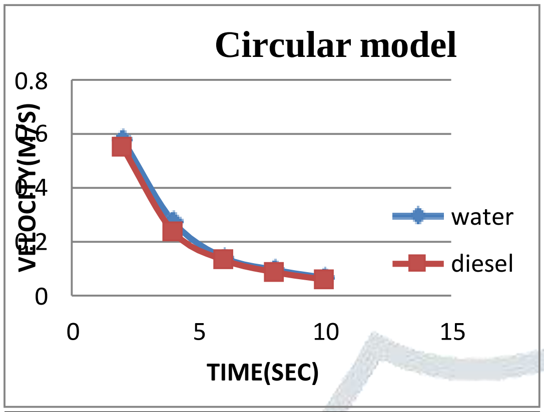


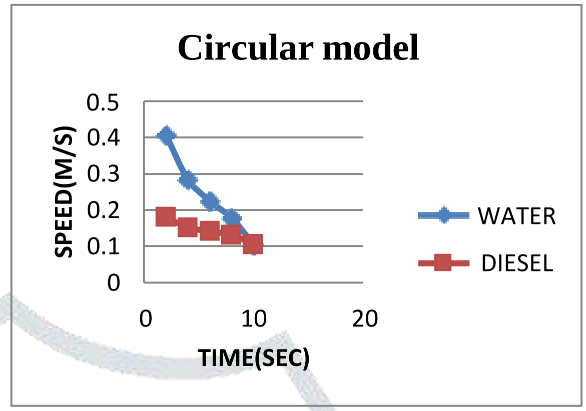
Graph 6.2: Speed vs. time comparisongraph between water and diesel for triangular profile.

In case of the triangular model were taken the reading with respect to the time takeand corresponding Speed of the model, due to the small variation in the density of the water (1000kg/m^3) and diesel (820-840 kg/m^3) in the graph 6.1 resistance offeredby the diesel is slightly more than compare to the water due to viscosity difference and there may be a less velocity can be easily plotted. So, in case for the fig 6.2

varies maximum speed in the first 2, 4, 6 Seconds and corresponding speed also plotted. Hence finally concluded that in the triangular model the resistance is more in the diesel so the vortex formation can be view clearly in water hence through photography and formula-based analysis were correct.

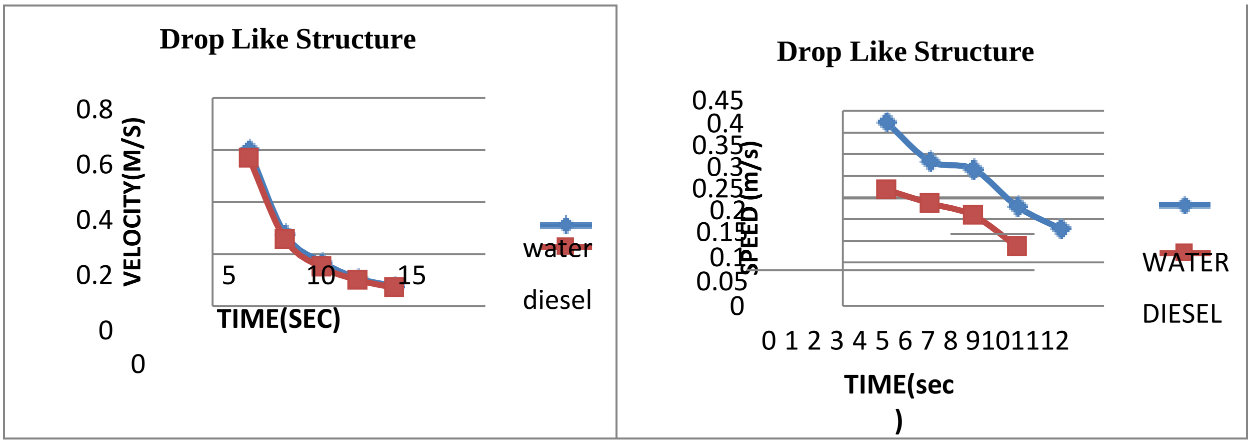
Case ii) Circular model:





Graph 6.3: velocity vs. time comparison graph between water anddiesel for circular profile.

Case iii) Drop like structure model:



Graph 6.5: velocity vs. time comparison graph between water anddiesel for drop like structure profile.

rrect.

CONCLUSIONS

The qualitative analyses of vortex formations were carried out. Different vortexformations are determined on the surface of water and diesel in a towing tank basedupon the resistance offered by the geometrical bodies at different dimensions. 2.Different vortex of different geometrical models such as triangle ,circle and droplike structure have been found, visualized and photographed .Different geometrical bodies show different vortex which depends on the resistance offered by the drag medium increases with respect to the resistance offered by body.

3. In water the density is high than compared to the diesel and, but the viscosity is less than the diesel, so that the visualization effect and drag force minimizes the velocity of the body. Hence the surface visualization of vortex can be achieved qualitatively using water and diesel, in that water gives better performance that diesel.

4. We have compared physical parameter like speed, velocity, and time with respectto drag medium over the surface of the fluid. We concluded that there is a slight decrease in the drag force in diesel, variation in the velocity with respect to time between the water and diesel. Hence vortex field is minimum in diesel due to the less density and high viscosity and water get better vortex formation in the field lineapproach.

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