International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 6 June 2022, pp: 2065-2070 www.ijaem.net ISSN: 2395-5252

Design and Fabrication of Floating Garbage Collection System

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Submitted: 15-06-2022 Revised: 25-06-2022 Accepted: 27-06-2022

ABSTRACT: Collection of floating garbage for calm water bodies like lakes, ponds, etc. in present day is manual and time consuming in these water bodies. A floating garbage collection system using the concept of free vortex is proposed. The system is made efficient by studying the different properties like pump characteristics, vessel height and diameter, immersion depth. Some parameters like vessel height diameter were fixed to study the rest of the parameters. Various vortex profiles were generated and tabulated by changing the immersion depth of the vessel and flowrate of the pump. These results will be non-dimensionalised and compared to achieve the optimum flow of the system. The pump characteristics have also been studied and a suitable pump can be selected for the correct application which will be changed according to the garbage collection radius and capacity of garbage collection. At the final stages, we plan to carry out flow visualization and velocity measurements with the help of Particle Image Velocimetry or PIV which is an optical method of visualization. It is used to obtain instantaneous velocity measurements where the fluid is seeded with tracer particles which, for sufficiently small particles, are assumed to faithfully follow the flow dynamics.

KEYWORDS: Floating garbage collection, vortex profile tracing, Particle Image Velocimetry, non-dimensionalisation

NOMENCLATURE

u_θ-Tangential Velocity
r - Radial distance used to measure free surface vortex profile
ω - Angular velocity
D - Depth of immersion (Distance between brim of the collector and the surface of water)
H - Height of water from bottom of the reservoir.
h(r) - Distance between the point on vortex surface profile and the maximum waterlevel in the reservoir
r - Distance of the point on vortex surface profile from the centre of the container
Q - Flow rate
R - Radius of the container

I. INTRODUCTION

In India, every year after the Lord Ganapati and Durga Mata visarjan a layer of floating garbage is formed on the surface of stagnant water bodies. The garbage includes flowers, garlands, plastic bags, etc. which damages the ecosystem. In many of the water bodies the garbage is collected manually (using nets) which is not very efficient. Designing and fabricating a floating garbage collector for lakes and ponds is a way in which we as engineers can contribute to society.

1.1 PROBLEM STATEMENT

To develop a system which will help in collecting and removing the suspended (floating) garbage, which is responsible for creating a disturbance in the ecological system of which aquatic life is affected directly.

1.2 SCOPE OF DESIGNING A FLOATING GARBAGE COLLECTION SYSTEM

1. To implement free flow vortex in relatively calm water bodies like lakes and ponds, for collection of floating garbage and naturally grown floating vegetation and make the process of cleaning huge lakes and ponds more efficient and reducing human efforts.

2. To know its behaviour at different conditions (like depth of vortex, garbage size, flow rate, pump specifications, etc.)

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3. To develop a cost effective and reliable garbage collecting system.

4. To design and fabricate a cost-effective working model of a garbage collection system.

5. To carry out an experimentation process focusing on planar measurements of vortex profile and observe the flow visualization by changing parameters making the device more effective for general use.

II. METHODOLOGY

An experimental setup was designed to study the flow of water in the garbage collector. A free vortex flow was observed by previous groups[1][2]. In a free vortex, fluid swirls around a centre solely due to gravity, with no external energy source[3][4][5]. In free vortex flow,

$u_\theta r$ = constant

The experiment performed was to evaluate and analyse the different flow behaviours of an evolved vortex and the effect of change in different parameters on the development and strength of the vortex and a vortex profile was graphed.

For experimentation, it is necessary to have certain parameters fixed and tabulate results on certain parameters one by one. The important parameters to be considered for design of the setup are container shape and size, pump size, flow rate, height to which the container is submerged in water and pipe size. Type of garbage, dry or wet, biodegradable or non-biodegradable, size of garbage, etc. are some additional parameters to be considered in the product development stage.

The parameters fixed were the container height, width, shape, pump size. The parameters varied were the height to which the container is submerged in water also known as depth of immersion (D) and flow rate(Q). The H, h(r), r, D and Power input (see nomenclature) were measured.

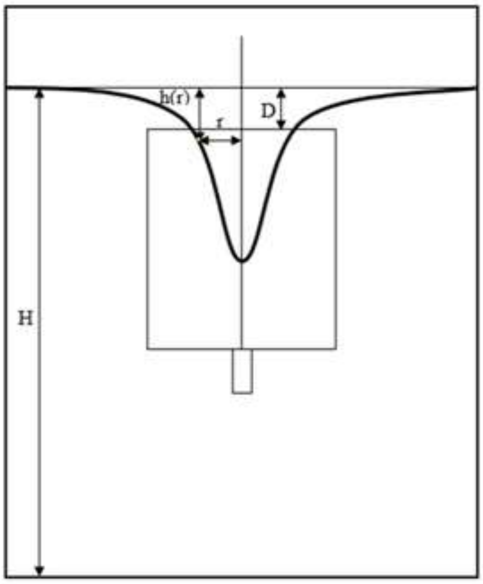

Fig. 2.1 Schematic of vortex surface profile

2.1 PARTICLE IMAGE VELOCIMETRY

Particle image velocimetry[6] (PIV) is an optical method to calculate the local flow velocity orthe instantaneous velocity of the fluid. The velocity is measured with the help of tracer particles.

This PIV method is used to calculate the tangential velocity of a particle. A video was recorded in the DSLR camera at 25 fps and individual frames were extracted. Two consecutive frames were merged and a print out in 1:1 ratio was taken. Paths of particlesat a radial distance of 10, 20, 30, 40 and 50mm were marked and measured manually with a measuring scale.

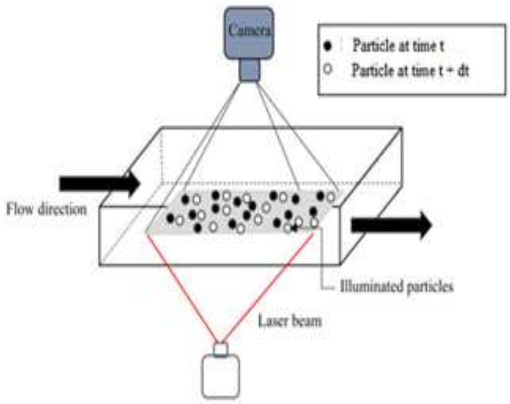

Fig. 2.2Example of PIV

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2.2 Experimental Setup Construction

The setup was designed into two parts namely the inlet outlet pipe assembly and collector vessel assembly. A flow control valve is attached to the inlet part of the setup to control the flow rate of the system. A vertical rotameter is used to measure the flow rate of the system, which is attached at the outlet side of the pump. As the outlet is in the same reservoir as the inlet, a perforated tube is attached to minimise the turbulence of the flow.

The collector vessel assembly consists of a transparent acrylic tube to pass the laser sheet for flow visualisation. The base of the collector is also a 10mm thick acrylic sheet to which the collector is stuck with the help of silicon sealant. Threaded rods are used to adjust the collector height under the water and a baseplate is used to provide support to the assembly.Guide vanes of 5x5cm are attached to the collector along the direction of vortex flow to stabilise the vortex.

2.3 EXPERIMENTAL SETUP SCHEMATIC DIAGRAM AND PHOTOS

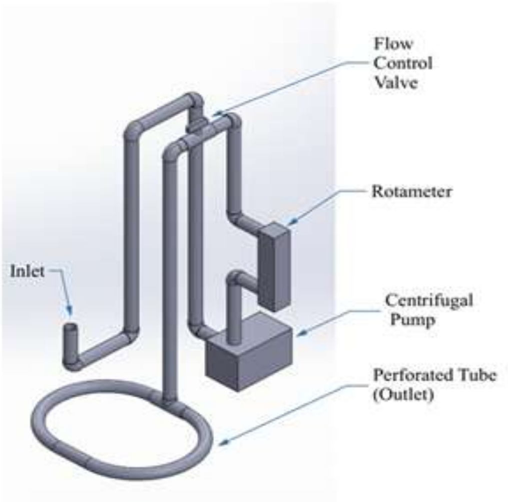

Fig. 2.3Inlet- Outlet pipe assembly

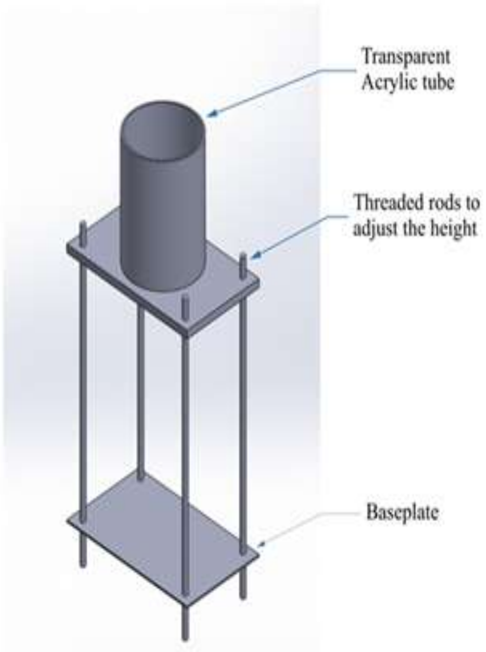

Fig. 2.4Collector vessel assembly

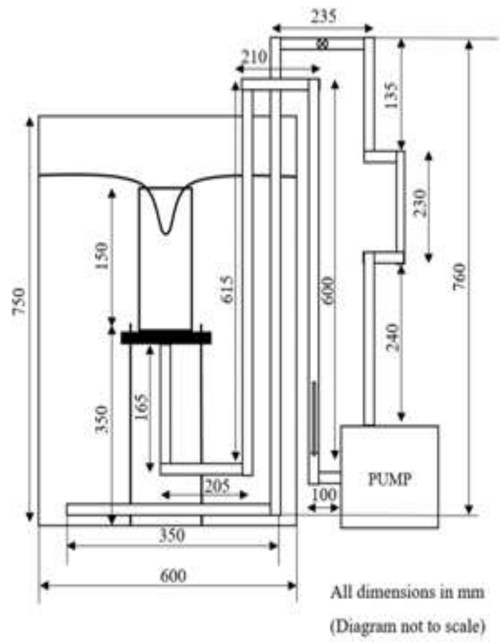

Fig. 2.5Dimensions of the setup

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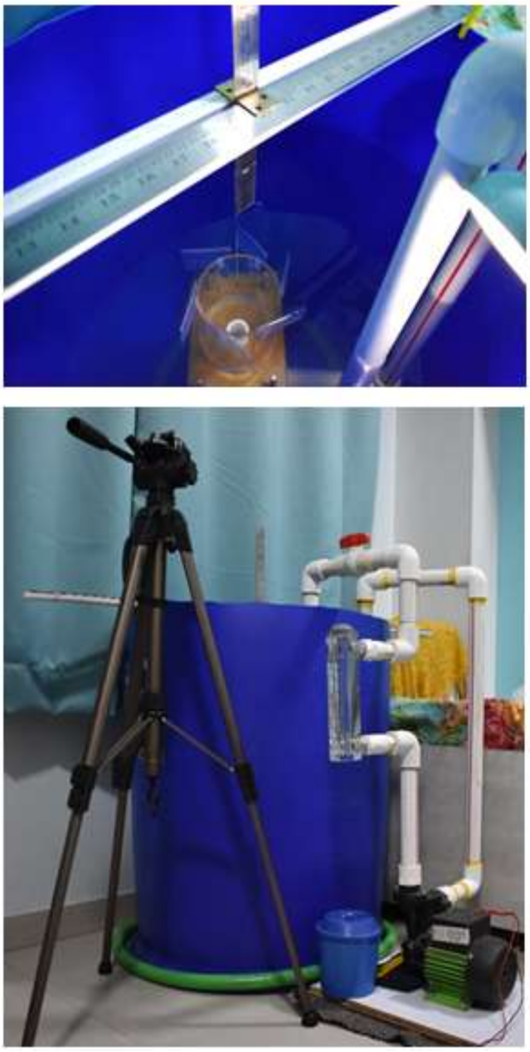


Fig. 2.6Design setup

III. RESULTS

3.1 VORTEX PROFILE TRACING AND NON-DIMENSIONALIZING

The vortex profile was traced with the help of a vortex profile measuring instrument consisting of horizontal and vertical scale. Two parameters were varied for the measurement of profile viz. discharge and depth of immersion. Discharge at which measurements were taken: 1800lph, 1500lph, 1200lph and 900lph. Along with discharge the depth of immersions was: 20mm, 25mm, 30mm and 35mm. The graphs for the given discharge and depth of immersion were plotted. The obtained values were non-dimensionalized by taking the ratio of r to R and h(r) to R and graphs were plotted.

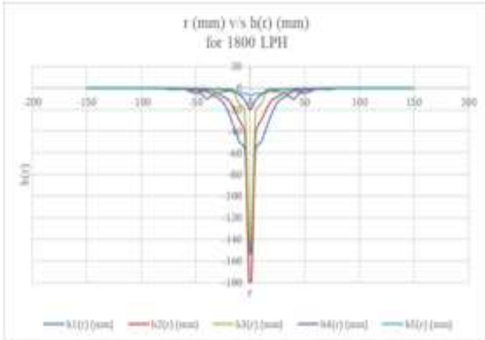


Fig. 3.1r (mm) v/s h(r) (mm) for 1800 LPH

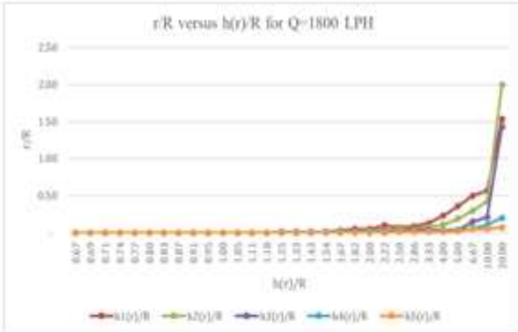


Fig. 3.2r/R v/s h(r)/R for 1800 LPH

3.2 TANGENTIAL VELOCITY CALCULATION

By visualising the flow using a laser sheet, movement of individual particles can be traced. Due to this one can easily deduce the nature of flow and as well as calculate the velocity of particles by several calculations. A set of calculations are shown below:

Radial distance from the center: 30mm
Number of frames stacked: 2
Frame rate: 25fps

Time $= \frac{\text{No. of frames}}{2*\text{Frame rate}}$

Time $= \frac{2}{2*25}$

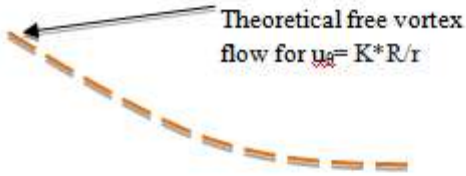
Time = 0.04 sec
Displacement of particle: 5 mm (Assume linear path as time period is short)

Tangential velocity, $u_\theta = \frac{\text{Displacement}}{\text{Time}}$

$u_\theta = \frac{5}{0.04}$

u_θ = 125 mm/s

Similarly, other particle paths were traced and their tangential velocities were calculated and a graph was plotted.



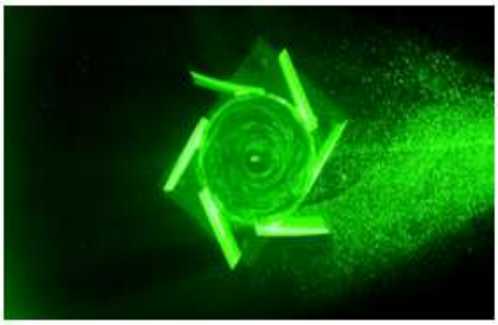


Fig. 3.3Marked particle path

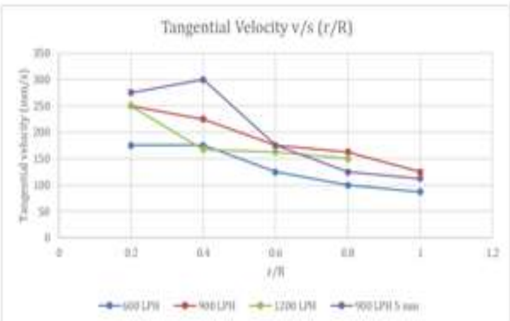


Fig. 3.4Graph for tangential velocity

IV. CONCLUSION

A set of iterations were performed and values of parameters like Input power of the pump Q, D, H, r, h(r) were tabulated. With the help of these values, the profile of the vortex was traced with the help of a graph. Using particle image velocimetry (PIV), tangential velocity of particles at different locations in the free vortex inside and outside the collector were measured.It was found that as depth of immersion increases from 15 mm to 35 mm the maximum distance between the point on vortex surface profile and water level in the reservoir $h_{max}(r)$ decreases from 154 mm*(maximum observed value was limited as the vortex profile formed was extending inside the inlet of the system) to 7 mm at constant flow rate (1800 LPH). When the flow rate of the pump is increased from 900 LPH to 1800 LPH, the $h_{max}(r)$ increases from 71 mm to 154 mm*(maximum observed value) when the depth of immersion is kept constant at 15 mm. It is also observed that when flowrate increases and depth of immersion decreases then $h_{max}(r)$ is increased. When the flow rate is increased from 600 LPH to 1500 LPH, the tangential velocity of the particles in the vortex also increased from 35 mm/sec (just outside the collector) to 325 mm/sec (inside the collector). Small vortices were observed near the guide vanes as the water entered inside the collector. These vortices' tangential velocity increased from 30 mm/sec to 125 mm/sec as the flow rate was increased from 600 LPH to 1500 LPH. It can also be concluded that the depth of immersion is directly proportional to the power consumption of the pump when flow rate is kept constant. It is observed that the power consumption of the pump varies from 205.2 W to 254.5 W for the flow rate range of 900 LPH to 1800 LPH. The tangential velocity versus r/R graph follows the properties of free vortex flow.

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