IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Measurement of Velocity of Flow in Open Channel by Hydrometric Pendulum

V S Chavhan[1]

[1]Department of Civil Engineering, Savitribai Phule Pune University, Pune, Maharashtra

Abstract

In an open channel velocity of flow are measured by using Pitot tube, Current meter, Float and Acoustic Doppler current profiler (ADCP). Pitot tube is not suitable for low velocity also there is chances of blockage of Pitot tube due to soil particle, Current meter cannot be used where there is much floating grass or weeds, Float methods require more persons for measurements and measurement of velocity by ADCP is costly. This paper intends to provide a new simple method of velocity measurement in open channel. This method is based on the principle of drag force exerted by flowing fluid on submerged spherical body. In this new method, velocity of flow was measure by suspending sphere with string known as Hydrometric pendulum. In this study experiments were performed by suspending sphere with string in Laboratory flume of size 6.00m length, 300mm width and 300mm depth and proposed a correlation between velocity of flow and deflection of string.

Keywords: Drag force, Spherical body, String angle.

1. INTRODUCTION

A flow with free surface in a channel is known as open channel, which includes irrigation channel, stream and rivers. The channel may be classified as a Natural channel **[4]** developed naturally and has irregular section of varying shapes and artificial channel **[4]** is the one which is built artificially for carrying water for various purposes. In natural channel, measurement of flow involves, measurement of both sectional area and velocity every time as the sectional area is constantly changing. In artificial channel, if the section of the flow is constant as in the case of rigid channel **[4]**, it is necessary to measure the section area once only and thereafter measurement of flow involves only measurement of velocity of flow.

Each instant, the continuing growth of population increases demands on our water resources. More water is needed for all the processes of life. Conservation and associated water measurement are being recognized as important tools for making the best use of available water. Accurate delivery of the necessary amounts of water to the crop at the correct times can both conserve water and improve the quantity and quality of agricultural products. Thus, the water measurement has a key role to play.

Previous research conducted velocity measurement in the Hydraulic flume includes (R K Rai. 2000) with single concrete sphere of diameter 61mm and submerged weight 1.614N in a 600 mm wide laboratory flume and in result R K Rai presented a calibration chart **[2]** between angle of deflection of string in degree and velocity of flow in m/s. Another research conducted includes the experiments performed (V S Chavhan et al. 2015) with five concrete sphere of diameter ranges from 50 mm to 20 mm **[1]** in a laboratory flume of 300 mm wide, 300 mm deep and 6 m length in which velocity range is 0.1m/s to 0.75m/s. In result he presented a correlation between experimental velocity (V_E) and theoretical velocity (V_T) **[1]**. The sphere velocity is calculated from string angle so it is called theoretical velocity (V_T) and the experimental velocity (V_E) is calculated from continuity equation.

This study concentrates on uses of steel sphere of diameter ranges from 51mm to 13 mm instead of concrete sphere on measurement of velocity of flow in laboratory flume. Systematic test were conducted by starting the flow in the hydraulic flume. The main interest was to quantify the effect of steel sphere in measurement of velocity of flow.

1.1. Drag force:

If a body is immersed in a large mass of flowing fluid or an object moving through a large mass of stationary fluid a body experiences a force. The force exerted by the fluid on the body has two components, one in the direction of flow and another in the perpendicular direction of flow, the component in the direction of flow is known as Drag force [4] and the perpendicular component is known as Lift force **[4].** However, for symmetrical body such as sphere, there is no lift force **[4]** thus the total force exerted by the fluid is equal to the drag force on the body.

For a body immersed in large mass of flowing fluid having mass density, at uniform velocity V, the mathematical expression **[4]** for the calculation of the drag force is written in equation

(1) in which F_d is drag force and A is exposed area of the body.

$F_d = Cd\ A\ \rho V^2$ **[4]**.. (1)

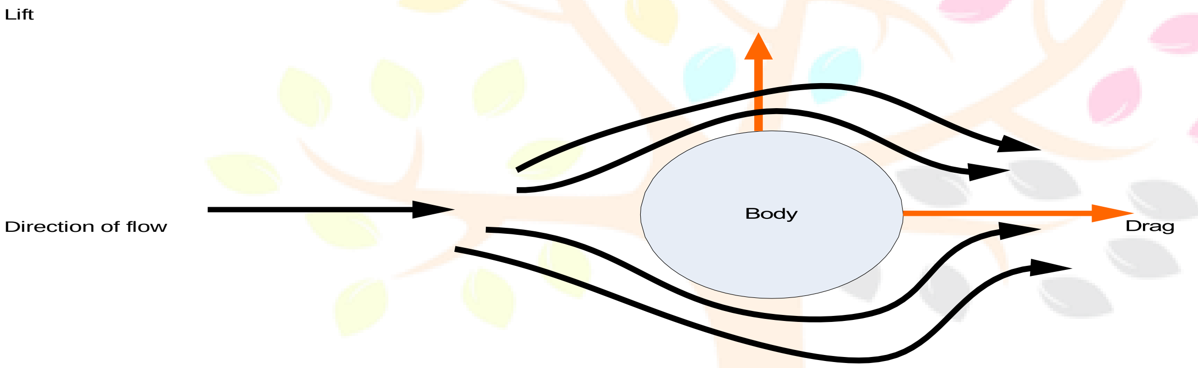


Figure 1. Drag and lift force on a body by flowing fluid.

2 Experimental Setup and Methodology:

The hydraulic tests for this study were conducted in the hydraulic flume previously described **[1]** by author V S Chavhan et al. 2015. The experimental setup is the arrangement for the angle measurement of the string and the arrangement for towing the sphere in laboratory flume. The arrangement for the angle measurement consist of a set square with protractor on which degrees are marked to read up to one degree as shown in photo. The protractor is fixed to the rod by making hole in the protractor as shown in photo. A white paper is pasted on backside of the protractor for more visibility of angle measurement. Then the setup is fixed in the channel of flume as shown in Figure 2.

The test program included total of six experiment with steel sphere diameter 51mm-(1), 45mm-(2),40mm-(3), 30mm-(4), 25mm-(5) and 13mm-(6). The experimentation was carried out for the depth of flow y=25cm by suspending sphere with string in experimental setup. The center of sphere is at a depth of 0.6 times depth of flow from free surface. The flow was started in flume after suspending sphere to experimental setup. Due to velocity of flow the sphere deflect and thus string angle change. For various strings angle discharge was measured with orifice meter of diameter 35mm fitted in inlet pipe of diameter 70mm by measuring pressure difference. Also, the depth of flow was measured with pointer gauge mounted on channel of flume. The velocity of the flow is then calculated by using continuity equation. The sphere velocity is calculated from deflected string angle so it is denoted as V_S and the experimental velocity is calculated from continuity equation and it is denoted as V_Q. The V_{S-1}, V_{S-2}, V_{S-3}, V_{S-4}, V_{S-5} and V_{S-6} are the sphere velocity calculated from deflection of string for steel sphere 51mm, 45mm, 40mm, 30mm, 25mm and 13mm respectively. The V_{Q-1}, V_{Q-2}, V_{Q-3}, V_{Q-4}, V_{Q-5} and V_{Q-6} are the experimental velocity calculated from continuity equation for steel sphere 51mm, 45mm, 40mm, 30mm, 25mm and 13mm respectively.

Figure 2. Experimental setup in Hydraulic flume

3 Observation, Result and Discussion:

The submerged spherical body in flowing fluid remains in static equilibrium under the action of following three forces. The submerged weight of the body (W) acting vertically downwards, drag force (F_d) acting on the body in the direction of fluid flow that is horizontal, The tensile force (T) in the string acting at an angle (θ) with the vertical **[2].** Lift force acting on the body in the direction perpendicular to the direction of fluid motion is zero as the body is spherical **[4].** The application of Lami's theorem or the equation of static equilibrium to the submerged spherical body under the action of the above mentioned three forces gives drag force equation then equating this drag force equation with equation (1) yields equation (2).

$V = C \sqrt{\tan \theta}$ …... (2)

Concept sketch for deriving equation (2) is shown in figure 2.

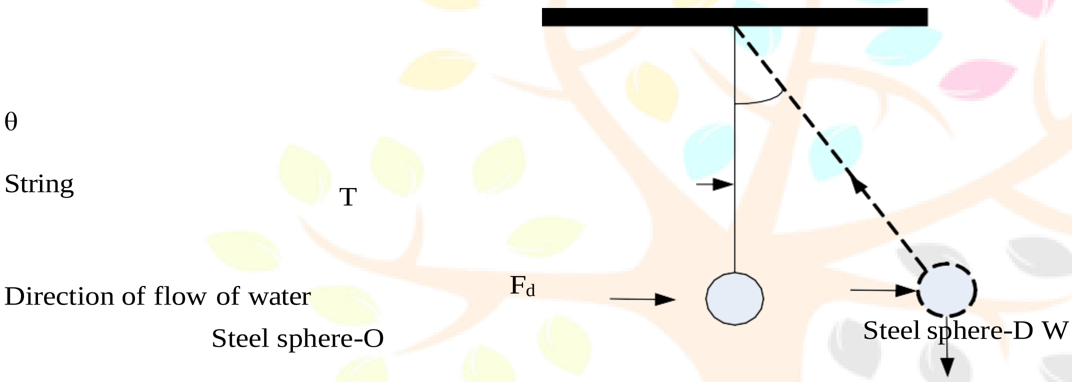


Figure 3. Conceptual sketch for deriving equation (2).

Steel sphere-O represent position of sphere before starting flow and steel sphere-D represent deflected position of sphere at angle θ due to the flow.

Equation (2) is used for calculating velocity of flow. For velocity measurement note the deflection of string i.e., angle (θ) and then put it in equation (2) we will get velocity of flow.

The constant C is depending on diameter of sphere, material of sphere, Weight of the sphere, density of the fluid and coefficient of drag of sphere. Average value of coefficient of drag of spherical body is 0.45 for Reynolds number ranging from 103 to 105. The velocity equation for all spheres is derived and shown in Table 1. Table 1 also displays properties of steel sphere.

Table 1. Properties of steel sphere

Diameter in mm	Weight in gm	Weight Submerged Weight in N	Constant for equation (2)	Equation
1	36	.577	.15	$V=3.15\sqrt{\tan\theta}$
5	72	.181	.98	$V=2.98\sqrt{\tan\theta}$
0	64	.260	.82	$V=2.82\sqrt{\tan\theta}$
0	10	.940	.43	$V=2.43\sqrt{\tan\theta}$
5	2	.527	.18	$V=2.18\sqrt{\tan\theta}$
3	6	.047	.2613	$V=1.26\sqrt{\tan\theta}$

ϕ

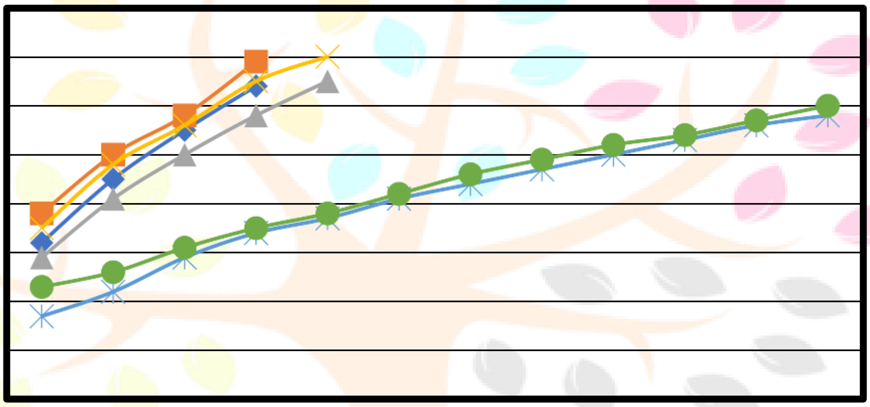
Constant (C)

Figure 4. Variation of constant (C) with ϕ

Table 2. Results for test run on steel sphere ϕ=51mm, ϕ=45mm and ϕ=40mm.

String angle in degree	Steel sphere (ϕ=51mm)		Steel sphere (ϕ=45mm)		Steel sphere (ϕ=40mm)	
	V_{S-1}	V_{Q-1}	V_{S-2}	V_{Q-2}	V_{S-3}	V_{Q-3}
	.42	.5.	.39	.46	.37	.42
			.56	.6	.53	.55

Figure 3 shows constant C is a function of diameter of sphere ϕ. It is evident from the Figure 3 that with increase in diameter of sphere constant for the equation also increases. Table 2 displays result for test run on steel sphere ϕ=51mm, ϕ=45mm and ϕ=40mm. It indicates that velocity for steel sphere of ϕ=51mm is available for string angle 1 degree only. This is due to heavy weight of sphere. It also indicates that velocity for steel sphere of ϕ=45mm and ϕ=40mm is available for string angle 2 degree. The velocity i.e., V_S and V_Q for steel sphere of ϕ=51mm, ϕ=45mm and ϕ=40mm are in agreement with each other. Even though V_S and V_Q are in agreement with each other, steel sphere of ϕ=51mm, ϕ=45mm and ϕ=40mm cannot be used for velocity measurement as they are applicable for string angle of 2 degree only.



VQ, VS

(Velocity m/sec)

V S-4 V Q-4 V S-5
V Q-5 V S-6 V Q-6

ɵ (String Angle in Degree)

Figure 5. Velocity curve for steel sphere of ϕ=30mm, ϕ=25mm and ϕ=13mm Figure 4 displays Velocity curve for steel sphere of ϕ=30mm, ϕ=25mm and ϕ=13mm. The graph results shows that the velocity i.e. V_S and V_Q for steel sphere of ϕ=30mm, ϕ=25mm and ϕ=13mm are in agreement with each other. For steel sphere of ϕ=13mm velocity can be measured up to 12 degree also it indicates that gives a large range of readings as compared

with steel sphere of ϕ=30mm and ϕ=25mm. The velocity range for steel sphere of ϕ=30mm is from 0.32m/s to 0.64m/s for string angle 1 degree to 4 degree respectively. The velocity range for steel sphere of ϕ=25mm is from 0.29m/s to 0.65m/s for string angle 1 degree to 5 degree respectively. The velocity range for steel sphere of ϕ=13mm is from 0.17m/s to 0.58m/s for string angle 1 degree to 12degree respectively

4. CONCLUSION

The series of experiment presented here indicate acceptable results for various velocities and deflection of string angle which are in agreement. It is seen that as the diameter of sphere reduces from 51mm to 13mm the string angle increases from 1 degree to 12 degree. The range of maximum velocity is from 0.42 m/s to 0.58 m/s for steel sphere ϕ=51mm and ϕ=13mm respectively. The range of minimum velocity varies from 0.17 m/s to 0.29 m/s for sphere ϕ=13mm and ϕ=25mm respectively. The range of velocity for sphere ϕ=13mm is from 0.17 m/s to 0.58 m/s is wider as compared with other sphere and useful for measurement of velocity in the laboratory flume.

This method of velocity measurement is based on drag force exerted by a flowing fluid on a submerged spherical body. After performing all the experiment it is concluded that this is very simple method of velocity measurement, it simply require the measurement of string angle and the velocity will be read from the calibration curve.

The main interest of this study was to verify experimentation for measurement of velocity with steel sphere. Since earlier studies were carried out with only concrete sphere and also concrete sphere is not durable and likely to be damaged. The results show that measurement of velocity is possible with steel sphere. In addition to this the future study can be done with different diameter sphere of other material such as acrylic for different size flume. This study can be further simulated on the field for prismatic channel and rivers.

REFERENCES

[1] Chavhan Vivek Sheshrao, et.al (2015), "Estimation of correlation between string angle and velocity of flow by using balls of different material and different diameter in laboratory flume", Vol. 7, Issue 6, pp. 1851-1856.

[2] R. K. Rai (2000), "A new method for measurement of velocity in open channel.", Journal of Applied Hydrology Vol XIII, Nos. 1&2.

[3] Snehasis Kundu and Koeli Ghoshal (2012), "Velocity Distribution in Open Channels: Combination of Log-law and Parabolic-law", World Academy of Science, Engineering and Technology 68, pp. 1735-1742.

[4] Modi P N and Seth S M. Hydraulics and Fluid Mechanics including hydraulic machines, Standard Book House, 1705-A, Nai Sarak. Delhi Water Pollution".

[5] Larry W. Mays, Water Resources Engineering, John Wiley & Sons (ASIA) Pte Ltd, 2 Clementi Loop #02-01 Singapore.