AN EXPERIMENTAL INVESTIGATION OF LIQUID FLOW FROM ORRIFICES AND SHORT TUBES

[1]ADEWOLE O.O, [2]OYINKANLA L.O.A.

[1]DEPARTMENT OF PHYSICS, UNIVERSITY OF IBADAN, NIGERIA.
[2]DEPARTMENT OF PHYSICS & ELECTRONICS ,THE POLYTECHNIC, IBADAN.
[1]Correspondence viz : koredeadewole@yahoo.com.

ABSTRACT: The current study involved investigation of liquid flow from orifices and short tubes. Certain fundamental physical laws govern the flow of liquids through various channel or medium, among which are the Poiseuille theorem, Bernoulli theorem, Darcy law, etc. An elaborate consideration of liquid flow from orifices and short tubes with a simple experimental investigation has been outlined with results of findings here. The findings are quite interesting and the flow observed under relevant governing physical laws. The horizontal ranges have been obtained and found to increase initially and subsequently decrease with decreasing depth. It is pertinent to state that the horizontal velocities of water as it comes out from different holes and the different ranges can be respectively calculated.
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1.0 INTRODUCTION

The flow of liquid in a tube or any channel is governed by some crucial fundamental physical laws, inclusive among are the Bernoulli theorem, Poiseulle formula, Darcy's law, etc. Pressures at the ends of a tube are different, hence there exists a pressure difference or gradient. In, variably, a relationship may be established between the pressure P, radius a of the tube, the viscosity coefficient η, its length l and the volume V of liquid flowing through the tube per second. The streamlines are normally parallel to the axis of the tube and from Bernoulli's theorem, after applying this method to a series of accurate viscosity determinations he assumed that the liquid in contact with the walls of the tube was at rest, which is a correct assumption experimentally.

2.0 METHODOLOGY

The investigation is based on the theorems of Torricelli and Poiseuille. The liquid is used is a low viscosity one, which is ordinary water and the liquid can is made of beverages cans of the domestic type used is Bournvita cans.

3.0 DISCUSSION

Various physical expressions have been derived to explain the flow of liquid through different channels or media. The Poiseulle theorem is expressed as; $V= \pi Pa^4/8\eta l$ which gives the total volume flowing through l section of the tube per second. These laws governing fluid flows in pipes are arrived at from conclusions drawn from considering different factors which flow through a pipe or a channel, such as streamlines. The Bernoulli's theorem in agreement with the conservation of energy principle within a closed system expresses the variation of pressure along a streamline.

The Bernoulli theorem holds positively for incompressible, low viscosity liquids, the incoming mass brings in energy and the mass leaving carries off energy and this is mathematically expressed; $P + h\rho g + {}^1/_2\,\rho v^2$ = constant , ……(1)

In interpretation, at any point along a streamline in an ideal fluid flowing steadily, the summation of the pressure, the kinetic energy per unit volume and the potential energy per unit volume is a constant. If a liquid flows through a pipe having constriction, the velocity at the constriction is increased and the pressure is accordingly reduced.

Some factors influencing liquid flow are friction, viscosity, temperature, and pressure. Friction leads to the dissipation of part of the energy in form of heat in flowing stream, and its consequence is a gradual reduction in pressure in relation to the direction of flow.

4.0 TORRICELLI'S THEOREM

If A_0 is the area of the free surface of a liquid, C_0 is the velocity of the liquid and z is the depth of the orifice below the free surface, with the head of liquid maintained constant:

$\frac{P_0}{\rho} + \frac{1}{2}C_0^2 = k$ .... (2)

,where k=constant.

$\frac{P_0}{\rho} + \frac{1}{2}C^2 - gz = k$ ....(3)

The equations are equal and thus;

$\frac{P_0}{\rho} + \frac{1}{2}C^2 = \frac{P_0}{\rho} + \frac{1}{2}C^2 - gz$ ....(4)

Therefore, $C^2 = C_0^2 + 2gz$ ....(5)

$A_0 C_0 = AC$ *viz the continuity equation and thus;*

$C_0^2 - \frac{A^2}{A_0^2}C^2 + 2gz$ ....(6)

$C^2 - \frac{2gzA_0^2}{A_0^2 - A^2}$ ....(7)

If the orifice is small, A^2 may be neglected and

$C^2 = 2gz$

,where $z - h - y$, the equation becomes;

$C^2 - 2g(h - y)$ ....(8)

Hence as (h-y) increases, C increases correspondingly. This relationship known as Torricelli's theorem (Atkins, 1988, 1989, Avison, 1989) implies that when the liquid particles reach the vena contracta they have the same velocity as if they fell directly from the free surface.

Now from A.K. Tamuli's theory (1986), the horizontal distance x, moved in time t is given by;

$x - ct$ ....(9)

During this time, the liquid has fallen through a height given by;

$y = \frac{1}{2}gt^2$ ....(10)

However, the vertical and horizontal motions expressed by equations (9) and (10) are independent of each other. Eliminating t between both equations, we get;

$y = \frac{1}{2}g\frac{(x)^2}{(C)}$ ....(11)

Eliminating C^2 between equations (8) and (11), we have;

$C^2 = g\frac{x^2}{2y}$

With $C^2 - 2g(h - y)$;

$2g(h - y) = g\frac{x^2}{2y}$, which implies that;

$x^2 = 4g(h - y)y$ ....(12)

By differentiating (12) with respect to y, we found that at maximum x; y=h/2

4.1 EFECT OF VELOCITY AND DEPTH

Torricelli's theorem states that, the velocity of the emerging liquid is the same as that obtainable if it falls from a height h and expressed as; $v = \sqrt{2gh}$................................ (13)

The relationship between (h-g) and x for an emerging liquid from the bottom of a can of height h, depth y above the ground and range x is expressed as; $x^2 = 4(h - g)y$........................ (14)

Differentiating the expression results to;

,$2x\frac{dx}{dy} = \frac{\partial(4(h-y)y)}{\partial y}$ .... (15)

=4y(-1) + 4(h-y), (16)

hence; $\frac{dx}{dy} = 4h - 8y, for \max x, \frac{dx}{dy} = 0$, thus 4h-8y= 0 and h=2y,...... (17)

Thus, the maximum x occurs at y=h/2, that is the middle of the can. This implies that the orifices at the middle of the constant liquid head h should theoretically have the longest range when the base of the can is the origin.

Substituting y=h/2 into equation .(12) above gives;

$$x^2 = 4\left(h - {}^{h}\!/_{2}\right){}^{h}\!/_{2} = \frac{4h^2}{4} \quad \ldots\ldots (18)$$

,which implies that;

$$x^2 - h^2 \quad \ldots\ldots (19)$$

Thus, $x = \mp h$ .... (20)

Obviously, x=h since length is positive in magnitude.

According to Atkin, though the pressure is greatest at the bottom hole with a concomitant maximum efflux speed, it does not follow that this gives a maximum range. Torricelli's and Poseuilli's equations (Newman et al, 1951) which are both of significance in treating a liquid in motion depend on the following assumptions that; the liquid is non-viscous, the flow is streamlined(no turbulence), the holes are of equal size, there is no air resistance and that the water can is wide enough to eliminate surface tension effects.

From equations (5) and (8) above, the horizontal velocities of water as it comes out from the different holes and the different ranges can be calculated respectively. This equations were the impetus for this investigation and the results found experimentally have been presented in subsequent tables; (4.1) and (4.2).

RESULTS

Liquid flow from orifices : Table 4.1

Hole No	*y(cm)*	*x(cm)*	*y(cms⁻²)*	*(h-y)(cm)*
1	*25*	*10.5*	*99.05*	*5*
2	*20*	*12.5*	*140.07*	*10*
3	*15*	*18.5*	*171.55*	*15*
4	*10*	*15.0*	*198.09*	*20*
5	*5*	*12.0*	*221.47*	*25*

Liquid flow with short tubes: Table 4.2

Tube No.	*y(cm)*	*x(cm)*	x^2 *(cm²)*	*h-y (cm)*	*(h-y)² (cm)*	*y(h-y)² (cm³)*
1	*25*	*12.5*	*156.25*	*5*	*25*	*625*
2	*20*	*19.0*	*361.00*	*10*	*100*	*2,000*
3	*15*	*23.5*	*552.25*	*15*	*225*	*3,375*
4	*10*	*19.0*	*361.00*	*20*	*400*	*4,000*
5	*5*	*18.5*	*342.25*	*25*	*625*	*3,125*

5.0 CONCLUSION

The experimental results obtained in this investigation have been presented in tables (4.1) and (4.2) above. The height of the water above the datum level or depth below a free water surface have been presented for liquid flow in orifices and short tubes. The horizontal range is found to increase initially and subsequently decrease with decreasing depth as shown in the tables above and also expressions have been presented that can be used to obtain the horizontal velocities of water as it comes out from different holes and the different ranges respectively.

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