

Study of Effect of Altered Piezometric Heads in Experimental Investigation of Bernoulli's Equation

Adil Wazeer^{1*} and Kaushalendra Kumar Dubey²

^{1&2}Fluid and Turbomachinery Lab, Galgotias University, Greater Noida, India

*Corresponding author

E-Mail: wazeeradil@gmail.com

(Received 11 February 2019; Revised 28 February 2019; Accepted 30 March 2019; Available online 10 April 2019)

Abstract - Bernoulli's equation is found to be one of the most popular topics of the elementary physics. The paper presents the experimental behavior of the famous Bernoulli's equation when the piezometric heads are altered and varied with respect to the heads 10cm and 15cm. The value of h in centimeters have been recorded in altered time periods and heads and in all the nine tubes. The calculation of the total energy (E) by changing the heads is obtained and the results achieved while equating the graphs between the total energy and distance from the reference point by changing the heads has been computed.

Keywords: Bernoulli's Equation, Piezometric, Total Energy Head, Discharge

I. INTRODUCTION

Bernoulli's theorem states that whenever there is a continuous connection between particles of flowing mass of liquid, the total energy at any section of flow will remain same provided there is no reduction or addition of energy at any point. The theorem is based on the law of conservation of energy. The equation states that at two sections of flow field the total energy remains the same, provided that there is no loss or gain of energy between the two sections. The equation is valid only for steady flow.

$$E = \frac{p_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + Z_2 \quad (1)$$

Where;

E = Total energy

$\frac{p_1}{\rho g}$ = Pressure energy per unit weight of fluid or pressure head at point 1.

$\frac{v_1^2}{2g}$ = Kinetic energy per unit weight or kinetic head at point 1.

Z_1 = Potential energy per unit weight or potential head at point 1.

$\frac{p_2}{\rho g}$ = Pressure energy per unit weight of fluid or pressure head at point 2.

$\frac{v_2^2}{2g}$ = Kinetic energy per unit weight or kinetic head at point 2.

Z_2 = Potential energy per unit weight or potential head at point 2.

p_1 = pressure of fluid at point 1.

p_2 = pressure of fluid at point 2.

v_1 = velocity of fluid at point 1.

v_2 = velocity of fluid at point 2.

ρ = density of fluid.

g = acceleration due to gravity.

The terms in the Bernoulli equation as generally written in hydraulics are often referred to as heads since the units are commonly expressed as feet. This concept of fluid columns standing to various heights is valuable and appropriate in applications to the flow of incompressible fluids. However, when it is applied to compressible fluids considerable error may be introduced [1]. One possible interpretation of Bernoulli's equation is that there is a conversion of internal motion into directed motion [2]. The Bernoulli equation is well known in hydrodynamics [3-6] and electromechanics [7]. Recently its scope was also extended to Ferro hydrodynamics (FHD) [8, 9], which, according to Rosensweig [9], "deals with mechanics of fluid motion influenced by strong forces of magnetic polarization."

II. DESCRIPTION OF SETUP

The experimental Bernoulli's test rig is installed at Fluid and Turbo Machinery laboratory, School of Mechanical Engineering, Galgotias University, Greater Noida, India. The complete setup is well designed and arranged in a good quality environment. The present experimental setup for Bernoulli's theorem is self-contained recirculating unit. The setup accompanies the Sump tank, Constant Head tank, Centrifugal Pump for lifting water, Measuring tank, etc. Control and By-pass valves are also provided to regulate the flow of water in Constant Head tank. A conduit, made of Perspex, of varying cross-section is provided, which is having converging and diverging section. Piezometer tubes are fitted on this test section at regular interval. The inlet of

the conduit is connected to constant head tank. At the outlet of conduit, a valve is provided to regulate the flow of water through the test section. After achieving the steady state, discharge through test section can be measured with the help of measuring tank and stop watch.

Inlet tank : Capacity 25 liters
 Stop watch : Digital
 Control panel comprises : Standard ON/OFF switch, Mains Indicator, etc.



Fig. 1 Bernoulli's experimental test rig.



Fig. 2 Nine Piezometric tubes.

A. Utilities required

1. Bernoulli's experimental test rig
2. Power supply: Single phase, 220V, 50 Hz, 5 Amp with earth connection.
3. Water supply
4. Space required of floor area needed: 1.6m * 0.5m.
5. Drain

B. Specifications of the Setup

Test Section : Metallic Acrylic
 Piezometer tubes : Material P.U. Tubes (9 Nos.)
 Water circulation : FHP pump
 Flow measurement : Using measuring tank with piezometer, capacity 42 liters.
 Sump tank : Capacity 85 liters

III. EQUATIONS

A. Discharge (Q):

$$Q = \frac{A * R}{t} \tag{2}$$

B. Velocity of fluid (V):

$$V = \frac{Q}{a} \tag{3}$$

C. Total Energy (E):

$$E = \frac{p}{\rho g} + \frac{v^2}{2g} + Z \tag{4}$$

$$\frac{P}{\rho g} = h \tag{5}$$

Where;

E = Total Energy

$\frac{P}{\rho g}$ = Pressure energy per unit weight of fluid or pressure head

$\frac{v^2}{2g}$ = Kinetic energy per unit weight of kinetic head

Z = Potential energy per unit weight or potential head

P = Pressure of fluid (m of water)

V = Velocity of fluid (m/s)

Q = Discharge through test section

v = Volume of water collected in measuring tank

t = Time taken for R

g = Acceleration due to gravity = 9.8 m/s²

A = Area of measuring tank = 0.1 m²

TABLE I TABLE SHOWING CROSS SECTIONAL AREA AND DISTANCE FROM REFERENCE POINT OF TEST POINTS

S. No. of Test Points	Cross sectional area, a (m ²)	Distance from Reference point, S (m)
1	6.1575 x 10 ⁻⁴	0.03
2	4.9088 x 10 ⁻⁴	0.059
3	3.4636 x 10 ⁻⁴	0.088
4	2.4053 x 10 ⁻⁴	0.117
5	1.5394 x 10 ⁻⁴	0.146
6	2.4053 x 10 ⁻⁴	0.175
7	3.4636 x 10 ⁻⁴	0.204
8	4.9088 x 10 ⁻⁴	0.233
9	6.1575 x 10 ⁻⁴	0.262

IV. RESULTS AND DISCUSSION

The value of h (cm) when computed from $R=10$ cm indicates a scale of 23.5cm in the first tube and gradually inclines to decrease from second tube onwards from 22.8cm to 15.5cm in fifth tube. Straight from sixth tube the measure of h again increases and continues till ninth tube to the scale of 20.2cm thus taking an overall time of 55.8 seconds. Similarly when

h is computed by taking $R=15$ cm, parallel trend prevails and takes 89 seconds for its completion.

Total Energy (E) is calculated for each tube and in order to recognize the trend, the value of total energy in the first tube is 0.328m which descends to 0.32m in second tube and then again upsurges in third tube by 0.329m. From fourth tube onwards the value of E decreases till the last tube.

TABLE II VALUES OF H AT DIFFERENT PIEZOMETRIC HEAD (R)

S. No.	R (cm)	t (sec)	h (cm) at piezometric tube no.								
			1	2	3	4	5	6	7	8	9
1	10	55.8	23.5	22.8	21.5	19.5	15.5	18.9	19.5	20	20.2
2	15	89	32.5	32	31.8	30.3	27	28.8	31.5	32	32.5

As evident from the graph between the Total Energy (E) and Distance (S), when $R=10$ cm, the graph primarily follows a linear contour and suddenly increases when the energy is beyond 0.5m and then slowly decreases. When $R=15$ cm, the overall graph represents a decrease in the total energy with the increase in the distance. There is a slight increase of E when the distance is between 0.05-0.1m.

TABLE III TOTAL ENERGY OUTCOME WITH RESPECTIVE TO PIEZOMETRIC TUBE NUMBERS

S. No.	Tube No.	Total Energy, E, when R=10cm	Total Energy, E, when R=15cm
1	1	0.3558	0.328
2	2	0.3492	0.32
3	3	0.34	0.329
4	4	0.33	0.327
5	5	0.55	0.321
6	6	0.48	0.312
7	7	0.4	0.31
8	8	0.39	0.309
9	9	0.35	0.3

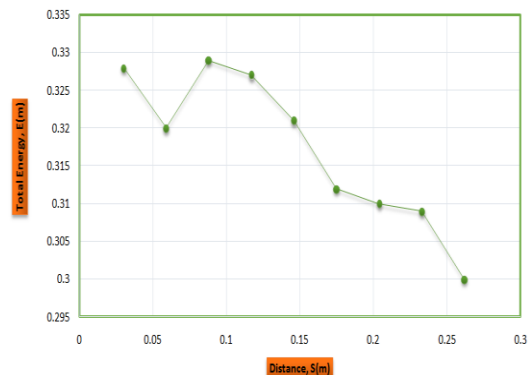


Fig. 4 Plot of Distance vs Total Energy with R = 15 cm

V. CONCLUSION

1. When h is computed with $R=10$ cm then its value first increases up to 5th tube and then increases from 6th tube onwards. Similar trend is observed when $R=15$ cm is taken for h calculation.
2. When $R=10$ cm, the graph between E and S originates with a linear relationship and ends with a decrease of E while increasing S .
3. When $R=15$ cm, the graph between E and S signifies an overall decrease in total energy when S is increased.

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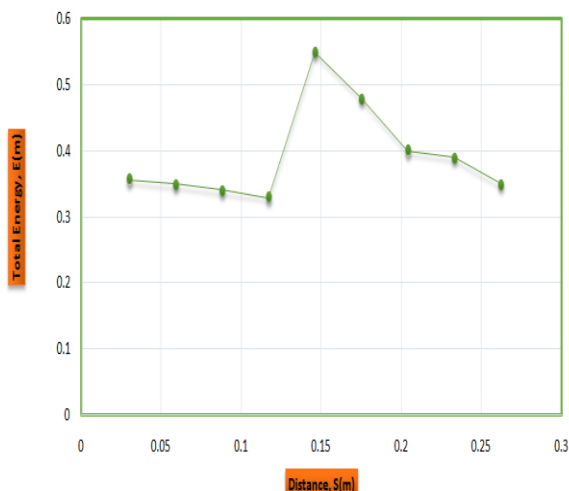


Fig. 3 Plot of Distance vs Total Energy with R = 10 cm